Response of Eight Sweet Corn (*Zea mays* L.) Hybrids to Topramezone

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Abstract. Topramezone is a newly introduced herbicide for use in field corn (*Zea mays* L.) that may have potential for weed management in sweet corn. Tolerance of eight sweet corn hybrids to topramezone applied postemergence (POST) at 0, 50, 75, 100, 150, and 300 g a.i. ha⁻¹ were studied at one Ontario location in 2000 and two locations in 2001 and 2002. Topramezone applied POST at 50, 75, 100, and 150 g ha⁻¹ did not cause any visual injury in Calico Belle, CNS 710, Delmonte 2038, FTF 222, FTF 246, GH 2684, Reveille, and Rival sweet corn hybrids at 7 days after treatment (DAT) and caused minimal injury (less than 5%) at 300 g ha⁻¹ in all hybrids. The initial sensitivity observed in these hybrids was minimal and transient with no effect on visual injury at 14 and 28 DAT. Topramezone applied POST did not reduce plant height, cob size, or marketable yield of the sweet corn hybrids included in this study. Based on these results, topramezone applied POST at the rates evaluated can be safely applied to Calico Belle, CNS 710, Delmonte 2038, FTF 222, FTF 246, GH 2684, Reveille, and Rival sweet corn.

Sweet corn (*Zea mays* L.) is an important field-grown vegetable crop in Ontario; nearly 170,000 t of sweet corn are produced on 14,000 ha with a farm-gate value of \$22.8 million (Mailvaganam, 2006). 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 (OMAFRA, 2006). More research is needed to identify POST herbicides that can effectively control emerged problem broadleaf and grass weeds in sweet corn production.

Topramezone is a newly introduced pyrazolone postemergence herbicide. Topramezone inhibits the activity of the 4-hydroxyphenyl pyruvate dioxygenase (HPPD) enzyme, which in susceptible weeds disrupts carotenoid synthesis, causing leaf bleaching, necrosis, and plant death (Anonymous, 2006). In field corn, topramezone can be applied in tank mixes with atrazine to control several broadleaf and grass weeds such as palmer amaranth (*Amaranthus palmeri*), common lambsquarters (*Chenopodium album*), velvetleaf (*Abutilon theophrasti*), Kochia (*Kochia scoparia*), *Amaranthus* spp., *Polygonum* spp., *Sinapis* spp., *Solanum* spp., barnyardgrass (*Echinochloa crus-galli*), *Digitaria*

spp., *Setaria* spp., fall panicum (*Panicum dichotomiflorum*), proso-millet (*Panicum miliaceum*), and goosegrass (*Eleusine indica*), including ALS, glyphosate, and triazine-resistant biotypes (Anonymous, 2006).

The currently registered POST herbicides in sweet corn do not satisfactorily control late-emerging velvetleaf and triazine-resistant redroot pigweed (*Amaranthus retroflexus*). Atrazine suppresses velvetleaf and does not control the triazine-resistant biotypes, and bromoxynil provides only fair control of *Amaranthus* spp. Bentazon is weak on pigweed and ragweed (*Ambrosia artemisiifolia*) and can significantly injure some sweet corn hybrids (Diebold et al., 2004). Mesotrione can also injure some sweet corn hybrids (O'Sullivan et al., 2002) and does not control many annual grass weeds, including *Setaria* spp., fall panicum, and witchgrass (*Panicum capillare*). Topramezone controls many of these troublesome weeds (Anonymous, 2006; OMAFRA, 2006) and therefore would be of benefit to sweet corn growers in Ontario.

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 (foramsulfuron), bentazon, CGA152005 (prosulfuron), mesotrione, nicosulfuron, primisulfuron, and RPA201772 (isoxaflutole) (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. To our knowledge, there is no published information on the sensitivity of sweet corn hybrids to POST applications

of topramezone. The objective of this study was to determine the tolerance of eight commonly grown processing sweet corn hybrids—Calico Belle, CNS 710, Delmonte 2038, FTF 222, FTF 246, GH 2684, Reveille, and Rival—to topramezone.

