Tolerance of Three Sweet Corn Hybrids to a Postemergence Tankmix of Nicosulfuron plus Bromoxynil

Cheryl-Ann L. Corbett and Nader Soltani¹

Ridgetown College, University of Guelph, Ridgetown, ON, Canada N0P 2C0

Allan S. Hamill

Agriculture and Agri-Food Canada Agriculture and Agri-Food Canada, Harrow, ON, Canada N0R 1G0

Peter H. Sikkema, Stephen Bowley, and Darren E. Robinson

Department of Plant Agriculture, University of Guelph, ON, Canada N1G 2W1

Additional index words. bromoxynil, nicosulfuron, sweet corn, synergism

Abstract. Trials were conducted over 2 years at three locations in Ontario to determine the tolerance of three sweet corn hybrids to postemergence application of nicosulfuron (25 and 50 g·ha⁻¹), bromoxynil (280 and 560 g·ha⁻¹), and nicosulfuron plus bromoxynil (25 + 280 g·ha⁻¹ and 50 + 560 g·ha⁻¹). All hybrids showed injury 7 days after treatment (DAT). The crop largely recovered from the injury in most treatments, as indicated by the ratings completed 14 and 28 DAT. However injury from the tankmix of nicosulfuron plus bromoxynil at both rates still appeared to be synergistic at 7, 14, and 28 DAT. Visual injury, height reductions and yield loss in the nicosulfuron plus bromoxynil (50 + 560 g·ha⁻¹) treatment were more severe than in the other herbicide treatments. Yield of BSS5362 was significantly decreased in the nicosulfuron (50 g·ha⁻¹) and nicosulfuron plus bromoxynil (50 + 560 g·ha⁻¹) but was not affected by any other herbicide-hybrid combination. Caution must be exercised when using this tankmix combination, as there is potential to cause significant visual injury, height reductions and yield loss.

Sweet corn is the second largest vegetable crop in Ontario in terms of farm value (Mail-vaganam, 2004). Sweet corn seedlings are not very vigorous and the crop is more susceptible to injury from herbicides and from weed competition-induced yield reductions than field corn (Robinson et al., 1993). There are no postemergence herbicide tankmix options for the control of both broadleaf and grass weeds in sweet corn in Ontario. Many weed management programs in sweet corn contain atrazine. High rates of atrazine may cause excessive injury in susceptible rotational crops and may also result in groundwater contamination. Lower rates of atrazine can minimize these risks but may also result in decreased weed control performance (Ontario Ministry of Agriculture and Food, 2004). Additionally, many weed species have evolved triazine-resistant biotypes which cannot be controlled with atrazine (Heap, 2004).

Nicosulfuron is a sulfonylurea herbicide. Sulfonylurea herbicides provide control of susceptible species by inhibiting the ALS enzyme. These herbicides have a more favorable environmental profile than atrazine because they are active at low doses, have low potential for groundwater contamination, and have low mammalian toxicity. Nicosulfuron controls many annual grass weeds (Dobbels and Kapusta, 1993; DuPont, 2003), quackgrass

[*Agropyron repens* (L.) Beauv.] (DuPont, 2003) as well as redroot pigweed (*Amaranthus retroflexus*) and Pennsylvania smartweed (*Polygonum pensylvanicum* L.) (Kapusta et al. 1994). Nicosulfuron must be tankmixed with a broadleaf herbicide to provide effective broad-spectrum weed control (Dobbels and Kapusta, 1993).

Sweet corn hybrids exhibit differential tolerance to nicosulfuron. Some hybrids are completely tolerant while others are extremely sensitive (Grey et al., 2000; Morton and Harvey 1992; O'Sullivan et al., 2000; Robinson et al., 1993, 1994; Stall and Bewick 1992). O'Sullivan and Bouw (1998) and O'Sullivan et al. (1995) observed significant injury to some sweet corn hybrids (notably Delmonte 2038, Merit, and Silver Extra Sweet) when nicosulfuron-rimsulfuron was applied at 25 or 50 g·ha⁻¹.

