Chapter IV

Mesotrione, *S*-metolachlor, and Atrazine Mixtures Preemergence in Corn (*Zea mays*)

Abstract: Field experiments were conducted in 2001, 2002, and 2003 to evaluate the effectiveness of preemergence (PRE) mesotrione alone and in tank mixtures with *S*-metolachlor and atrazine for weed control in corn. Corn injury was 11 to 18% with all treatments in 2002, when rainfall was 3.2 cm within 10 d after PRE applications, but no injury was observed in 2001 and 2003 when rainfall was 0 and 1.1 cm within 10 d after PRE applications. Rainfall following PRE herbicide applications also influenced weed control, where weed control was generally low with all herbicide treatments in 2001. Mesotrione at 160 g/ha controlled common lambsquarters and smooth pigweed at least 95% in 2002 and 2003, but control was 70% or less in 2001. PRE mesotrione at rates of 230 or 310 g/ha controlled common ragweed at least 83% in 2002 and 2003, but control was greater than 88% with mixtures of mesotrione at rates above 160 g/ha plus *S*-metolachlor plus atrazine at 560 g/ha. Morningglory species (ivyleaf morningglory, pitted morningglory, and tall morningglory) were not consistently controlled by mesotrione alone. In 2002 and 2003, mixtures of all mesotrione rates plus *S*-metolachlor plus atrazine at 1,100 g/ha controlled morningglory species at least 90%. Corn treated with mesotrione at any rate plus *S*-metolachlor plus atrazine at 1,100 g/ha consistently produced high yields**.**

Nomenclature: Atrazine; mesotrione; *S*-metolachlor; common lambsquarters, *Chenopodium album* L. #[1] CHEAL; common ragweed, *Ambrosia artemisiifolia* L. # AMBEL; ivyleaf morningglory, *Ipomoea hederacea* (L.) Jacq. # IPOHE; morningglory species, *Ipomoea* spp. # IPOSS; pitted morningglory, *Ipomoea lacunosa* L. # IPOLA, smooth pigweed, *Amaranthus hybridus* L. # AMACH; tall morningglory, Ipomoea

[1] 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.

purpurea (L.) Roth # PHBPU; corn, Zea mays L. 'Dekalb DKC64-10 (RR2)', 'Pioneer 33B51', 'Pioneer 33G26'.

Additional index words: Herbicide mixtures, HPPD-inhibiting herbicides, triketone herbicides.

Abbreviations: DAT, days after treatment; PRE, preemergence; WAT, weeks after treatment.

INTRODUCTION

Traditional corn weed management programs have relied on PRE applications of a broadleaf herbicide plus a grass herbicide for residual season-long weed control. These standard PRE programs usually include atrazine in combinations with a chloroacetamide herbicide for broad-spectrum weed control. In 2003, atrazine was applied to 68% of the 32 million hectares of corn planted in the United States and the average rate was 1.14 kg/ha (Anonymous 2004a). However, there are concerns with atrazine use, which include detection in surface and groundwater, residual activity, and the development of triazine resistant weeds (Ahrens 1994). Reductions in atrazine use have prompted a search for broadleaf weed control alternatives in corn.

Mesotrione is a PRE and POST herbicide for weed control in corn. It has a good environmental profile and a distinct mode of action as an inhibitor of the enzyme p-hydroxyphenylpyruvate dioxygenase (HPPD, EC1.13.11.27) (Mitchell et al. 2001). Mesotrione is registered in corn for control of broadleaf weeds, including some species that are triazine- and acetolactate synthase-resistant, and some grasses (Sutton et al. 2002). In previous research, mesotrione PRE controlled smooth pigweed and common lambsquarters, but control of common ragweed and morningglory species (*Ipomoea* spp.) was inconsistent and dependent upon a timely rainfall following application (Armel et al. 2003a; Armel et al. 2003b; Ohmes et al. 2000). Armel et al. (2003a) reported improved weed control with tank mixtures of mesotrione plus acetochlor or atrazine over that of mesotrione alone. Other research has shown that isoxaflutole, which also inhibits the HPPD enzyme, in mixtures with metolachlor plus atrazine improved weed control compared with metolachlor plus atrazine (Taylor-Lovell and Wax 2001). Mesotrione also has the potential to enhance control of several weed species in a mixture with metolachlor plus atrazine. Metolachlor was applied on 19% of the corn hectareage in the United States in 2001 for PRE control of grasses and some small-seeded broadleaf weeds (Anonymous 2004a).

