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Weed Control in Field Corn (*Zea mays*) with RPA 201772 Combinations with Atrazine and S-Metolachlor[1]

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Abstract: The premix atrazine + S-metolachlor is commonly used to control a wide range of weeds in corn, but it is weak on velvetleaf and several other broadleaf species. RPA 201772, used at reduced rates in combination with atrazine + S-metolachlor, may improve the weed control spectrum. In field studies at Urbana and Dekalb in 1998 and 1999, RPA 201772 was combined with a premix of atrazine at 1,820 g ai/ha and S-metolachlor at 1,408 g ai/ha to compare RPA 201772 rate effects on corn injury, weed control, and yield. RPA 201772 was applied at 0, 26, 53, 78, 105, and 132 g ai/ha early preplant (EPP), preplant incorporated (PPI), and preemergence (PRE). Compared with atrazine + S-metolachlor alone, RPA 201772 combinations did not improve giant foxtail control. However, RPA 201772 at 26 or 53 g/ha increased control of redroot pigweed, common lambsquarters, ivyleaf morningglory, common ragweed, giant ragweed, and velvetleaf in some environments. At Urbana in both years, RPA 201772 at 26 g/ha in combination with atrazine + S-metolachlor increased velvetleaf control 15% compared with the premix alone. RPA 201722 at 26 to 78 g/ha decreased velvetleaf densities with all application methods. Greater weed control and higher corn yield occurred in treatments applied PRE or PPI compared with EPP applications, except where conditions were dry after PRE applications. This research demonstrates the benefit of RPA 201772 at low rates for broadleaf weed control with less potential for crop injury compared with high RPA 201772 rates.
Nomenclature: RPA 201772 (proposed common name, isoxaflutole), 5-cyclopropyl isoxazol-4-yl-2-mesyl-4-trifluoromethylphenyl ketone; common lambsquarters, *Chenopodium album* L. #[3] CHEAL; common ragweed, *Ambrosia artemisiifolia* L. # AMBEL; giant foxtail, *Setaria faberi* Herrm. # SETFA; giant ragweed, *Ambrosia trifida* L. # AMBTR; ivyleaf morningglory, *Ipomoea hederacea* (L.) Jacq. # IPOHE; redroot pigweed, *Amaranthus retroflexus* L. # AMARE; velvetleaf, *Abutilon theophrasti* Medicus # ABUTH; corn, *Zea mays* L.
Additional index words: HPPD inhibitor, isoxaflutole, reduced herbicide rates.
Abbreviations: DAE, days after emergence; DAT, days after treatment; EPP, early preplant; PPI, preplant incorporated; PRE, preemergence.

INTRODUCTION

RPA 201772 is a soil-residual herbicide that controls a wide range of grass and broadleaf species in field corn. The herbicide offers a favorable environmental profile including a low use rate, rapid dissipation, and very low mammalian toxicity (Luscombe and Pallett 1996; Vrabel et al. 1995). RPA 201772 inhibits 4-hydroxyphenylpyruvate dioxygenase (HPPD), an enzyme found in the pathway for carotenoid biosynthesis. Symptomology is characterized by bleaching of shoot growth, which is followed by necrosis, and then ultimately plant death (Pallett et al. 1997, 1998).

RPA 201772 offers flexibility in application timing, with early preplant (EPP), preplant incorporated (PPI), and preemergence (PRE) applications (Mosier et al. 1997; Wrucke et al. 1997). This herbicide has been shown to provide control of many weed species important in Midwest corn production, including common ragweed, giant ragweed, common lambsquarters, *Amaranthus* spp., kochia [*Kochia scoparia* (L.) Schrad.], and barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], and is very effective on velvetleaf, even with low rates (Knezevic et al. 1998; Loubiere et al. 1996).