Tolerant sweet corn hybrids are able to metabolize the parent herbicide to a less-phytotoxic metabolite (Burton et al., 1994, as cited in Grey et al., 2000). Symptoms of susceptible hybrids include reduced stalk height (Williams and Harvey, 1996), reduced vigor (Morton and

Harvey, 1992), reduced marketable yield (Stall and Bewick, 1992), and decreased leaf number (Robinson et al., 1994). Nicosulfuron injury is often greater when sweet corn is treated with an organophosphorus insecticide (eg terbufos) as both pesticides are metabolized by the same metabolic pathway (Stall and Bewick, 1992; Williams and Harvey, 1996).

Bromoxynil is a nitrile herbicide that inhibits PSII. The site of action of bromoxynil is different from that of atrazine, and most weed populations that are resistant to atrazine remain susceptible to bromoxynil. Bromoxynil is a contact herbicide that can cause temporary crop injury (leaf scorching). Injury from bromoxynil is more likely to occur when the herbicide is applied under adverse growing conditions such as cool and wet or hot and humid weather (Bayer CropScience, 2002). Corn injury is increased when bromoxynil is applied in a tankmix with nicosulfuron/rimsulfuron. This injury can be minimized by applying the herbicides sequentially with at least 12 h between applications (Bayer CropScience, 2002). Injury from bromoxynil does not appear to be restricted to particular hybrids.

Nicosulfuron plus bromoxynil is a registered tankmix for all hybrids of field corn grown in Ontario (DuPont, 2003), but no studies have examined the effects of the tankmix of nicosulfuron plus bromoxynil on sweet corn. A one-pass application of nicosulfuron plus bromoxynil would be a useful broad-spectrum, postemergence treatment if it were registered in sweet corn. The objective of this study was to determine the tolerance of three different sweet corn hybrids to a postemergence tank mix of nicosulfuron plus bromoxynil at once and twice the label rates for field corn.

Materials and methods

This study was conducted at the Huron Research Station, Exeter, Ont., in 2002 and 2003, at Ridgetown College, Ridgetown, Ont., in 2002 and 2003, and at the Greenhouse and Processing Crop Research Centre, Harrow, Ont., in 2003. Soil characteristics for each site and year are indicated in Table 1. The experiment was a split-plot design with four replications (each main plot measuring 2.25 × 10 m) and three hybrids (FTF246, BSS5362, and CNS710R). The main plot was herbicide treatment, and subplots were sweet corn hybrid (one hybrid row per subplot).

Dates of planting and emergence for each year and location are summarized in Table 2. The sweet corn was overseeded and thinned to a uniform population of 50,000 plants/ha. The sweet corn hybrids tested (BSS5362, CNS710, and FTF246) were chosen because

Table 1. Soil characteristics at Exeter, Ridgetown, and Harrow, Ont., in 2002 and 2003.

Site	Year	Soil class	Soil texture (%)				
			pH	Organic matter	Sand	Silt	Clay
Exeter	2002	Clay loam	8.0	4.5	26	37	37
	2003	Perth Clay Loam	7.7	4.0	23	47	30
Ridgetown	2002	Loam	5.9	6.0	46	29	25
	2003	Loam	7.2	9.2	49	34	17
Harrow	2003	Fox Sandy Loam	6.6	2.6	82	5	13

Received for publication 23 Sept. 2004. Accepted for publication 4 Oct. 2004.

¹To whom all correspondence should be addressed; e-mail nsoltani@ridgetownc.uoguelph.ca.

Table 2. Summary of planting and application dates at Exeter, Ridgetown, and Harrow, Ont., in 2002 and 2003.

Site	Year	Planting date	Emergence date	Application date
Exeter	2002	23 May	1 June	18 June
	2003	3 June	13 June	24 June
Ridgetown	2002	22 May	3 June	12 June
	2003	5 June	11 June	24 June
Harrow	2003	6 June	12 June	25 June

they were among the most popular processing hybrids grown in Ontario. The experimental plots were maintained weed free by applying *S*-metolachlor-benoxacor-atrazine at 2.16 kg·ha⁻¹ a.i. immediately after planting and by cultivation and hand weeding.