Limited information is available on the efficacy of mesotrione PRE in mixtures with metolachlor and atrazine. The objectives of this research were (1) to evaluate broadleaf weed control and corn response to mesotrione applied PRE alone and in mixtures with *S*-metolachlor and atrazine and (2) to compare control from these mixtures with control from *S*-metolachlor plus atrazine.

MATERIALS AND METHODS

Experiments were conducted in 2001, 2002, and 2003 at the Eastern Shore Agricultural Research and Extension Center near Painter, VA. 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 and State University (Donohue and Heckendorn 1994) and additional nitrogen was applied at the V5 growth stage of corn. Corn was planted 4.0 cm deep at a seeding rate of 57,000 seed/ha on April 30, 2001, April 24, 2002, and April 23, 2003. Corn hybrids planted were 'Pioneer 33G26'[2] in 2001, 'Dekalb DKC64-10 (RR2)'[3] in 2002, and 'Pioneer 33B51' in 2003.

Plots were four rows wide in 0.76 cm 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.[4] All herbicide treatments were applied PRE within 2 d after planting. Treatments included

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[2] Pioneer Hi-Bred International, Inc., 400 Locust Street, Suite 800, Des Moines, IA 50306-3453.

[3] Monsanto Co., 800 North Lindbergh Boulevard, St. Louis, MO 63167.

[4] TeeJet 8003VS flat-fan spray nozzles, Spraying Systems Co., P.O. Box 7900, Wheaton, IL 60189.

mesotrione alone, mixtures of mesotrione plus *S*-metolachlor, and mixtures of mesotrione plus *S*-metolachlor plus atrazine. Specific treatments and rates were mesotrione at 160, 230, and 310 g ai/ha alone, in mixtures with *S*-metolachlor at 1,060 g ai/ha (mesotrione-*S*-metolachlor ratios of 1:7, 1:5, and 1:3, respectively), and in mixtures with *S*-metolachlor at 1,060 g/ha plus atrazine at 560 or 1,100 g/ha (mesotrione-*S*-metolachlor-atrazine ratios of 1:7:4, 1:5:2, and 1:3:2, respectively, or 1:7:7, 1:5:5, and 1:3:4, respectively). Ratios were thus achieved by increasing the rates of mesotrione and atrazine while maintaining consistent rates of *S*-metolachlor. Additional treatments included *S*-metolachlor at 1,060 g/ha plus atrazine at 560 g/ha or 1,100 g/ha. Treatments were arranged in a randomized complete block design with three replications.

Weed species present in all three years included common lambsquarters, common ragweed, and morningglory species (ivyleaf moringglory, pitted morninglory, and tall morningglory). Smooth pigweed was present in 2002 and 2003. 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 2 and 4 WAT and visual weed control was evaluated at 6 WAT. 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.

Data were subjected to analysis of variance, and means were separated using Fisher's protected LSD test at P=0.05 significance level (Steel et al. 1997). The nontreated check was not included with percentage data analyses, but was included with corn yield analyses. ANOVA revealed significant year by treatment interactions for all weed species and corn yield, therefore all data are presented separately by year.

RESULTS AND DISCUSSION

Rainfall during the 10 d after PRE herbicide treatment varied among years. In 2001, no rainfall occurred in the 10 d after treatment (DAT), but rainfall was above 3.0 cm and 1.0 cm in the first 10 d after PRE herbicide treatment in 2002 and 2003, respectively (Table 4.1). Rainfall between 11 and 20 d after PRE application was at least 2 cm in all years.

Corn Response. There was no corn injury in 2001 and 2003, but corn was injured 11 to 18% with all treatments in 2002 at 2 WAT when rainfall accumulated 3.2 cm within 10 DAT (data not shown). Armel et al. (2003a) reported similar corn response with PRE mesotrione, acetochlor, or atrazine combinations when applications were followed by significant rainfall. Corn rapidly recovered from early-season injury by any treatment, and at 4 WAT injury did not exceed 2%.