Several instances of RPA 201772 phytotoxicity in corn have been documented and appear to be related to

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[3] 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.

application timing (Sprague et al. 1997) and high RPA 201772 rate (Curvey and Kapusta 1996; Geier and Stahlman 1997; Obermeier et al. 1995; Sprague et al. 1998). Corn hybrids vary in susceptibility to RPA 201772 because of differences in the rate of herbicide metabolism (Sprague and Penner 1998). Hybrids that metabolize RPA 201772 more rapidly are less susceptible. Corn injury from RPA 201772 is also related to environmental conditions (cool and wet) and soil characteristics including organic matter content and soil type (Geier and Stahlman 1997; Obermeier et al. 1995; Sprague et al. 1998). Selection of more tolerant hybrids, reducing the rate of RPA 201772, or applying the herbicide several weeks before planting could potentially reduce phytotoxicity to corn.

Low rates of RPA 201772 have been applied in combination with atrazine + S-metolachlor to improve control of several weed species compared with atrazine + S-metolachlor alone. The atrazine + S-metolachlor premix is inconsistent in controlling velvetleaf, so the addition of a herbicide such as RPA 201772, which has high velvetleaf activity, could improve control (Mosier et al. 1995; Young et al. 1998). The development of resistance is also likely to be delayed for species that are controlled by both RPA 201772 and atrazine + S-metolachlor.

EPP applications of RPA 201772 in combination with S-metolachlor + atrazine might be effective where the rainfall required to activate the herbicides is limited, because the early application allows more time for a rainfall event before planting. However, RPA 201772 has been shown to control small weeds even after they emerge, potentially reducing the necessity of an activating rainfall before weed emergence (Luscombe et al. 1994). A disadvantage of EPP applications is a reduction in the amount of herbicide available at the time of planting due to dissipation between application and planting. Compared with PRE applications, applying RPA 201772 PPI is likely to improve weed control under dry conditions, but potentially reduce weed control in excessively moist environments (Wrucke et al. 1997). Dilution of the herbicide by the cultivation may be especially detrimental where low herbicide rates are used.

The objective in this field study was to determine how RPA 201772 applied at several rates in combination with atrazine + S-metolachlor affected control of velvetleaf, giant foxtail, and other weed species present at two locations. A second objective was to compare EPP, PPI, and PRE applications for weed control with each herbicide combination. Additionally, the effects of each factor on corn injury and yield were determined.

MATERIALS AND METHODS

Corn studies were conducted in 1998 and 1999 at Urbana and Dekalb, IL in areas that had not been treated with RPA 201772 for at least 3 yr. At Dekalb, the trial areas consisted of Drummer silty clay loam (fine-silty, mixed, mesic Typic Endoaquolls) with pH 6.1 and 4.5% organic matter in 1998 and Flanagan silt loam (fine, smectitic, mesic Aquic Argiudolls) with 5.0% organic matter and pH 6.1 in 1999. Both trial areas in Urbana consisted of Flanagan silt loam with pH 6.5 and 4.8% organic matter.

Each of the fields had been planted in soybean [*Glycine max* (L.) Merr.] the previous year and chisel-plowed each fall after soybean harvest. In the spring before EPP applications, trial areas were tilled with a field cultivator. The studies were planted on the dates given in Table 1, at a seeding rate of 74,000 seeds/ha in plots four rows wide by 10 m long with 75 cm between rows. The field experiments were established as randomized complete block designs with four replicates. The corn hybrids used in the studies were Dekalb 512RR and Pioneer 3335 at the Dekalb location and Pioneer 3335 and Dekalb 589RR at Urbana in 1998 and 1999, respectively.

