

## Chapter V

### Mesotrione, Nicosulfuron plus Rimsulfuron, and Atrazine Mixtures in Corn (*Zea mays*)

**Abstract:** Field experiments were conducted in 2002 and 2003 to evaluate total postemergence (POST) weed control in corn with mesotrione alone and in combinations with the commercial mixture of nicosulfuron plus rimsulfuron at full and reduced rates, and atrazine. Treatments were compared to nicosulfuron plus rimsulfuron POST, and *S*-metolachlor plus atrazine preemergence (PRE) alone and followed by (fb) nicosulfuron plus rimsulfuron POST. All treatments controlled common lambsquarters greater than 96% except nicosulfuron plus rimsulfuron POST alone, where control was 45 to 92%. Smooth pigweed control was greater than 92% with all treatments. The most consistent control of common ragweed and morningglory species (pitted morningglory and ivyleaf morningglory) was with the addition of atrazine to either mesotrione alone or to mesotrione plus nicosulfuron plus rimsulfuron combinations. Large crabgrass control varied between 2002 and 2003. In 2002, all POST treatments controlled large crabgrass between 51 and 78%, but in 2003, only nicosulfuron plus rimsulfuron POST controlled large crabgrass greater than 88%. *S*-metolachlor plus atrazine PRE followed by nicosulfuron plus rimsulfuron POST controlled large crabgrass at least 93%. Mixtures of nicosulfuron plus rimsulfuron with mesotrione improved giant foxtail control over mesotrione alone. Corn yields primarily reflected broadleaf weed control, and were generally higher with the addition of atrazine.

**Nomenclature:** Atrazine; mesotrione; nicosulfuron; rimsulfuron; *S*-metolachlor; common lambsquarters, *Chenopodium album* L. #<sup>1</sup> CHEAL; common ragweed, *Ambrosia artemisiifolia* L. # AMBEL; giant foxtail, *Setaria faberi* Herrm. # SETFA; ivyleaf morningglory, *Ipomoea hederacea* (L.) Jacq. # IPOHE; large crabgrass, *Digitaria sanguinalis* (L.) Scop. # DIGSA; morningglory species, *Ipomoea* spp. # IPOSS; pitted

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<sup>1</sup> Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

morningglory, *Ipomoea lacunosa* L. Roth # IPOLA; corn, *Zea mays* L. ‘Dekalb DKC60-09 (RR2)’, ‘Pioneer 33B51’, ‘Pioneer 33G56’.

**Additional index words:** Sulfonylurea herbicides, reduced herbicide rates, total postemergence, triketone herbicides.

**Abbreviations:** DAP, days after planting; fb, followed by; POST, postemergence; PRE, preemergence; WATP, weeks after treatment with POST herbicides.

## INTRODUCTION

Traditional corn weed management programs have relied on PRE combinations of grass and broadleaf herbicides for residual season-long weed control. However, adequate rainfall after application is required for herbicide activation and optimal weed control (Tapia et al. 1997). The risk of inadequate rainfall for PRE herbicide activation, the introduction of effective postemergence (POST) grass and broadleaf herbicides, the development of herbicide resistant crops, and the need for corn growers to reduce work loads have promoted a trend towards use of total POST programs for weed control in corn (Kapusta et al. 1994). With total POST programs, herbicides and rates can be selected based on weed spectrums and densities present in each field (Tapia et al 1997). POST herbicides are currently available to control annual grass and broadleaf weeds in corn, but complete and consistent broad-spectrum control may require tank-mixtures of a grass and broadleaf herbicide (Dobbels and Kapusta 1993; Rabaey and Harvey 1997).

Mesotrione is a PRE or POST triketone herbicide that controls several annual broadleaf weeds, but grass activity is limited (Armel et al. 2003; Beckett et al. 1999; Johnson et al. 1999). Mesotrione has a short soil half-life of 5 to 15 d (WSSA 2002), which makes application rate and timing important for controlling weeds that emerge after POST applications. Research indicates that combining mesotrione with atrazine POST increased control of emerged and later-emerging weeds (Bradley et al. 2000; Johnson et al. 1999).

Nicosulfuron plus rimsulfuron<sup>2</sup> is a commercial sulfonylurea herbicide mixture in a 2:1 ratio that controls several grass and broadleaf weeds POST in corn (Anonymous 2003). Mixtures of mesotrione, nicosulfuron plus rimsulfuron, and atrazine POST may enhance control of several broadleaf weed and annual grass species and therefore provide broad-spectrum weed control. However, tank-mixtures of POST grass and broadleaf herbicides, particularly at reduced rates, have reduced weed control efficacy (Chow 1983; Hartzler and Foy 1983; Isaacs et al. 2002).