Weed Control. *Common lambsquarters*. Common lambsquarters control with all treatments was at least 95% in 2002 and 2003, when rainfall occurred within 10 DAT (Table 4.2). Others have reported similar common lambsquarters control with mesotrione and metolachlor plus atrazine applied PRE (Bhowmik 2003; Lingenfelter and Curran 2004; Thomas et al. 2004). However in 2001, when no rainfall occurred within 10 DAT, mixtures of mesotrione at 230 or 310 g/ha plus *S*-metolachlor plus atrazine at 1,100 g/ha controlled common lambsquarters 70 and 77%, respectively. All other treatments controlled common lambsquarters less than 53% in 2001. Armel et al. (2003a) also observed low common lambsquarters control from mesotrione PRE when timely rainfall was not received following application.

Common ragweed. In the two years with higher rainfall within 10 DAT, mesotrione alone at 230 and 310 g/ha controlled common ragweed 83 to 91%, but control with 160 g/ha was 69 to 77% (Table 4.2). Armel et al. (2003b) also observed at least 80% control with mesotrione rates above 230 g/ha. In 2001, when rain was not received within 10 DAT, common ragweed control was below 58% by all rates of mesotrione. In 2002 and 2003, mixtures of all mesotrione rates with *S*-metolachlor plus either atrazine rate controlled common ragweed similar to *S*-metolachlor plus atrazine at 1,100 g/ha, where control was 89 to 99%. In 2001, when no rainfall occurred within 10 DAT, either mesotrione rate with *S*-metolachlor plus atrazine at 1,100g/ha controlled common ragweed 75 to 82% compared to 35% by *S*-metolachlor plus atrazine at 1,100 g/ha alone.

Morningglory species. Morningglory species control was low in 2001 (Table 4.3). Without rainfall, even mesotrione at 310 g/ha mixed with *S*-metolachlor plus atrazine at 1,100 g/ha did not control morningglory species above 65%, whereas control with all other treatments was 46% or less. However, with timely rainfall following application, mesotrione at 230 and 310 g/ha controlled morningglory species 78% in 2002 and 90 to

94% in 2003. Ohmes et al. (2000) reported at least 85% morningglory species control with mesotrione PRE. In 2002 and 2003, mixtures of mesotrione at either rate with *S*-metolachlor plus atrazine at 1,100 g/ha controlled morningglory species at least 90%.

Smooth pigweed. Smooth pigweed was present only in 2001 and 2003 and initial rainfall in 2003 enhanced control. Smooth pigweed control in 2001 with mesotrione alone at either rate was less than 71% and control with *S*-metolachlor plus atrazine at either rate was 39 to 40% (Table 4.3). However, mesotrione combined with either *S*-metolachlor or *S*-metolachlor plus atrazine controlled smooth pigweed 85 to 99%. Control in 2003 was at least 98% by all treatments.

Corn Yield. Although rainfall did not occur within 10 DAT in 2001, rainfall in June and July totaled 37 cm, compared to 22 cm in both 2002 and 2003 (data not shown). Yields were likely affected more by weed control than rainfall in either year. In all three years, corn treated with mesotrione at either rate plus *S*-metolachlor plus atrazine at 1,100 g/ha consistently produced high yields (Table 4.4). In 2001, corn treated with mesotrione alone at 160 and 230 g/ha and *S*-metolachlor plus either rate of atrazine produced yields similar to nontreated corn, but in the other two years, all herbicide-treated corn produced higher yields than the nontreated. In 2002 and 2003, when rainfall occurred within 10 DAT, corn treated with mesotrione at 230 or 310 g/ha plus *S*-metolachlor produced yields similar to yields produced by corn treated with systems which included atrazine in the mixture.