Herbicide treatments were applied EPP, PPI, or PRE. The EPP treatments were applied 12 to 23 d before planting on dates given in Table 1. After the PPI applications, the entire trial area was tilled with a field cultivator at an operating depth of 6 cm to incorporate existing treatments. The PRE treatments were applied within 24 h after corn planting. At each application timing, the eight herbicide treatments were applied with a CO_2 backpack sprayer through 8003 flat fan nozzles at 234 L/ha and 207 kPa. The herbicide treatments included the premix atrazine + S-metolachlor (1,820 g/ha + 1,408 g/ha, respectively) in combination with RPA 201772 at 0, 26, 53, 78, 105, or 132 g/ha. Additionally, treatments containing a low rate of the premix (atrazine at 910 g/ha + S-metolachlor at 704 g/ha) were applied with RPA 201772 at 105 or 132 g/ha. The atrazine + S-metolachlor formulation included S-metolachlor at 288 g ai/L, atrazine at 372 g ai/L, and herbicide safener benoxacor [±-2,2-dichloro-1-(3,4-dihydro-3-methyl-2*H*-1,4-benzoxazyn-4-yl)ethanone].

Weed control was evaluated approximately 30 and 60 d after emergence (DAE), and corn injury was evaluated 15, 30, and 60 DAE, each visually on a scale of 0 (no control) to 100 (complete plant death). Corn injury ratings were based on combined symptomology including bleaching, chlorosis, and stunting. The ratings presented in the tables were based on visible weed control taken

Table 1. Treatment dates, weed densities, and precipitation in field studies at the research centers near Dekalb and Urbana, IL in 1998 and 1999 with early preplant (EPP), preplant incorporated (PPI), and preemergence (PRE) herbicide applications.

	Dekalb		Urbana	
	1998	1999	1998	1999
Treatment or harvest	Dates			
EPP	April 24	April 29	April 8	April 7
PPI	May 14	May 11	April 23	April 30
PRE	May 14	May 11	April 23	May 1
Harvest	October 26	October 21	September 23	September 20
Weed species	Densities (plants/m^2)[a]			
Giant foxtail	25	86	120	110
Common lambsquarters	2	8	6	5
Redroot pigweed	—	11	3	4
Velvetleaf	5	17	11	4
Ivyleaf morningglory	—	—	3	8
Giant ragweed	—	3	—	—
Common ragweed	1	—	—	—
Time interval	Precipitation (mm)			
Between EPP and PRE	70	30	27	109
1st week after PRE	3	53	37	10
2nd week after PRE	3	20	71	17

[a] Plants were counted in nontreated areas at 30 days after corn emergence. Dash (−) indicates the plant density was not uniform or too low to evaluate.

30 DAE of corn. Because the 60 DAE ratings were very similar to those taken 30 DAE, only the 30 DAE ratings are included in the tables. Velvetleaf densities were determined 30 DAE of corn by combining the counts from two 0.5-m^2 sections randomly chosen within each plot and the data were transformed using the equation (count + 1)$^{1/2}$. At corn maturity, the two center rows of each plot were harvested with a combine to determine corn yield, and moisture was adjusted to 15.5%.

Table 2. Impact of rates of RPA 201772 in combination with the premix of atrazine + S-metolachlor and application timings on weed control at Dekalb in 1998.[a]

Herbicide rates[b]		Weed species[c]			
RPA 201772	Atrazine + S-metolachlor[d]	SETFA	CHEAL	AMBEL	ABUTH
g/ha		% Control[e]			
0	1,820 + 1,408	88 a–c	99 a	93 b	86 d
26	1,820 + 1,408	92 a	99 a	97 ab	90 cd
53	1,820 + 1,408	90 ab	99 a	93 b	91 bc
78	1,820 + 1,408	90 ab	99 a	97 ab	96 a
105	1,820 + 1,408	88 a–c	99 a	96 ab	95 ab
132	1,820 + 1,408	87 bc	99 a	99 a	94 a–c
105	910 + 704	84 c	99 a	98 a	94 a–c
132	910 + 704	88 a–c	99 a	96 ab	93 a–c
Application timing[f]					
Early preplant		90 b	99 a	96 a	94 a
Preplant incorporated		93 a	99 a	97 a	93 ab
Preemergence		83 c	99 a	95 a	91 b

[a] Means are compared within columns and those followed by a common letter are not different according to Pdiff option in SAS at the 5% level for herbicide treatment or application timing.