Treatments at Exeter and Ridgetown were applied with a CO₂ pressurized backpack sprayer with XR8002VS flat fan nozzles at 200 L·ha⁻¹, at 241 and 207 kPa, respectively. At Harrow, treatments were applied with a CO₂ pressurized backpack sprayer at 210 kPa with XR11003VS flat fan nozzles at 200 L·ha⁻¹. All applications were made postemergence (POST) to sweet corn at the three to five leaf stage (see Table 2). The treatments were nicosulfuron at 25 g·ha⁻¹ with 0.2% Agral 90 v/v, nicosulfuron at 50 g·ha⁻¹ with Agral 90 at 0.4% v/v, bromoxynil at 280 g·ha⁻¹, bromoxynil at 560 g·ha⁻¹, nicosulfuron at 25 g·ha⁻¹ with Agral 90 at 0.2% v/v plus bromoxynil at 280 g·ha⁻¹, and nicosulfuron at 50 g·ha⁻¹ with Agral 90 at 0.4% v/v plus bromoxynil at 560 g·ha⁻¹.

Crop injury was assessed 7, 14, and 28 DAT by a visual evaluation of symptoms. A rating of 0 was assigned to plots with no visible effects and a rating of 100 was assigned to plots with complete plant mortality. Plant height from five randomly selected corn plants was recorded 21 DAT. Height was measured from the soil surface to the highest point of each corn plant with the leaves fully extended. The entire row of sweet corn in each plot was harvested at maturity.

All data were subjected to analysis of variance. Tests were combined over locations and years and analyzed using the PROC MIXED procedure of SAS (version 8, SAS Institute Inc., Cary, N.C.). Variances were partitioned into the fixed effects of herbicide treatment, hybrid, and herbicide × hybrid interaction and into the random effects of test, block(test), test × treatment, test × hybrid and test × 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 assumptions of the variance analysis, percent injury at 7, 14, and 28 DAT were subjected to an arcsine square root transformation (Bartlett 1947). Treatment means were separated using Fisher's protected LSD. The Type I error was set at 0.05 for all statistical comparisons.

Results and Discussion

Visual injury. Tests of fixed effects indicated that there was an interaction between hybrid and herbicide for visual injury 7, 14, and 28

DAT indicating a difference in response for these three hybrids to the herbicide treatments evaluated (Table 3).

BSS5362. All herbicide rates and combinations caused injury to BSS5362 at 7, 14, and 28 DAT except for the 1× rate of bromoxynil at 14 DAT (Tables 4, 5, and 6). Visual injury 7 DAT from the 1× rate of nicosulfuron was 6%, and injury from the 1× rate of bromoxynil was 4%, but crop injury from the tankmix application of both herbicides at their 1× rates was 13%. Crop injury from the 2× rate of nicosulfuron was 13%, and injury from the 2× rate of bromoxynil was 6%, but crop injury from the tankmix application of both herbicides at their 2× rates was 23%. These results are indicative of a synergistic rather than additive effect when bromoxynil and nicosulfuron are applied as a tankmix.

CNS710R. CNS710R was the most tolerant hybrid in terms of percent injury 7 or 14 DAT (Tables 4 and 5). At 7 DAT, CNS710R was not affected by nicosulfuron at 1× or 2× or by bromoxynil at the 1× rate. Bromoxynil at the 2× rate caused a 4% injury, which was not different from the injury observed at the 1× rate of nicosulfuron plus bromoxynil. The greatest injury was observed at the 2× rate of nicosulfuron plus bromoxynil. The injury to this hybrid from both the 1× and 2× rates of nicosulfuron plus bromoxynil was synergistic in nature, as the injury from the combination was much greater than the injury from the individual herbicides added together. There was no injury to CNS710R at 14 DAT from any herbicide treatment except from the 2× rate of nicosulfuron plus bromoxynil (Table 5). This injury also was synergistic, as injury from the 2× rate of nicosulfuron and the 2× rate of bromoxynil were each <1%. CNS710R was

intermediate in injury to BSS5362 and FTF246 at 28 DAT (Table 6). Injury to CNS710R was observed at the 1× and 2× rates of nicosulfuron plus bromoxynil. The injury from the 2× rate of nicosulfuron plus bromoxynil (3%) was synergistic, as the injuries from 2× nicosulfuron and 2× bromoxynil were each <1%.