Reducing herbicide rates can increase grower profits and limit pesticide input into the environment (Alm et al. 2000; Prostko and Meade 1993). Application rates of some POST herbicides can be substantially reduced below recommended registered rates depending on weed species, application timing, environmental conditions, and application accuracy (Putnam 1990). Research in soybean [*Glycine max* (L.) Merr.] indicated that certain POST herbicide rates could be reduced to as low as one-fourth of the registered rate (Baldwin and Oliver 1985).

The objectives of these studies were to evaluate control of several broadleaf weeds, large crabgrass, and giant foxtail in a total POST weed management program with mixtures of mesotrione, nicosulfuron plus rimsulfuron at full and reduced rates, and with or without atrazine. Another objective was to compare weed control by these total POST mixtures to standard PRE and PRE fb POST weed management programs.

## **MATERIALS AND METHODS**

Experiments were conducted at the Eastern Shore Agricultural Research and Extension Center near Painter, VA at separate locations in 2002 and 2003 and are designated as 2002, 2003, 2003a, and 2003b. The soil type was a Bojac sandy loam (Typic Hapludults) with approximately 1% organic matter and a pH of 6.1. Seedbeds were prepared by chisel plowing followed by tandem disking and tillage with an S-tine field cultivator with double rolling baskets. Fertilizer was applied broadcast before planting according to current recommendations from the Virginia Polytechnic Institute

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<sup>2</sup> Steadfast herbicide, E.I. DuPont de Nemours & Co., Crop Protection, Walkers Mill, Barley Mill Plaza, Wilmington, DE 19880-0038.

and State University (Donohue and Heckendorn 1994) and additional nitrogen was applied at the V5 growth stage. Corn hybrids planted were ‘Pioneer 33G56’<sup>3</sup> in 2002, ‘Pioneer 33B51 in 2003 and 2003b, and ‘Dekalb DKC60-09 (RR2)’<sup>4</sup> in 2003a. Corn was planted 4.0 cm deep at a rate of 57,000 seed/ha (Table 5.1).

Plots were four rows wide in 0.76 m spacing with an herbicide-treated area of 2.5 by 6.1 m, leaving a 0.9-m nontreated area between plots. Herbicides were applied with a tractor-mounted sprayer delivering 235 L/ha at 210 kPa through flat fan spray nozzles.<sup>5</sup> Herbicide application data for each location are presented in Table 5.1. Common lambsquarters, common ragweed, and morningglory species were at cotyledon stage in 2003b at time of PRE applications. Weed densities and heights were recorded at time of POST applications (Table 5.2). The experimental design was randomized complete block with a three by two factorial treatment arrangement plus controls. Factors were nicosulfuron plus rimsulfuron and atrazine POST at various rates. Factorial treatments in 2002 and 2003 included mesotrione POST at 105 g ai/ha, the mixture of nicosulfuron plus rimsulfuron POST at 0 plus 0, 17 plus 9, or 34 plus 17 g ai/ha, respectively, and atrazine POST at 0 or 560 g ai/ha. In 2003a and 2003b, mesotrione and atrazine rates were the same as in 2002 and 2003, however nicosulfuron plus rimsulfuron mixture was applied POST at 0 plus 0, 13 plus 7, or 26 plus 13 g/ha. Control treatments included nicosulfuron plus rimsulfuron POST, *S*-metolachlor at 870 g ai/ha plus atrazine at 1100 g ai/ha PRE alone and fb nicosulfuron plus rimsulfuron POST. Rates of nicosulfuron plus rimsulfuron in control treatments were 34 plus 17 g/ha, respectively, in 2002 and 2003, and 26 plus 13 g/ha, respectively, in 2003a and 2003b. All POST treatments included 1% v/v crop oil concentrate.<sup>6</sup>

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<sup>3</sup> Pioneer Hi-Bred International, Inc., 400 Locust Street, Suite 800, Des Moines, IA 50306-3453.

<sup>4</sup> Monsanto Co., 800 North Lindbergh Boulevard, St. Louis, MO 63167.

<sup>5</sup> TeeJet 8003VS flat-fan spray nozzles, Spraying Systems Co., P. O. Box 7900, Wheaton, IL 60189.

<sup>6</sup> Agridex, a mixture of 83% paraffinic mineral oil and 17% polyoxyethylene sorbitan fatty acid ester, Helena Chemical Co., 5100 Poplar Avenue, Memphis, TN 38137.