Materials and Methods

Field studies were conducted at the Huron Research Station, Exeter, Ontario, in 2001 and 2002 and the University of Guelph, Ridgetown Campus, Ridgetown, Ontario, in 2000 to 2002. 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 2001; and 34% sand, 33% silt, 33% clay, 3.8% organic matter, and pH of 8.0 in 2002. 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 2000; 51% sand, 32% silt, 17% clay, 5.5% organic matter, and pH of 7.2 in 2001; and 51% sand, 32% silt, 17% clay, 5.5% organic matter, and pH of 7.2 in 2002. 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 was based on the manufacturer's recommended use rates at the time the study was initiated. Treatments consisted of a non-treated control and five rates of topramezone (a.i. of 50, 75, 100, 150, and 300 g ha⁻¹). Eight of the most commonly grown processing sweet corn hybrids in southwestern Ontario encompassing a range of endosperm genotypes were selected. Hybrids included: Calico Belle (*se*), CNS 710 (*sh₂*), Delmonte 2038 (*su*), FTF 222 (*su*), FTF 246 (*su*), GH 2684 (*se*), Reveille (*su*), and Rival (*su*). The main plots were 6 m wide (eight rows) by 10 m long at Exeter and 6 m wide by 8 m long at Ridgetown. The row spacing was 75 cm and plants were thinned to a final plant population of 50,000 plants/ha. A preemergence application of a preformulated mixture of S-metolachlor plus atrazine (1:0.8) was applied immediately after planting with an a.i. of 2.16 kg ha⁻¹ in all trials, and plots were maintained weed-free by interrow cultivation and hand hoeing as required.

Topramezone was applied to 4 to 5 leaf stage sweet corn with a CO₂-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. 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 fully extended. The entire row of

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sweet corn in each plot was harvested by hand at maturity and cob size, marketable (cobs greater than 5 cm in diameter) and total yield were determined. Because the statistical analyses 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 (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 arsine square root transformation (Bartlett, 1947). Treatment means were separated using Fisher's protected least significant difference. 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. Visual injury symptoms included chlorosis and bleaching (whitening) of the leaves. Topramezone applied POST at 50, 75, 100, and 150 g·ha⁻¹ did not cause any visual injury in Calico Belle, CNS 710, Delmonte 2038, FTF 222, FTF 246, GH 2684, Reveille, and Rival sweet corn hybrids at 7 DAT but caused minimal injury (less than 5%) at 300 g·ha⁻¹ in all hybrids (Table 1). There was no visual injury in any hybrid-topramezone rate combinations at 14 and 28 DAT (data not shown). Visual injury generally did not increase as topramezone rate increased, which is in contrast with previous research on many of the same sweet corn hybrids (O'Sullivan et al., 2001, 2002). One HPPD inhibitor, RPA 201,772 (isoxaflutole), injured Calico Belle 10% to 100% and caused 10 and 73% visual injury in Rival, Delmonte 2038, GH 2690, CNS 710, and Reveille (O'Sullivan et al., 2001). O'Sullivan et al. (2002) observed that mesotrione, also an HPPD inhibitor, significantly injured Delmonte 2038 and Calico Belle, caused slight injury to Rival, and did not injure CNS 710. In the present study, all hybrids showed no or minimal (less than 5%) injury at all topramezone rates evaluated.

Plant height. Sweet corn height data are reported for each hybrid and rate individually, and heights were compared among rates and hybrids (Table 2). The visual injury observed in this study was reflected in the plant height. Topramezone applied POST at all rates did not reduce sweet corn hybrid

Table 1. Sweet corn hybrid visual injury (%) 7 d after treatment with topramezone applied postemergence at Exeter, ON, Canada, in 2001 to 2002 and Ridgeway, ON, Canada, in 2000 to 2002.^z

Sweet corn hybrid	Topramezone rate (a.i. g·ha ⁻¹)					Standard error
	50	75	100	150	300	
	%					
Calico Belle	0 bX	0 bX	0 bX	0 bX	2 aX	1
CNS 710	0 bX	0 bX	0 bX	0 bX	2 aX	1
Delmonte 2038	0 bX	0 bX	0 bX	0 bX	4 aX	2
FTF 222	0 bX	0 bX	0 bX	0 bX	2 aX	1
FTF 246	0 bX	0 bX	0 bX	0 bX	2 aX	1
GH 2684	0 bX	0 bX	0 bX	0 bX	2 aX	1
Reveille	0 bX	0 bX	0 bX	0 bX	2 aX	1
Rival	0 bX	0 bX	0 bX	0 bX	2 aX	1
Standard error	0	0	0	0	2	