FTF246. FTF246 was intermediate in injury to BSS5362 and CNS710R at 7 and 14 DAT but less injured than either hybrid at 28 DAT (Tables 4, 5, and 6). At 7 DAT, all herbicide treatments except for the 1× rate of nicosulfuron caused injury, with the greatest injury caused by the 2× rate of nicosulfuron plus bromoxynil. The injury from the 1× and 2× rates of nicosulfuron plus bromoxynil was synergistic, as the injury from the combination was much greater than the sum of the injury from the 1× or 2× rates of nicosulfuron or the 1× or 2× rates of bromoxynil. At 14 DAT, injury was only observed at the 2× rate of nicosulfuron plus bromoxynil (6%). This injury also appeared synergistic, as the injury from the 2× rate of nicosulfuron was 0% and the 2× rate of bromoxynil caused only 1% injury. Injury was not observed in this hybrid with any herbicide rate or combination at 28 DAT.

Crop injury at the 1× rate of nicosulfuron plus bromoxynil appeared synergistic for all three varieties at 7 DAT. Injury at the 2× rate of nicosulfuron plus bromoxynil was synergistic for all three varieties at 7 and 14 DAT, and synergistic in CNS710R at 28 DAT. No injury was observed 28 DAT for one hybrid (FTF246) and injury had markedly decreased by 28 DAT for the other two hybrids (BSS5362 and CNS710R). O'Sullivan et al. (2000) found that injury to eleven sweet corn hybrids was generally more severe at 50 g·ha⁻¹ nicosulfuron than at 25 g·ha⁻¹.

Injury was most severe at 7 DAT, which is also when the largest differences between treatments were observed. Visual injury from most herbicide rates and herbicide combinations was transient, as most hybrid-treatment combinations had recovered by 28 DAT (Table 5). Grey et al. (2000) found that injury to sweet corn from 15 g·ha⁻¹ nicosulfuron varied by hybrid as well as by year, but that most hybrids had recovered over the season to present no significant differences at harvest.

Table 3. Tests of fixed effects for herbicide treatment, sweet corn hybrid and treatment by hybrid interaction.

Effect	Day 7	Day 14	Day 28	Ht	Yield
Treatment	0.0001	0.0001	0.0065	0.0001	0.3041
Hybrid	0.0025	0.0077	0.0062	0.0006	0.0106
Treatment × hybrid	0.0002	0.0006	0.0260	0.4108	0.0216

Table 4. Mean percent injury to sweet corn hybrids 7 d after treatment with various postemergence herbicides.^a

Herbicide treatment	Herbicide rate (g·ha ⁻¹ a.i.)	Hybrid (%)		
		BSS5362	CNS710R	FTF246
Check	0	0 a	0 a	0 a
Nicosulfuron	25	6 b	0 a	0 ab
Nicosulfuron	50	13 c	1 ab	3 bc
Bromoxynil	280	4 b	1 ab	3 bc
Bromoxynil	560	6 b	4 bc	5 c
Nicosulfuron plus Bromoxynil	25 + 280	13 c	5 c	7 c
Nicosulfuron plus Bromoxynil	50 + 560	23 d	12 d	15 d

^aMeans presented have been back transformed to the original scale; means pressurized followed by the same letter are not significantly different according to a Fisher's protected LSD test ($P \leq 0.05$).

BSS5362 showed more injury than FTF246 or CNS710R with all herbicide rates and herbicide combinations at all three assessment times. CNS710R was the least injured hybrid at 7 and 14 DAT, but it showed greater injury than FTF246 at 28 DAT. Both Grey et al. (2000) and O'Sullivan et al. (2000) found hybrid differences with regards to severity of injury among sweet corn cultivars.