Corn injury and weed control were evaluated visually on a 0 to 100% scale, with 0 equal to no plant response and 100 equal to complete plant death. Corn injury was evaluated at 2 and 4 weeks after treatment with POST herbicides (WATP) and visual weed control evaluations were made on several dates, but only the final evaluation at 8 WATP is presented. Individual weed species evaluations are presented, with the exception of morningglory species. In 2003, pitted and ivyleaf morningglory densities were more uniform throughout the experimental area compared to in 2003a and 2003b, where pitted morningglory was predominant and ivyleaf morningglory was scattered. Corn yields were determined by harvesting grain from the center two rows of each plot with a commercial combine modified for small plots. Yields were adjusted to 15.5% moisture before analysis.

All data were subjected to analysis of variance, and means were separated using Fisher's protected LSD test at  $P = 0.05$  (Steel et al. 1997). Data were also subjected to a factorial analysis of variance to evaluate the significance of nicosulfuron plus rimsulfuron rate and atrazine rate effects. Control treatments were not included in the two-way analyses. These factorial analyses are not shown in the tables but will be discussed where significance occurred. When the analysis of variance revealed no significant treatment by location interaction, data were pooled over location. The nontreated check was not included with percentage data analyses, but was included with the corn yield analyses. Visual estimates of percent weed control were arcsine transformed, but nontransformed percentages are presented with mean separations based on transformed data. Nontransformed data for corn injury are presented.

## RESULTS AND DISCUSSION

**Corn Response.** Corn injury was variable between all locations at 2 WATP (Table 5.3). Injury with all treatments at all locations was less than 16% and was only significant in 2002 and 2003a. Injury by mesotrione plus nicosulfuron plus rimsulfuron combinations was similar to injury by nicosulfuron plus rimsulfuron POST alone. Corn injury at 4 WATP was less than 6% with all treatments (data not shown).

**Weed Control.** Weed species evaluated included common lambsquarters and common ragweed at all four locations, smooth pigweed in 2002 and 2003b, morningglory species at all locations in 2003, large crabgrass in 2002, 2003, and 2003a and giant foxtail in 2003 and 2003a. Data were averaged over locations for common lambsquarters and morningglory species control and corn yields in 2003a and 2003b. Weed control trends were similar between all evaluation dates, therefore only 8 WATP evaluations are presented. At all locations, significant rainfall provided PRE herbicide activation and actively growing weeds at time of POST applications.

*Common lambsquarters.* In both 2002 and 2003, all treatments controlled common lambsquarters greater than 96% except nicosulfuron plus rimsulfuron alone where control in 2002 was 45% and in 2003 was 92% (Table 5.4). Unacceptable control of common lambsquarters has been reported with either nicosulfuron or rimsulfuron (Eberlein et al. 1994; Lueschen et al. 1992; Tonks and Eberlein 2001), however in other research rimsulfuron provided 91% control (Renner and Powell 1998). Radliff and Kapusta (1989) indicated that common lambsquarters height and growing condition have resulted in control variability. Common lambsquarters was less than 13 cm tall in 2002 compared to less than 5 to 7 cm in 2003, which may have influenced control with nicosulfuron plus rimsulfuron alone.

Common lambsquarters control was pooled over 2003a and 2003b. Results were similar to those in 2002, where all treatments provided 99% control except nicosulfuron plus rimsulfuron alone, where control was 65% (Table 5.4). Other researchers have reported excellent control of common lambsquarters with POST mesotrione applications (Armel et al. 2003; Beckett and Taylor 2000; Lackey et al. 1999; Menbere and Ritter 2001).

*Common ragweed.* Common ragweed control with mesotrione alone ranged from 34 to 53% (Table 5.5). Addition of atrazine to mesotrione improved control to 98% or greater at all locations. Similar increases in control of other broadleaf weeds were observed with the addition of atrazine to mesotrione POST (Bradley et al. 2000; Johnson et al. 2002). Nicosulfuron plus rimsulfuron POST alone provided unacceptable common ragweed control at all locations, ranging from 10 to 62%. Lueschen et al. (1992) observed poor

and inconsistent common ragweed control with nicosulfuron. At all locations, the main effect of atrazine rate was significant for common ragweed control. Pooled over atrazine rate, POST factorial treatments without atrazine averaged 47% in 2002, 61% in 2003, 41% in 2003a, and 42% in 2003b (data not shown). With the addition of atrazine, control averaged greater than 96% at all locations. Control with *S*-metolachlor plus atrazine PRE fb nicosulfuron plus rimsulfuron POST was greater than 90% at all locations except in 2003a where control was 77%. Less rainfall was received in 2003a within 10 days after PRE application than at any other location, possibly resulting in reduced control from the PRE treatment.