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

Table 2. Sweet corn hybrid height (cm) 28 d after treatment with topramezone applied postemergence at Exeter, ON, Canada, in 2001 to 2002 and Ridgeway, ON, Canada, in 2000 to 2002.^z

Sweet corn hybrid	Topramezone rate (a.i. g·ha ⁻¹)						Standard error
	0	50	75	100	150	300	
	cm						
Calico Belle	108 aYZ	108 aYZ	109 aYZ	108 aYZ	107 aYZ	109 aYZ	6
CNS 710	103 aZ	102 aZ	103 aZ	103 aZ	103 aZ	103 aZ	8
Delmonte 2038	115 aX	116 aX	115 aX	116 aX	115 aX	115 aX	6
FTF 222	112 aXY	113 aXY	111 aXY	113 aXY	112 aXY	115 aX	6
FTF 246	114 aX	114 aXY	113 aXY	114 aXY	114 aXY	113 aXY	5
GH 2684	111 aXY	111 aXY	112 aXY	112 aXY	112 aXY	111 aXY	5
Reveille	105 aZ	108 aYZ	109 aYZ	109 aYZ	108 aYZ	110 aXYZ	5
Rival	108 aYZ	109 aYZ	110 aYZ	108 aYZ	108 aYZ	109 aYZ	6
Standard error	5	6	5	5	5	5	

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

heights (Table 2). Plant height was unaffected by increasing topramezone rate. Studies with other herbicides have shown rate and hybrid can affect plant height in sweet corn. O'Sullivan et al. (2002) found a reduction in plant height that was dependent on mesotrione rate in Delmonte 2038; however, mesotrione did not adversely affect Calico Belle, CNS 710, or Rival height. Thifensulfuron applied POST at 12 g·ha⁻¹ reduced sweet corn height by 76 cm in Delmonte 2038 and 26 cm in GH2684; and heights were generally reduced as the herbicide rate increased (Soltani et al., 2005). Robinson et al., (1994) reported POST nicosulfuron applications significantly reduced Zenith sweet corn height. Grey et al. (2000) reported height reduction in four of 10 sweet corn hybrids treated with nicosulfuron. O'Sullivan et al. (2000) observed reduced plant height with increased nicosulfuron rates in 11 hybrids evaluated. In two other experiments, plant height was reduced in five and three 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 cob size was compared among topramezone rates and sweet corn hybrids (Table 3). Responses were similar to visual injury and height. Topramezone applied POST at 50, 75, 100, 150, and 300 g·ha⁻¹ did not cause any reduction in cob size in Calico Belle, CNS 710, Delmonte 2038, FTF 222, FTF 246, GH 2684, Reveille, or Rival sweet corn hybrids

(Table 3). Other studies have shown that herbicides such as thifensulfuron applied POST can reduce cob size 9% to 67% in some sweet corn hybrids such as Delmonte 2038 and GH 2684 (Soltani et al., 2005).

Yield. Sweet corn yield data are reported for each hybrid and rate individually, and yields were compared among topramezone rates and hybrids (Table 4). Topramezone applied POST at 50, 75, 100, 150, and 300 g·ha⁻¹ did not reduce Calico Belle, CNS 710, Delmonte 2038, FTF 222, FTF 246, GH 2684, Reveille, or Rival sweet corn hybrid yields (Table 4). Again, these results are in contrast to other studies that have shown Delmonte 2038 is one of the most sensitive hybrids in Ontario exhibiting as much as 94% yield reduction when treated with some herbicides, including some HPPD enzyme inhibitors such as mesotrione or RPA 201,772 (isoxaflutole) (O'Sullivan et al., 2001, 2002). Yield was unaffected as topramezone rate was increased from 50 to 300 g·ha⁻¹, which is in contrast with Grey et al. (2000) and O'Sullivan and Sikkema (2001) who found differential hybrid yield reduction and rate responses with other herbicides in sweet corn. Thifensulfuron applied POST reduced yield 21% to 98% in Delmonte 2038 and GH 2684 sweet corn hybrids (Soltani et al., 2005). O'Sullivan et al. (2000) observed significant variability in yield loss among a range of sweet corn hybrids treated with nicosulfuron. Grey et al.