Height. The test of fixed effects indicated that there was no interaction between treatment and hybrid for the parameter height, indicating that all hybrids responded similarly to the herbicides evaluated. The mean height of sweet corn 28 DAT was unaffected by either rate of nicosulfuron or bromoxynil, or the 1× rate of nicosulfuron plus bromoxynil (Table 7). A significant reduction in height from the untreated plots was observed at the 2× rate of nicosulfuron plus bromoxynil. Robinson et al. (1994) observed that POST applications of nicosulfuron at 35 g·ha⁻¹ significantly decreased crop height in the hybrid 'Zenith' in 1991 but not 1993, attributing the decrease to greater environmental stresses (such as drought

or pest damage) in 1991. At 15 g·ha⁻¹ nicosulfuron, Grey et al. (2000) reported significant decreases in height for four of ten hybrids in 1992 but only two hybrids in 1993. They attributed this to herbicide application timing (15 cm in 1992 compared to 40 cm in 1993). In one location-year, O'Sullivan et al. (2000) observed that plant height decreased with increased nicosulfuron application (from 25 to 50 g·ha⁻¹) in all eleven hybrids. At two other location-years, plant height was only reduced in five and three hybrids, respectively. Herbicide application was delayed at one location-year to the seven-leaf stage, which has been shown to increase nicosulfuron injury in several sweet corn hybrids (Robinson et al. 1993). However, the trends indicated in this research and in the research of O'Sullivan et al. (2000) indicate that the degree of plant stunting increases with increased nicosulfuron dose and is compounded by stressors such as application timing or additional xenobiotics (such as bromoxynil or certain insecticides) that are detoxified by metabolism (Morton et al., 1993; Williams and Harvey, 1996).

Yield. A test of fixed effects indicated an interaction between treatment and hybrid for the parameter yield, indicating that there were differences in the way different hybrids responded to the herbicide treatments evaluated. The yield of FTF246 was unaffected by any herbicide treatment or rate (Table 7). There were no differences between the untreated control and any herbicide treatment in hybrid CNS710R, but there was a significant difference between the 2× rate of nicosulfuron and the 2× rate of nicosulfuron plus bromoxynil. In hybrid BSS5362, there was a decrease in yield when nicosulfuron or the tankmix of nicosulfuron plus bromoxynil were applied at the 2× rate. These yield data indicate that no yield losses occurred when nicosulfuron, bromoxynil, or nicosulfuron plus bromoxynil were used at the 1× rates in these three sweet corn hybrids. Dobbels and Kapusta (1993) observed that field corn yields were lower at one location when nicosulfuron was used alone rather than in combination with bromoxynil, but there was no difference at another location. They attributed the yield loss to a lack of common lamb's-quarters control by nicosulfuron alone at the location with decreased yield. The sweet corn plots in this study were treated with a preplant application of *S*-metolachlor-benoxacor-atrazine and then hand-weeded to eliminate weed competition to ensure that the results reflected yield loss due to herbicide injury rather than weed competition.

Significant yield loss only occurred at 2× nicosulfuron or 2× nicosulfuron plus bromoxynil in one hybrid (BSS5362). There was no yield loss from any herbicide treatment in two hybrids (CNS710R and FTF246). Grey et al. (2000) applied nicosulfuron at 15 g·ha⁻¹ and found that only one of eleven hybrids had a decreased yield. Robinson et al. (1994) observed that POST applications of nicosulfuron at 35 g·ha⁻¹ resulted in complete crop loss in one hybrid (Merit) in 1991 and 1993, a 50% reduction in yield in another (Zenith) in 1991, but no reduction in yield in Zenith in 1993. O'Sullivan et al. (2000) observed complete yield loss in 'Delmonte 2038', no yield loss in some other hybrids, and moderate yield reductions in some hybrids that were more severe at 50 g·ha⁻¹ nicosulfuron than at 25 g·ha⁻¹. Stall and Bewick (1992) determined that four of twelve hybrids demonstrated a response to nicosulfuron rate whereby marketable yield was significantly lower at 72 g·ha⁻¹ than at 18 g·ha⁻¹. This body of evidence indicates that yield reduction in sweet corn in response to nicosulfuron application is both hybrid and rate dependant.