*Smooth pigweed.* Smooth pigweed control in 2002 was greater than 92% with all treatments (Table 5.6). In 2003b, control with all treatments was greater than 97%. Armel et al. (2003) reported effective smooth pigweed control with mesotrione. Other researchers have also experienced effective control of *Amaranthus* species with mesotrione, nicosulfuron, and rimsulfuron POST (Beckett and Taylor 2000; Dobbels and Kapusta 1993; Eberlein et al. 1994; Mekki and Leroux 1994).

*Morningglory species.* Morningglory species control was 79% with mesotrione alone in 2003 and pooled over 2003a and 2003b (Table 5.6). Armel et al. (2003) reported control of a mixture of tall morningglory [*Ipomoea purpurea* (L.) Roth], ivyleaf morningglory, and pitted morningglory with mesotrione ranged from 76 to 86%. However, other research reported variable control from 33 to 86% with mesotrione alone (Johnson et al. 1999). Morningglory species control was not improved at any location with the combination of mesotrione plus nicosulfuron plus rimsulfuron without atrazine over either herbicide alone. However, the addition of atrazine to mesotrione alone or to combinations of nicosulfuron plus rimsulfuron improved control of morningglory species.

*Large crabgrass.* *S*-Metolachlor plus atrazine PRE fb nicosulfuron plus rimsulfuron POST provided consistent large crabgrass control over the three locations, where control ranged from 93 to 98% (Table 5.7). Control by *S*-metolachlor plus atrazine PRE alone was 95% in 2002 and 81% in 2003 and 2003a. Generally, large crabgrass control was higher in 2003 and 2003a than in 2002 with total POST treatments. In 2002, large

crabgrass was up to 10 cm tall, whereas in 2003 and 2003a large crabgrass was up to 5 cm tall at time of POST applications. Based on results in 2002 compared to in 2003 and 2003a, application timing may have been late in 2002 for optimum large crabgrass control with total POST treatments.

Mesotrione controlled large crabgrass 51% in 2002, 76% in 2003 and 74% in 2003a (Table 5.7). Control by mesotrione was improved 26% with the addition of atrazine in 2002, but in 2003 and 2003a control was improved by only 7 and 13%, respectively. At all locations, large crabgrass control with nicosulfuron plus rimsulfuron alone was similar to control with mesotrione plus the higher rate of nicosulfuron plus rimsulfuron and was better than mesotrione alone. The interaction of nicosulfuron plus rimsulfuron rate by atrazine rate was significant for large crabgrass control in 2003 and 2003a. At both locations, addition of atrazine improved control with treatments that included the lower rate of nicosulfuron plus rimsulfuron, but had no effect on treatments including the higher rate (data not shown).

*Giant foxtail.* Giant foxtail control with mesotrione alone was 17% in both 2003 and 2003a and was only slightly improved with the addition of atrazine (Table 5.8). Other researchers have reported insufficient giant foxtail control with mesotrione (Armel et al. 2003; Ohmes et al. 2000). All POST treatments that included nicosulfuron plus rimsulfuron at either rate controlled giant foxtail at least 98% in both years. Mekki and Leroux (1994) found that giant foxtail was controlled with nicosulfuron, rimsulfuron, or the combination at reduced rates. However, other results have shown a reduction in control when nicosulfuron is applied at less than the registered rate as a tank-mix with atrazine (Dobbels and Kapusta 1993). Our results did not indicate antagonism from the addition of atrazine to the nicosulfuron plus rimsulfuron combination for giant foxtail control. A POST application of nicosulfuron plus rimsulfuron improved giant foxtail control with *S*-metolachlor plus atrazine PRE alone.

**Corn Yield.** In general, corn yields were higher at all locations in 2003 compared to 2002 (Table 5.9). Rainfall was more consistent throughout the 2003 growing season than in 2002. At all locations, the highest yields were with *S*-metolachlor plus atrazine PRE fb nicosulfuron plus rimsulfuron POST and mesotrione plus either rate of nicosulfuron plus

rimsulfuron plus atrazine POST. In fact, the main effect of atrazine was significant at all locations. Corn yields in plots that included atrazine POST were 5250 kg/ha in 2002, 10250 kg/ha in 2003, and 9110 kg/ha averaged over 2003a and 2003b (data not shown). Yields in plots without atrazine POST were 2250 kg/ha in 2002, 8430 kg/ha in 2003, and 6730 kg/ha averaged over 2003a and 2003b.