[b] Herbicide treatments are averaged over application methods.

[c] Weed species are listed by Bayer code: giant foxtail (SETFA), common lambsquarters (CHEAL), common ragweed (AMBEL), and velvetleaf (ABUTH).

[d] The premix formulation contains atrazine at 372 g ai/L, S-metolachlor at 288 g ai/L, and benoxacor.

[e] Control ratings made at 30 d after corn emergence.

[f] Data for application timings were averaged across herbicide treatments.

Treatment-by-location and by-year (environment) interactions were significant with all variables; thus, the data for each environment are presented separately. With most variables, interactions between herbicide treatment and application timing were not significant; therefore data were presented as averages of each, and where interactions were significant, an explanation of the effect was given. Data were subjected to analysis of variance, and mean separations were done using the Pdiff option in SAS at the 5% level. Fisher's protected LSD at the 5% significance level was used to compare velvetleaf densities within each environment.

RESULTS AND DISCUSSION

Giant foxtail control at Dekalb in 1998 ranged from 84 to 92% with the different herbicide treatments averaged over all application methods (Table 2). RPA 201772 did not improve giant foxtail control at any rate compared with atrazine + S-metolachlor alone. Broadleaf weed control was excellent with most herbicide combinations at Dekalb in 1998. Timely precipitation and good growing conditions after the EPP applications improved uptake of the herbicide treatments in that environment. Control of common lambsquarters was 99% for all herbicide treatments, indicating that the reduction in the rate of either herbicide had little effect on control.

Common ragweed control was at least 93% with each herbicide treatment and application timing. However, common ragweed control was better with the herbicide treatment containing the tank-mix of the highest rates of each herbicide (RPA 201772 at 132 g/ha and atrazine at 1,820 g/ha + S-metolachlor at 1,408 g/ha) compared with the premix alone or the premix with RPA 201772 at 53 g/ha. Velvetleaf control at Dekalb in 1998 ranged from 86 to 96%. Including RPA 201772 at rates of 53 g/ha or greater with the premix increased velvetleaf control at least 5% compared with the premix alone.

The effect of application method varied depending on weed species at Dekalb in 1998. Control of common ragweed and common lambsquarters did not differ with application timing. However, velvetleaf control was 3% greater with EPP than with PRE applications. Giant foxtail control with the PRE application was 7 and 10% less than the EPP and the PPI applications, respectively. This environment had much less precipitation after the PRE timing, with only 6 mm in the 2 wk after application, compared with 27 to 108 mm in other environments (Table 1). Previous studies have shown increased giant foxtail control using PRE compared with EPP applications under typical environmental conditions (Buhler 1991; Johnson et al. 1997). The advantage of an EPP application is likely to occur only in environments where conditions after PRE applications are dry (Buhler 1991). Incorporation under such conditions may also aid in distributing the herbicides into the weed germination zone when rainfall is not adequate.

At Dekalb in 1999, giant foxtail control ranged from 86 to 90% for the different herbicide combinations averaged over all application methods (Table 3). The addition of RPA 201772 at 105 or 132 g/ha to the low rate of the atrazine + S-metolachlor premix did not improve control compared with the premix alone at the high rate. Control of redroot pigweed and giant ragweed was at least 95% with most herbicide combinations. Treatments without RPA 201772 provided slightly less control than those with RPA 201772 at rates of at least 26 g/ha for giant ragweed or at least 53 g/ha for redroot pigweed. Velvetleaf control increased from 64% in the absence of RPA 201772 to 74% with RPA 201772 at 53 g/ha and 82% with RPA 201772 at 78 g/ha. The combination of RPA 201772 with atrazine + S-metolachlor at the highest rates of each resulted in 88% velvetleaf control. Reducing the atrazine + S-metolachlor to 910 g/ha + 704 g/ha caused a 7% decrease in control compared with the high rate of the premix combined with RPA 201772 at equivalent rates.