Conclusions

Injury to all three sweet corn hybrids by all herbicide treatments was transient, and all three hybrids had markedly improved by 28 DAT. Yield was not affected by herbicide treatment in two of three hybrids (CNS710R and FTF246), but BSS5362 exhibited a decrease in yield when treated with the 2× rate of nicosulfuron or the 2× rate of nicosulfuron plus bromoxynil. CNS710R and FTF246 are

Table 5. Mean percent injury to sweet corn hybrids 14 d after treatment with various postemergence herbicides.^z

Herbicide treatment	Herbicide rate (g·ha ⁻¹ a.i.)	Hybrid (%)		
		BSS5362	CNS710R	FTF246
Check	0	0 a	0 a	0 a
Nicosulfuron	25	4 bc	0 a	0 a
Nicosulfuron	50	8 c	1 a	0 a
Bromoxynil	280	1 ab	0 a	0 a
Bromoxynil	560	2 b	1 a	1 a
Nicosulfuron plus Bromoxynil	25 + 280	6 c	1 a	1 a
Nicosulfuron plus Bromoxynil	50 + 560	13 d	5 b	6 b

^zMeans presented have been back transformed to the original scale; means within a column followed by the same letter are not significantly different according to a Fisher's protected LSD test ($P \leq 0.05$).

Table 6. Mean percent injury to sweet corn hybrids 28 d after treatment with various postemergence herbicides.^z

Herbicide treatment	Herbicide rate (g·ha ⁻¹ a.i.)	Hybrid (%)		
		BSS5362	CNS710R	FTF246
Check	0	0 a	0 a	0 a
Nicosulfuron	25	1 b	0 ab	0 a
Nicosulfuron	50	5 d	0 ab	0 a
Bromoxynil	280	1 b	1 ab	0 a
Bromoxynil	560	1 b	0 ab	0 a
Nicosulfuron plus Bromoxynil	25 + 280	2 c	1 bc	0 a
Nicosulfuron plus Bromoxynil	50 + 560	5 d	3 c	1 a

^zMeans presented have been back transformed to the original scale; means within a column followed by the same letter are not significantly different according to a Fisher's protected LSD test ($P \leq 0.05$).

Table 7. Height (28 d after treatment) and yield of sweet corn hybrids treated with various postemergence herbicides.^z

Herbicide treatment	Herbicide rate (g·ha ⁻¹ a.i.)	Mean ht ^y (cm)	Yield (t·ha ⁻¹)		
			BSS5362	CNS710R	FTF246
Check	0	84 b	18.9 b	14.1 ab	17.1 a
Nicosulfuron	25	84 b	17.9 ab	14.3 ab	17.1 a
Nicosulfuron	50	82 b	17.3 a	15.0 b	17.5 a
Bromoxynil	280	85 b	19.0 b	14.5 ab	17.5 a
Bromoxynil	560	81 b	19.1 b	14.4 ab	17.5 a
Nicosulfuron plus bromoxynil	25 + 280	82 b	18.7 b	14.1 ab	17.1 a
Nicosulfuron plus bromoxynil	50 + 560	74 a	16.6 a	13.5 a	17.7 a
LSD (0.05)		4	1.3	1.3	1.3

^zMeans within a column followed by the same letter are not significantly different according to a Fisher's protected LSD test ($P \leq 0.05$).

^yHeights have been averaged for BSS5362, CNS710, and FTF246 sweet corn hybrids.

listed on the nicosulfuron label as tolerant to nicosulfuron whereas BSS5362 is not (DuPont, 2003). Bromoxynil is registered on all sweet corn hybrids. BSS5362 consistently had more severe injury and greater yield loss than the other two hybrids when treated with 1× or 2× rates of nicosulfuron plus bromoxynil. Hybrid yield response to either rate of nicosulfuron plus bromoxynil reflected the sensitivity of a particular hybrid to nicosulfuron and was not influenced by the addition of bromoxynil. Recommendations for hybrid tolerance to a postemergent tankmix of nicosulfuron plus bromoxynil should consider hybrid tolerance, though caution must be exercised as this tankmix combination has potential to cause significant visual injury, height reductions and yield loss.