Yields were most influenced by the addition of atrazine to POST treatments. The species present, common lambsquarters, common ragweed, and morningglory species, were all controlled effectively with the addition of atrazine, which resulted in higher corn yields. In other research, effective broadleaf weed control was obtained with mixtures of mesotrione, nicosulfuron, rimsulfuron, and atrazine (Whaley 2005). In addition, smooth pigweed was very susceptible to mesotrione and to nicosulfuron plus rimsulfuron alone. Giant foxtail was controlled with either rate of nicosulfuron plus rimsulfuron, so giant foxtail competition in these plots was not an issue. Corn yields were reduced, however, in mesotrione alone plots due to insufficient common ragweed or giant foxtail control.

POST applications were made at the V2 to V3 corn stage in our studies. Based on these results, corn yields were likely influenced more by level of weed control rather than by early season weed competition. Research has indicated that weed competition in corn should be reduced by the V4 to V5 stage of corn growth for improved yields (Kapusta et al. 1994).

Our results confirm that herbicides and rates in a total POST herbicide program may differ based on species present and weed heights at the time of application. O'Sullivan and Bouw (1993) reported that rates as low as one-quarter of registered rates will control broadleaf weeds at a level similar to full labeled rates. Consistent large crabgrass control may require the full rate of nicosulfuron plus rimsulfuron in mixtures with mesotrione, particularly at high densities or heights. It has been reported by others that reduced herbicide rates may not adequately control annual grasses under high grass densities (Defelice et al. 1989; O'Sullivan and Bouw 1993). Nicosulfuron plus rimsulfuron controlled giant foxtail at either the full or reduced rate in our studies.

These experiments were conducted under favorable conditions with good soil moisture and generally small weeds; however, our results may have been different under

conditions of lower rainfall and larger weeds. Under conditions less favorable for weed control, full registered rates of all herbicides may be needed to minimize the risk of inadequate control (Rabaey and Harvey 1997). Other research has shown that combinations of mesotrione, nicosulfuron plus rimsulfuron, and atrazine in a total POST program can provide similar levels of weed control and corn yields as a standard PRE fb POST herbicide program (Whaley 2005).

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*Table 5.1.* Planting date, herbicide application dates, and corn height and stage at time of applications.<sup>a</sup>

	Location			
	2002	2003	2003a	2003b
Planting date	April 30	April 23	April 23	April 23
PRE application date	April 30	May 1	April 24	May 6
Corn height (cm) at PRE	—	1	—	8
V-stage	—	Spike	—	1
POST application date	May 28	May 16	May 21	May 16
DAP	29	24	29	24
Corn height (cm) at POST	28	13	18	13
V-stage	3	2-3	3	2-3

<sup>a</sup> Abbreviations: PRE, preemergence; POST, postemergence; DAP, days after planting.

Table 5.2. Weed height and density at the time of postemergence applications.

Weed species	Location							
	2002		2003		2003a		2003b	
	Height - cm -	Density no./m <sup>2</sup>	Height - cm -	Density no./m <sup>2</sup>	Height - cm -	Density no./m <sup>2</sup>	Height - cm -	Density no./m <sup>2</sup>
Common lambsquarters	2-13	10	1-5	12	1-7	396	1-5	120
Smooth pigweed	2-20	9	2-5	12	—	—	4-5	12
Common ragweed	2-10	28	1-5	68	5-7	77	1-5	188
Morningglory species	—	—	5-10	20	4-5	8	5-10	10
Large crabgrass	2-10	10	2-5	48	1-4	16	—	—
Giant foxtail	—	—	2-10	176	2-7	4	—	—

Table 5.3. Corn response 2 WATP from POST mesotrione, nicosulfuron plus rimsulfuron, and atrazine combinations and from PRE *S*-metolachlor plus atrazine alone and fb nicosulfuron plus rimsulfuron POST.<sup>a</sup>

Herbicide treatment <sup>b</sup>	Rate		Corn Injury			
	2002, 2003	2003a, 2003b	2002	2003	2003a	2003b
	g ai/ha		%			
Mesotrione	105	105	8 ab <sup>c</sup>	3 a	7 bc	5 a
+ atrazine	560	560	4 ab	6 a	6 cd	7 a
+ nicosulfuron + rimsulfuron	17 + 9	13 + 7	5 ab	7 a	14 a	8 a
+ nicosulfuron + rimsulfuron	34 + 17	26 + 13	13 a	7 a	13 a	10 a
+ nicosulfuron + rimsulfuron + atrazine	17 + 9 + 560	13 + 7 + 560	3 b	7 a	7 bc	10 a
+ nicosulfuron + rimsulfuron + atrazine	34 + 17 + 560	26 + 13 + 560	3 bc	7 a	10 abc	11 a
Nicosulfuron + rimsulfuron	34 + 17	26 + 13	7 ab	8 a	11 ab	11 a
<i>S</i> -metolachlor + atrazine PRE	870 + 1100	870 + 1100	0 c	4 a	3 d	9 a
<i>S</i> -metolachlor + atrazine PRE fb	870 + 1100 fb	870 + 1100 fb	0 c	4 a	5 cd	15 a
nicosulfuron + rimsulfuron	34 + 17	26 + 13				
Nontreated <sup>d</sup>			0	0	0	0

<sup>a</sup> Abbreviations: WATP, weeks after treatment with POST herbicides; POST, postemergence; PRE, preemergence; fb, followed by.