Table 3. Impact of rates of RPA 201772 in combination with the premix of atrazine + S-metolachlor and application timings on weed control at Dekalb in 1999.[a]

Herbicide rates[b]		Weed species[c]			
RPA 201772	Atrazine + S-metolachlor[d]	SETFA	AMARE	AMBTR	ABUTH
g/ha		% Control[e]			
0	1,820 + 1,408	90 a	95 b	89 b	64 d
26	1,820 + 1,408	87 ab	96 b	95 a	68 d
53	1,820 + 1,408	88 ab	98 a	97 a	74 c
78	1,820 + 1,408	89 ab	98 a	98 a	82 b
105	1,820 + 1,408	87 ab	99 a	96 a	82 b
132	1,820 + 1,408	90 a	99 a	98 a	88 a
105	910 + 704	87 ab	99 a	98 a	79 b
132	910 + 704	86 b	99 a	97 a	81 b
Application timing[f]					
Early preplant		80 c	96 b	94 b	69 c
Preplant incorporated		90 b	98 a	96 ab	78 b
Preemergence		94 a	98 a	97 a	85 a

[a] Means are compared within columns and those followed by a common letter are not different according to Pdiff option in SAS at the 5% level for herbicide treatment or application timing.

[b] Herbicide treatments are averaged over application methods.

[c] Weed species are listed by Bayer code: giant foxtail (SETFA), redroot pigweed (AMARE), giant ragweed (AMBTR), and velvetleaf (ABUTH).

[d] The premix formulation contains atrazine at 372 g ai/L, S-metolachlor at 288 g ai/L, and benoxacor.

[e] Control ratings made at 30 d after corn emergence.

[f] Data for application timings were averaged across herbicide treatments.

Although differences among herbicide treatments were minor with several of the weed species at Dekalb in 1999, the effects of application timing were evident. Control of all species was greater with the PRE applications than with the EPP applications. This difference was most evident with giant foxtail and velvetleaf, where the increase in control was 14 and 16%, respectively. With these two species, control with treatments applied PPI was 4 to 7% less than PRE and approximately 10% greater than EPP. Adequate moisture at Dekalb in 1999 after the PRE applications probably contributed to the increased control.

At Urbana in 1998, giant foxtail control was similar with all treatments containing atrazine at 1,820 g/ha + S-metolachlor at 1,408 g/ha, regardless of RPA 201772 rate when averaged across all application methods (Table 4). However, decreasing the atrazine + S-metolachlor rate to 910 g/ha + 704 g/ha reduced giant foxtail control 5 to 8%. Velvetleaf control was less than 90% with any herbicide treatment. The addition of RPA 201772 at 26 g/ha to the premix increased control 15% compared with the premix alone. The greatest velvetleaf control occurred with applications of RPA 201772 at 78 or 132 g/ha in combination with the high rate of the premix.

In the comparison of application methods from Ur-

Table 4. Impact of rates of RPA 201772 in combination with the premix of atrazine + S-metolachlor and application timings on weed control at Urbana in 1998.[a]

Herbicide rates[b] RPA 201772	Atrazine + S-metolachlor[d]	Weed species[c] SETFA	ABUTH
g/ha		% Control[e]	
0	1,820 + 1,408	96 a	57 f
26	1,820 + 1,408	93 ab	72 e
53	1,820 + 1,408	94 ab	78 d
78	1,820 + 1,408	95 ab	85 ab
105	1,820 + 1,408	96 a	84 bc
132	1,820 + 1,408	96 a	89 a
105	910 + 704	88 c	81 b–d
132	910 + 704	91 bc	80 cd
Application timing[f]			
Early preplant		92 b	73 c
Preplant incorporated		91 b	78 b
Preemergence		98 a	84 a

[a] Means are compared within columns and those followed by a common letter are not different according to Pdiff option in SAS at the 5% level for herbicide treatment or application timing.