Control of broadleaf weeds in these experiments by mixtures which contained mesotrione, metolachlor, and atrazine was similar to or better than control by *S*-metolachlor plus atrazine, particularly when rainfall following herbicide application did not occur within 10 DAT. In the year with no rainfall following PRE applications, mesotrione controlled all weed species less than 71%. In the two years in which rainfall occurred within 10 DAT, all mesotrione rates controlled common lambsquarters and smooth pigweed at least 95%. PRE mesotrione rates of 230 or 310 g/ha controlled common ragweed at least 83%, but control was at least 89% with all rates of mesotrione in mixtures with atrazine. Mesotrione alone did not consistently control morningglory species, but in mixtures with *S*-metolachlor and atrazine at 1,100 g/ha morningglory species were controlled at least 90%.

Our results indicated that in the year with low rainfall, PRE herbicides would probably need to be followed by POST herbicides for control of escaped weeds. Armel et al. (2003a) indicated that under low rainfall conditions, mesotrione alone or in mixtures with acetochlor or atrazine applied PRE did not adequately control common lambsquarters, common ragweed, or morningglory species. In the years with timely rainfall following PRE applications, mesotrione at rates of 160 g/ha or above in mixtures with *S*-metolachlor and atrazine at either rate of 560 or 1,100 g/ha could adequately control common lambsquarters, common ragweed, and smooth pigweed, but consistent control of morningglory species would require mixtures with atrazine at 1,100 g/ha. On the sandy soils of eastern Virginia, mesotrione can be an effective component in PRE mixtures with *S*-metolachlor and atrazine for broadleaf weed control in corn.

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Table 4.1. Rainfall at 10-d intervals for 20 d after preemergence applications in 2001, 2002, and 2003.

Days after application	2001	2002	2003
		cm	
0-10	0	3.2	1.1
11-20	3.6	2.5	2.0
Total	3.6	5.7	3.1

Table 4.2. Common lambsquarters and common ragweed control 6 WAT with preemergence mesotrione, *S*-metolachlor, and atrazine treatments.[a]

		Control					
		Common lambsquarters			Common ragweed		
Herbicide treatment	Rate	2001	2002	2003	2001	2002	2003
	g ai/ha	%					
Mesotrione	160	25 de[b]	98 a	95 a	32 gh	77 e	69 f
Mesotrione	230	32 cd	99 a	99 a	54 cde	83 de	86 cd
Mesotrione	310	46 cd	98 a	99 a	57 cde	88 cd	91 abc
Mesotrione + metolachlor	160 + 1,060	32 cd	98 a	99 a	42 efg	79 e	74 ef
Mesotrione + metolachlor	230 + 1,060	48 bcd	99 a	99 a	46 d-g	92 bc	81 de
Mesotrione + metolachlor	310 + 1,060	52 bc	99 a	99 a	55 cde	94 abc	90 abc
Mesotrione + metolachlor + atrazine	160 + 1,060 + 560	52 bc	99 a	99 a	52 c-f	99 a	89 bcd
Mesotrione + metolachlor + atrazine	230 + 1,060 + 560	50 bc	99 a	99 a	60 bcd	99 a	90 abc
Mesotrione + metolachlor + atrazine	310 + 1,060 + 560	52 bc	99 a	99 a	69 abc	98 ab	95 ab
Mesotrione + metolachlor + atrazine	160 + 1,060 + 1,100	48 bcd	99 a	99 a	75 ab	99 a	95 ab
Mesotrione + metolachlor + atrazine	230 + 1,060 + 1,100	70 ab	99 a	99 a	81 a	99 a	98 a
Mesotrione + metolachlor + atrazine	310 + 1,060 + 1,100	77 a	99 a	99 a	82 a	99 a	98 a
Metolachlor + atrazine	1,060 + 560	7 e	99 a	99 a	22 h	83 de	76 ef
Metolachlor + atrazine	1,060 + 1,100	38 cd	99 a	99 a	35 fgh	98 ab	93 abc
Nontreated[c]		0	0	0	0	0	0

[a] Abbreviations: WAT, weeks after treatment.
[b] Means within a column followed by the same letter are not significantly different, according to Fisher's protected LSD at P = 0.05.
[c] The nontreated check was not included in the statistical anaylsis.