<sup>b</sup> All POST treatments included 1% v/v crop oil concentrate.

<sup>c</sup> Means within a column followed by the same letter are not significantly different, according to Fisher's protected LSD at P = 0.05.

<sup>d</sup> The nontreated check was not included in the statistical analysis.

Table 5.4. Common lambsquarters control 8 WATP from POST mesotrione, nicosulfuron plus rimsulfuron, and atrazine combinations and from PRE *S*-metolachlor plus atrazine alone and fb nicosulfuron plus rimsulfuron POST.<sup>a</sup>

Herbicide treatment <sup>b</sup>	Rate		Weed control		
			Common lambsquarters		
	2002, 2003	2003a, 2003b	2002	2003	2003a + 2003b <sup>c</sup>
	g ai/ha		%		
Mesotrione	105	105	97 a <sup>d</sup>	99 a	99 a
+ atrazine	560	560	99 a	99 a	99 a
+ nicosulfuron + rimsulfuron	17 + 9	13 + 7	99 a	99 a	99 a
+ nicosulfuron + rimsulfuron	34 + 17	26 + 13	96 a	99 a	99 a
+ nicosulfuron + rimsulfuron + atrazine	17 + 9 + 560	13 + 7 + 560	99 a	99 a	99 a
+ nicosulfuron + rimsulfuron + atrazine	34 + 17 + 560	26 + 13 + 560	99 a	99 a	99 a
Nicosulfuron + rimsulfuron	34 + 17	26 + 13	45 b	92 b	65 b
<i>S</i> -metolachlor + atrazine PRE	870 + 1100	870 + 1100	98 a	99 a	99 a
<i>S</i> -metolachlor + atrazine PRE fb	870 + 1100 fb	870 + 1100 fb	99 a	99 a	99 a
nicosulfuron + rimsulfuron	34 + 17	26 + 13			
Nontreated <sup>e</sup>			0	0	0

<sup>a</sup> Abbreviations: WATP, weeks after treatment with POST herbicides; POST, postemergence; PRE, preemergence; fb, followed by.

<sup>b</sup> All POST treatments included 1% v/v crop oil concentrate.

<sup>c</sup> Common lambsquarters control averaged over 2003a and 2003b.

<sup>d</sup> Means within a column followed by the same letter are not significantly different, according to Fisher's protected LSD at P = 0.05.

<sup>e</sup> The nontreated check was not included in the statistical analysis.

Table 5.5. Common ragweed control 8 WATP from POST mesotrione, nicosulfuron plus rimsulfuron, and atrazine combinations and from PRE *S*-metolachlor plus atrazine alone and fb nicosulfuron plus rimsulfuron POST.<sup>a</sup>

Herbicide treatment <sup>b</sup>	Rate		Weed control			
	2002, 2003	2003a, 2003b	Common ragweed			
	g ai/ha		2002	2003	2003a	2003b
			%			
Mesotrione	105	105	53 d <sup>c</sup>	45 d	34 d	37 cd
+ atrazine	560	560	99 a	98 a	98 a	99 a
+ nicosulfuron + rimsulfuron	17 + 9	13 + 7	40 d	68 c	34 d	44 c
+ nicosulfuron + rimsulfuron	34 + 17	26 + 13	49 d	69 c	53 c	43 c
+ nicosulfuron + rimsulfuron + atrazine	17 + 9 + 560	13 + 7 + 560	97 ab	99 a	97 a	98 ab
+ nicosulfuron + rimsulfuron + atrazine	34 + 17 + 560	26 + 13 + 560	94 bc	99 a	95 a	98 ab
Nicosulfuron + rimsulfuron	34 + 17	26 + 13	10 e	62 c	38 d	32 d
<i>S</i> -metolachlor + atrazine PRE	870 + 1100	870 + 1100	86 c	91 b	63 c	95 b
<i>S</i> -metolachlor + atrazine PRE fb	870 + 1100 fb	870 + 1100 fb	91 bc	97 a	77 b	97 ab
nicosulfuron + rimsulfuron	34 + 17	26 + 13				
Nontreated <sup>d</sup>			0	0	0	0

<sup>a</sup> Abbreviations: WATP, weeks after treatment with POST herbicides; POST, postemergence; PRE, preemergence; fb, followed by.