[b] Herbicide treatments are averaged over application methods.

[c] Weed species are listed by Bayer code: giant foxtail (SETFA) and velvetleaf (ABUTH).

[d] The premix formulation contains atrazine at 372 g ai/L, S-metolachlor at 288 g ai/L, and benoxacor.

[e] Control ratings made at 30 d after corn emergence.

[f] Data for application timings were averaged across herbicide treatments.

bana in 1998, weed control with the PRE applications was greater than with the PPI or EPP applications with every weed species. Control of broadleaf species was also greater with PPI applications than with EPP applications. However, an interaction between herbicide treatment and application timing occurred with common lambsquarters and ivyleaf morningglory at Urbana in 1998 (Table 5). For common lambsquarters, increasing the rate of RPA 201772 provided a greater benefit applied PRE or EPP than PPI. When applied PRE, RPA 201772 at 78 g/ha in combination with the premix applied PRE provided 15% greater control of common lambsquarters than the premix alone. With the EPP applications, the atrazine + S-metolachlor premix rate was as important as the RPA 201772 rate. In combination with RPA 201772 at 105 or 132 g/ha, reducing the rate of the premix decreased control 10 and 19%, respectively. Control of ivyleaf morningglory ranged from 37 to 82%, depending on herbicide treatment and application method. With EPP and PRE applications, RPA 201772 at 132 g/ha provided at least 10% greater control than all other rates when combined with the high rate of the premix. However, applied PPI, control of ivyleaf morningglory with RPA 201772 at 132 g/ha was similar to 78 and 105 g/ha RPA 201772. Reducing the premix rate

Table 5. Impact of rates of RPA 201772 in combination with the premix of atrazine + S-metolachlor and application timings on weed control at Urbana in 1998.[a]

Herbicide rates RPA 201772	Atrazine + S-metolachlor[c]	Application method[d]	Weed species[b] CHEAL	IPOHE
g/ha			% Control[e]	
0	1,820 + 1,408	EPP	83 g	37 l
26	1,820 + 1,408	EPP	78 h	47 k
53	1,820 + 1,408	EPP	88 ef	53 ij
78	1,820 + 1,408	EPP	93 cd	65 fg
105	1,820 + 1,408	EPP	88 ef	58 hi
132	1,820 + 1,408	EPP	97 ab	75 bc
105	910 + 704	EPP	78 h	50 jk
132	910 + 704	EPP	78 h	53 ij
0	1,820 + 1,408	PPI	88 ef	47 k
26	1,820 + 1,408	PPI	87 e–g	53 ij
53	1,820 + 1,408	PPI	88 ef	57 i
78	1,820 + 1,408	PPI	90 de	68 d–g
105	1,820 + 1,408	PPI	90 de	73 b–d
132	1,820 + 1,408	PPI	90 de	68 d–g
105	910 + 704	PPI	87 e–g	63 gh
132	910 + 704	PPI	96 bc	72 b–e
0	1,820 + 1,408	PRE	85 fg	50 jk
26	1,820 + 1,408	PRE	90 de	53 ij
53	1,820 + 1,408	PRE	98 ab	67 e–g
78	1,820 + 1,408	PRE	100 a	72 b–e
105	1,820 + 1,408	PRE	100 a	70 c–f
132	1,820 + 1,408	PRE	100 a	82 a
105	910 + 704	PRE	93 cd	57 i
132	910 + 704	PRE	98 ab	77 ab

[a] Means are compared within columns and those followed by a common letter are not different according to Pdiff option in SAS at the 5% level for each treatment.

[b] Weed species are listed by Bayer code: common lambsquarters (CHEAL) and ivyleaf morningglory (IPOHE).

[c] The premix formulation contains atrazine at 372 g ai/L, S-metolachlor at 288 g ai/L, and benoxacor.

[d] Abbreviations: EPP, early preplant; PPI, preplant incorporated; PRE, preemergence.