Table 3. Sweet corn hybrid cob size (g) treated with topramezone applied postemergence at Exeter, ON, Canada, in 2001 to 2002 and Ridgetown, ON, Canada, in 2000 to 2002.^z

Sweet corn hybrid	Topramezone rate (a.i. g·ha ⁻¹)						Standard error
	0	50	75	100	150	300	
Calico Belle	310 aY	310 aY	315 aY	317 aY	316 aY	318 aY	13
CNS 710	288 aZ	288 aZ	286 aZ	279 aZ	286 aZ	282 aZ	13
Delmonte 2038	344 aX	343 aX	330 aX	325 aX	356 aX	343 aX	15
FTF 222	311 aY	314 aY	310 aY	310 aY	315 aY	306 aY	14
FTF 246	298 aYZ	291 aYZ	305 aYZ	300 aYZ	302 aYZ	299 aYZ	13
GH 2684	313 aY	316 aY	315 aY	310 aY	318 aY	311 aY	12
Reveille	299 aYZ	295 aYZ	299 aYZ	294 aYZ	294 aYZ	301 aYZ	11
Rival	293 aYZ	304 aYZ	292 aYZ	304 aYZ	293 aYZ	304 aYZ	11
Standard error	9	9	10	9	10	10	

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

Table 4. Sweet corn hybrid marketable yield (t·ha⁻¹) treated with various rates of topramezone applied postemergence at Exeter, ON, Canada, in 2001 to 2002 and Ridgetown, ON, Canada, in 2000 to 2002.^z

Sweet corn hybrid	Topramezone rate (a.i. g·ha ⁻¹)						Standard error
	0	50	75	100	150	300	
Calico Belle	12.5 aYZ	13.0 aYZ	12.0 aYZ	12.8 aYZ	13.1 aYZ	13.4 aYZ	1.4
CNS 710	10.2 aZ	9.2 aZ	9.8 aZ	9.4 aZ	10.4 aZ	10.6 aZ	1.4
Delmonte 2038	16.5 aX	17.4 aX	17.0 aX	17.4 aX	17.6 aX	17.1 aX	1.4
FTF 222	13.6 aXY	12.6 aXY	13.3 aXY	12.7 aXY	14.1 aXY	13.4 aYZ	1.5
FTF 246	11.2 aYZ	11.5 aYZ	11.5 aYZ	11.6 aYZ	12.3 aYZ	12.1 aYZ	1.5
GH 2684	14.4 aXY	14.6 aXY	15.1 aXY	14.5 aXY	15.0 aXY	14.2 aXY	1.5
Reveille	12.4 aYZ	12.0 aYZ	12.5 aYZ	12.3 aYZ	13.0 aYZ	12.6 aYZ	1.5
Rival	11.5 aYZ	11.6 aYZ	12.0 aYZ	12.7 aYZ	12.8 aYZ	11.6 aYZ	1.4
Standard error	1.3	1.4	1.4	1.5	1.5	1.6	

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

(2000) found that only one of 11 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 four 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 herbicides such as AE F130360 (foramsulfuron), CGA 152,005 (prosulfuron), primisulfuron, and rimsulfuron (Diebold et al., 2003; O'Sullivan et al., 1998; O'Sullivan and Sikkema 2001, 2002; Van Wyche et al., 1997).

Conclusions

Differential sensitivity of sweet corn hybrids to other herbicides, including some HPPD enzyme inhibitors, has been reported in other studies conducted in Ontario (Die-

bold et al., 2003, 2004; O'Sullivan and Sikkema 2001, 2002; O'Sullivan et al., 1999, 2000, 2002; Soltani et al., 2005). In this study, differential sensitivity to topramezone POST was not observed in Calico Belle, CNS 710, Delmonte 2038, FTF 222, FTF 246, GH 2684, Reveille, or Rival sweet corn hybrids. Minimal visual injury seen in sweet corn hybrids at early growth stages was transient and did result in any reduction in plant height, cob size and yield. There was generally no difference in crop injury as the rate of topramezone was increased. Topramezone applied POST from 50 to 300 g·ha⁻¹ can be safely applied to Calico Belle, CNS 710, Delmonte 2038, FTF 222, FTF 246, GH 2684, Reveille, and Rival sweet corn hybrids.

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