<sup>b</sup> All POST treatments included 1% v/v crop oil concentrate.

<sup>c</sup> Means within a column followed by the same letter are not significantly different, according to Fisher's protected LSD at P = 0.05.

<sup>d</sup> The nontreated check was not included in the statistical analysis.

Table 5.6. Smooth pigweed and morningglory species control 8 WATP from POST mesotrione, nicosulfuron plus rimsulfuron, and atrazine combinations and from PRE *S*-metolachlor plus atrazine alone and fb nicosulfuron plus rimsulfuron POST.<sup>a</sup>

Herbicide treatment <sup>b</sup>	Rate		Weed control			
			Smooth pigweed <sup>c</sup>		Morningglory species <sup>d</sup>	
	2002, 2003	2003a, 2003b	2002	2003a	2003	2003a + 2003b
	g ai/ha		%			
Mesotrione	105	105	95 a <sup>e</sup>	98 a	79 bc	79 b
+ atrazine	560	560	99 a	99 a	86 ab	87 a
+ nicosulfuron + rimsulfuron	17 + 9	13 + 7	99 a	99 a	67 d	78 b
+ nicosulfuron + rimsulfuron	34 + 17	26 + 13	99 a	99 a	82 abc	77 b
+ nicosulfuron + rimsulfuron + atrazine	17 + 9 + 560	13 + 7 + 560	99 a	98 a	87 ab	88 a
+ nicosulfuron + rimsulfuron + atrazine	34 + 17 + 560	26 + 13 + 560	99 a	99 a	89 a	91 a
Nicosulfuron + rimsulfuron	34 + 17	26 + 13	95 a	99 a	79 bc	74 b
<i>S</i> -metolachlor + atrazine PRE	870 + 1100	870 + 1100	93 b	99 a	75 cd	78 b
<i>S</i> -metolachlor + atrazine PRE fb	870 + 1100 fb	870 + 1100 fb	99 a	99 a	84 abc	88 a
nicosulfuron + rimsulfuron	34 + 17	26 + 13				
Nontreated <sup>f</sup>			0	0	0	0

<sup>a</sup> Abbreviations: WATP, weeks after treatment with POST herbicides; POST, postemergence; PRE, preemergence; fb, followed by.

<sup>b</sup> All POST treatments included 1% v/v crop oil concentrate.

<sup>c</sup> Smooth pigweed data not available in 2003 and 2003a.

<sup>d</sup> Control data averaged over 2003a and 2003b. Morningglory species were not present in 2002. Morningglory species evaluated were pitted morningglory and ivyleaf morningglory.

<sup>e</sup> Means within a column followed by the same letter are not significantly different, according to Fisher's protected LSD at P = 0.05.

<sup>f</sup> The nontreated check was not included in the statistical analysis.

Table 5.7. Large crabgrass control 8 WATP from POST mesotrione, nicosulfuron plus rimsulfuron, and atrazine combinations and from PRE *S*-metolachlor plus atrazine alone and fb nicosulfuron plus rimsulfuron POST.<sup>a</sup>

Herbicide treatment <sup>b</sup>	Rate		Weed control		
	2002, 2003	2003a, 2003b	Large crabgrass		
	g ai/ha		2002	2003	2003a <sup>c</sup>
			%		
Mesotrione	105	105	51 d <sup>e</sup>	76 d	74 de
+ atrazine	560	560	77 b	83 bcd	87 bc
+ nicosulfuron + rimsulfuron	17 + 9	13 + 7	61 cd	78 cd	69 e
+ nicosulfuron + rimsulfuron	34 + 17	26 + 13	76 bc	95 a	84 bc
+ nicosulfuron + rimsulfuron + atrazine	17 + 9 + 560	13 + 7 + 560	64 bcd	87 a-d	80 cd
+ nicosulfuron + rimsulfuron + atrazine	34 + 17 + 560	26 + 13 + 560	78 b	89 abc	86 bc
Nicosulfuron + rimsulfuron	34 + 17	26 + 13	65 bcd	93 a	89 ab
<i>S</i> -metolachlor + atrazine PRE	870 + 1100	870 + 1100	95 a	81 cd	81 cd
<i>S</i> -metolachlor + atrazine PRE fb	870 + 1100 fb	870 + 1100 fb	98 a	93 ab	95 a
nicosulfuron + rimsulfuron	34 + 17	26 + 13			
Nontreated <sup>e</sup>			0	0	0

<sup>a</sup> Abbreviations: WATP, weeks after treatment with POST herbicides; POST, postemergence; PRE, preemergence; fb, followed by.