[e] Control ratings made at 30 d after corn emergence.

decreased ivyleaf morningglory control when combined with either rate of RPA 201772 applied EPP or with 105 g/ha RPA 201772 applied PPI or PRE.

Averaging all application methods at Urbana in 1999, each herbicide treatment controlled at least 90% of the giant foxtail (Table 6). Giant foxtail control was slightly improved when RPA 201772 at 105 or 132 g/ha was included with the high rate of the atrazine + S-metolachlor premix, compared with the premix alone. However, treatments with RPA 201772 at rates less than 105 g/ha did not improve giant foxtail control relative to the premix alone. Control of lambsquarters, redroot pigweed, and ivyleaf morningglory was excellent (at least 95%) with all herbicide treatments, and the treatments were not different with these species. Velvetleaf control was greater than 92% with all herbicide treatments containing RPA 201772 at any rate; however, without RPA 201772, velvetleaf control was 76%.

Table 6. Impact of rates of RPA 201772 in combination with the premix of atrazine + S-metolachlor and application timings on weed control at Urbana in 1999.[a]

Herbicide rates[b]		Weed species[c]				
RPA 201772	Atrazine + S-metolachlor[d]	SETFA	CHEAL	AMARE	IPOHE	ABUTH
g/ha		% Control[e]				
0	1,820 + 1,408	90 c	99 a	99 a	97 a	76 c
26	1,820 + 1,408	91 a–c	99 a	99 a	95 a	93 b
53	1,820 + 1,408	93 a–c	99 a	99 a	96 a	97 ab
78	1,820 + 1,408	93 a–c	99 a	99 a	98 a	98 a
105	1,820 + 1,408	94 ab	99 a	99 a	98 a	98 a
132	1,820 + 1,408	95 a	99 a	99 a	97 a	99 a
105	910 + 704	91 bc	99 a	99 a	95 a	98 a
132	910 + 704	93 a–c	99 a	99 a	98 a	98 a
Application timing[f]						
Early preplant		90 b	99 a	99 a	96 a	92 b
Preplant incorporated		91 b	99 a	99 a	96 a	96 a
Preemergence		97 a	99 a	99 a	98 a	96 a

[a] Means are compared within columns and those followed by a common letter are not different according to Pdiff option in SAS at the 5% level for herbicide treatment or application timing.

[b] Herbicide treatments are averaged over application methods.

[c] Weed species are listed by Bayer code: giant foxtail (SETFA), common lambsquarters (CHEAL), redroot pigweed (AMARE), ivyleaf morningglory (IPOHE), and velvetleaf (ABUTH).

[d] The premix formulation contains atrazine at 372 g ai/L, S-metolachlor at 288 g ai/L, and benoxacor.

[e] Control ratings made at 30 d after corn emergence.

[f] Data for application timings were averaged across herbicide treatments.

At Urbana in 1999, control of common lambsquarters, redroot pigweed, and ivyleaf morningglory was equivalent at all application timings. Giant foxtail control was 6 or 7% greater with the treatments applied PRE rather than PPI or EPP, respectively. Treatments applied PRE and PPI provided 4% greater velvetleaf control than the EPP application.

Because velvetleaf was present in all environments and was particularly sensitive to RPA 201772, densities were determined for each treatment. Transformed velvetleaf densities with each treatment, separated by location, are listed in Table 7. In the four environments, actual densities of velvetleaf in nontreated controls ranged from 4 to 17 plants/m^2 (2.2 to 4.2 transformed). Generally, the greatest velvetleaf densities occurred with EPP applications that contained only atrazine + S-metolachlor. Densities in this treatment were not different from the nontreated control in most environments. At Dekalb in 1998, RPA 201772 applied EPP or PRE at 78 g/ha with atrazine + S-metolachlor decreased velvetleaf densities compared with atrazine + S-metolachlor alone. At the same location in 1999, velvetleaf densities in treatments applied EPP and PPI were lower when RPA 201772 at 53 g/ha was combined with atrazine + S-metolachlor premix, compared with the premix alone. At Urbana, RPA 201772 at 26 g/ha added to atrazine + S-metolachlor premix decreased velvetleaf densities with all three application timings in 1998 and with EPP and PPI timings in 1999. Velvetleaf densities tended to decline with increasing RPA 201772 rate, indicating some benefit incurred from high rates of RPA 201772, especially when the rates of the atrazine and S-metolachlor are reduced.