Literature Cited

- Bartlett, M.S. 1947. The use of transformations. *Biometrics* 3:39–52.
- Bayer CropScience. 2002. Pardner® herbicide. Pt# 120268 Label. Bayer CropScience. 13 Apr. 2004. www.bayercropscience.ca/products/attachments/Pardner_E.PDF.
- Dobbels, A.F. and G. Kapusta. 1993. Postemergence weed control in corn (*Zea mays*) with nicosulfuron combinations. *Weed Technol.* 7:844–850.
- Dupont. 2003. Accent® 75 DF herbicide. 25116-20030731-F2 E Label. Dupont Canada Inc. 13 Apr. 2004. www.dupont.ca/ag/uploads/P140L_Accent%20Herbicide.pdf.
- Grey, T.L., D.C. Bridges, P. Raymer, D. Day, and D. Scott NeSmith. 2000. Differential tolerance of fresh market sweet corn cultivars to the herbicides nicosulfuron and primisulfuron. *HortScience* 35(6):1070–1073.
- Heap, I. The international survey of herbicide resistant weeds. 8 Sept. 2004. www.weedscience.com.
- Kapusta, G., R.F. Krausz, M. Khan, and J.L. Matthews. 1994. Effect of nicosulfuron rate, adjuvant and weed size on annual weed control in corn (*Zea mays*). *Weed Technol.* 8:696–702.
- Mailvaganam, S. 2004. Fresh market sales and sales to processors of specified commercial vegetable crops, Ontario, 2003. 13 Apr. 2004. www.gov.on.ca/OMAFRA/english/stats/hort/vegsale03.html.
- Morton, C.A., R.G. Harvey, J.J. Kells, D.A. Landis, W.E. Lueschen, and V.A. Fritz. 1993. In-Furrow Terbufos reduces field and sweet corn (*Zea mays*) tolerance to nicosulfuron. *Weed Technol.* 7:934–939.
- Ontario Ministry of Agriculture and Food. 2004. Guide to weed control 2004–2005. Publ. 75. Ont. Min. Agr. Food, Toronto.
- O'Sullivan, J., R.A. Brammall, and W.J. Bouw. 1995. Response of sweet corn (*Zea mays*) cultivars to nicosulfuron plus rimsulfuron. *Weed Technol.* 9:58–62.
- O'Sullivan, J. and W.J. Bouw. 1998. Sensitivity of processing sweet corn (*Zea mays*) cultivars to nicosulfuron/rimsulfuron. *Can. J. Plant Sci.* 78:151–154.
- O'Sullivan, J., P.H. Sikkema, and R.J. Thomas. 2000. Sweet corn (*Zea mays*) cultivar tolerance to nicosulfuron. *Can. J. Plant Sci.* 80:419–423.
- Robinson, D.K., D.W. Monks, and J.R. Schultheis. 1994. Effect of nicosulfuron applied postemergence and post-directed on sweet corn (*Zea mays*) tolerance. *Weed Technol.* 8:630–634.
- Robinson, D.K., D.W. Monks, J.R. Schultheis, and A.D. Worsham. 1993. Sweet corn (*Zea mays*) cultivar tolerance to application timing of nicosulfuron. *Weed Technol.* 7:840–843.
- Stall, W.M. and T.A. Bewick. 1992. Sweet corn cultivars respond differentially to the herbicide nicosulfuron. *HortScience* 27(2):131–133.
- Williams, B.J. and R.G. Harvey. 1996. Nicosulfuron tolerance in sweet corn (*Zea mays*) as affected by hybrid, rootworm insecticide, and nicosulfuron treatment. *Weed Technol.* 10:488–494.