Table 4.3. Morningglory species and smooth pigweed control 6 WAT with preemergence mesotrione, *S*-metolachlor, and atrazine treatments.[a]

		Control				
		Morningglory species[b]			Smooth pigweed[c]	
Herbicide treatment	Rate	2001	2002	2003	2001	2003
	g ai/ha	%				
Mesotrione	160	20 de[d]	61 d	77 d	31 f	98 a
Mesotrione	230	23 de	78 bc	90 ab	42 e	99 a
Mesotrione	310	39 bc	78 bc	94 ab	70 d	99 a
Mesotrione + metolachlor	160 + 1,060	28 cd	56 d	78 cd	85 c	99 a
Mesotrione + metolachlor	230 + 1,060	33 bcd	84 ab	87 bc	85 c	99 a
Mesotrione + metolachlor	310 + 1,060	40 bc	85 ab	92 ab	99 a	99 a
Mesotrione + metolachlor + atrazine	160 + 1,060 + 560	45 b	85 ab	90 ab	94 ab	99 a
Mesotrione + metolachlor + atrazine	230 + 1,060 + 560	43 b	78 bc	91 ab	99 a	99 a
Mesotrione + metolachlor + atrazine	310 + 1,060 + 560	46 b	87 ab	96 ab	98 a	99 a
Mesotrione + metolachlor + atrazine	160 + 1,060 + 1,100	40 bc	94 a	98 a	89 bc	99 a
Mesotrione + metolachlor + atrazine	230 + 1,060 + 1,100	45 b	91 ab	97 a	96 ab	99 a
Mesotrione + metolachlor + atrazine	310 + 1,060 + 1,100	65 a	90 ab	97 a	99 a	99 a
Metolachlor + atrazine	1,060 + 560	13 e	68 cd	50 e	40 e	99 a
Metolachlor + atrazine	1,060 + 1,100	27 cd	86 ab	87 bc	39 e	99 a
Nontreated[e]		0	0	0	0	0

[a] Abbreviations: WAT, weeks after treatment.
[b] Morningglory species evaluated were ivyleaf morningglory, pitted morningglory, and tall morningglory.
[c] Smooth pigweed was present only in 2001 and 2003.
[d] Means within a column followed by the same letter are not significantly different, according to Fisher's protected LSD at P = 0.05.
[e] The nontreated check was not included in the statistical anaylsis.

Table 4.4. Corn yield with preemergence mesotrione, *S*-metolachlor, and atrazine treatments.

Herbicide	Rate	Corn yield		
		2001	2002	2003
	g ai/ha	kg/ha		
Mesotrione	160	2880 ef[a]	5550 de	7610 f
Mesotrione	230	2890 ef	4720 e	8430 def
Mesotrione	310	6100 bcd	6290 b-e	8230 ef
Mesotrione + metolachlor	160 + 1,060	4480 cde	4860 e	8460 c-f
Mesotrione + metolachlor	230 + 1,060	4580 cde	6360 a-e	10350 ab
Mesotrione + metolachlor	310 + 1,060	5650 bcd	7710 abc	10640 ab
Mesotrione + metolachlor + atrazine	160 + 1,060 + 560	6400 abc	5870 cde	10020 abc
Mesotrione + metolachlor + atrazine	230 + 1,060 + 560	6360 abc	8150 ab	9370 b-e
Mesotrione + metolachlor + atrazine	310 + 1,060 + 560	5280 b-e	8380 a	9890 a-d
Mesotrione + metolachlor + atrazine	160 + 1,060 + 1,100	7060 ab	7530 a-d	10970 a
Mesotrione + metolachlor + atrazine	230 + 1,060 + 1,100	7030 ab	7810 abc	9690 a-e
Mesotrione + metolachlor + atrazine	310 + 1,060 + 1,100	8590 a	7590 abc	10040 ab
Metolachlor + atrazine	1,060 + 560	1660 f	6680 a-e	8160 ef
Metolachlor + atrazine	1,060 + 1,100	3870 def	7580 abc	9080 b-f
Nontreated		1930 f	220 f	2810 g

[a] Means within a column followed by the same letter are not significantly different, according to Fisher's protected LSD at P = 0.05.