<sup>b</sup> All POST treatments included 1% v/v crop oil concentrate.

<sup>c</sup> Large crabgrass was not present in 2003b.

<sup>d</sup> Means within a column followed by the same letter are not significantly different, according to Fisher's protected LSD at P = 0.05.

<sup>e</sup> The nontreated check was not included in the statistical analysis.

Table 5.8. Giant foxtail control 8 WATP from POST mesotrione, nicosulfuron plus rimsulfuron, and atrazine combinations and from PRE *S*-metolachlor plus atrazine alone and fb nicosulfuron plus rimsulfuron POST.<sup>a</sup>

Herbicide treatment <sup>b</sup>	Rate		Weed control	
	2002, 2003	2003a, 2003b	Giant foxtail <sup>c</sup>	
	g ai/ha		2003	2003a
			%	
Mesotrione	105	105	17 d <sup>d</sup>	17 d
+ atrazine	560	560	49 c	38 c
+ nicosulfuron + rimsulfuron	17 + 9	13 + 7	98 a	99 a
+ nicosulfuron + rimsulfuron	34 + 17	26 + 13	99 a	99 a
+ nicosulfuron + rimsulfuron + atrazine	17 + 9 + 560	13 + 7 + 560	98 a	99 a
+ nicosulfuron + rimsulfuron + atrazine	34 + 17 + 560	26 + 13 + 560	99 a	99 a
Nicosulfuron + rimsulfuron	34 + 17	26 + 13	99 a	99 a
<i>S</i> -metolachlor + atrazine PRE	870 + 1100	870 + 1100	87 b	91 b
<i>S</i> -metolachlor + atrazine PRE fb	870 + 1100 fb	870 + 1100 fb	99 a	99 a
nicosulfuron + rimsulfuron	34 + 17	26 + 13		
Nontreated <sup>e</sup>			0	0

<sup>a</sup> Abbreviations: WATP, weeks after treatment with POST herbicides; POST, postemergence; PRE, preemergence; fb, followed by.

<sup>b</sup> All POST treatments included 1% v/v crop oil concentrate.

<sup>c</sup> Giant foxtail was not present in 2002 and 2003b.

<sup>d</sup> Means within a column followed by the same letter are not significantly different, according to Fisher's protected LSD at P = 0.05.

<sup>e</sup> The nontreated check was not included in the statistical analysis.

Table 5.9. Corn yield from POST mesotrione, nicosulfuron plus rimsulfuron, and atrazine combinations and from PRE *S*-metolachlor plus atrazine alone and fb nicosulfuron plus rimsulfuron POST.<sup>a</sup>

Herbicide treatment <sup>b</sup>	Rate		Corn yield		
	2002, 2003	2003a, 2003b	2002	2003	2003a + 2003b <sup>c</sup>
	g ai/ha		kg/ha		
Mesotrione	105	105	1970 cd <sup>d</sup>	4650 d	5610 c
+ atrazine	560	560	4500 ab	8840 c	8800 a
+ nicosulfuron + rimsulfuron	17 + 9	13 + 7	1810 cd	10970 ab	6530 bc
+ nicosulfuron + rimsulfuron	34 + 17	26 + 13	2970 bc	9650 bc	8040 ab
+ nicosulfuron + rimsulfuron + atrazine	17 + 9 + 560	13 + 7 + 560	5200 a	10850 ab	9620 a
+ nicosulfuron + rimsulfuron + atrazine	34 + 17 + 560	26 + 13 + 560	6040 a	11040 ab	8900 a
Nicosulfuron + rimsulfuron	34 + 17	26 + 13	430 d	9640 bc	6700 bc
<i>S</i> -metolachlor + atrazine PRE	870 + 1100	870 + 1100	5600 a	11510 a	9620 a
<i>S</i> -metolachlor + atrazine PRE fb	870 + 1100 fb	870 + 1100 fb	5250 a	9620 bc	9240 a
nicosulfuron + rimsulfuron	34 + 17	26 + 13			
Nontreated			320 d	1900 e	1280 d

<sup>a</sup> Abbreviations: POST, postemergence; PRE, preemergence; fb, followed by.

<sup>b</sup> All POST treatments included 1% v/v crop oil concentrate.

<sup>c</sup> Corn yield averaged over 2003a and 2003b.

<sup>d</sup> Means within a column followed by the same letter are not significantly different, according to Fisher's protected LSD at P = 0.05.