Corn yields were less at Dekalb in 1999 than in other environments, most likely because of dry conditions lat-

Table 7. Impact of rates of RPA 201772 in combination with the premix of atrazine + S-metolachlor and application timings on velvetleaf density at two Illinois locations in 1998 and 1999.[a]

Herbicide		Dekalb						Urbana					
		1998			1999			1998			1999		
RPA 201772	Atrazine + S-metolachlor[b]	EPP[c]	PPI	PRE	EPP	PPI	PRE	EPP	PPI	PRE	EPP	PPI	PRE
g/ha		Plant/m^2 transformed[d]											
0	1,820 + 1,408	2.1	1.4	1.5	3.7	3.2	2.8	3.4	2.5	3.1	2.5	1.4	1.4
26	1,820 + 1,408	1.8	1.6	1.2	2.7	2.2	3.5	2.7	2.0	1.9	1.3	1.1	1.3
53	1,820 + 1,408	1.8	1.3	1.1	2.5	1.5	1.9	2.4	2.0	1.5	1.3	1.1	1.1
78	1,820 + 1,408	1.4	1.2	1.0	2.1	1.3	1.1	2.0	1.3	1.4	1.1	1.0	1.0
105	1,820 + 1,408	1.9	1.1	1.0	1.9	1.3	1.2	1.6	1.1	1.1	1.0	1.0	1.0
132	1,820 + 1,408	1.4	1.0	1.0	1.5	1.2	1.1	1.5	1.1	1.4	1.0	1.0	1.0
105	910 + 704	2.0	1.3	1.1	2.5	1.7	1.1	1.7	1.5	1.1	1.0	1.0	1.0
132	910 + 704	1.6	1.2	1.0	1.7	1.2	1.1	1.6	1.4	1.2	1.0	1.0	1.0
Nontreated			2.5			4.2			3.4			2.2	
Hand-weeded			1.0			1.0			1.0			1.0	
LSD (0.05)[e]			0.5			1.1			0.5			0.3	

[a] Data are based on combined counts from two 0.5-m^2 sections within each plot taken 30 d after emergence of corn.

[b] The premix formulation contains atrazine at 372 g ai/L, S-metolachlor at 288 g ai/L, and benoxacor.

[c] Abbreviations: EPP, early preplant; PPI, preplant incorporated; PRE, preemergence.

[d] Data were transformed using the equation $(\text{count} + 1)^{1/2}$, where count is the number of velvetleaf plants per square meter.

[e] LSD values can be used to compare herbicide treatment or application timing within each environment.

Table 8. Impact of rates of RPA 201772 in combination with the premix of atrazine + S-metolachlor and application timings on corn yield at two Illinois locations in 1998 and 1999.[a]

Herbicide rates[b]		Dekalb		Urbana	
RPA 201772	Atrazine + S-metolachlor[c]	1998	1999	1998	1999
g/ha		kg/ha			
0	1,820 + 1,408	12,470 bc	9,760 ab	11,990	12,040
26	1,820 + 1,408	13,260 b	8,840 b	11,820	12,190
53	1,820 + 1,408	12,850 bc	8,980 ab	12,200	12,430
78	1,820 + 1,408	14,420 a	9,900 a	11,900	12,460
105	1,820 + 1,408	12,850 bc	9,310 ab	11,820	12,130
132	1,820 + 1,408	12,180 c	8,930 ab	12,170	12,270
105	910 + 704	12,780 bc	9,160 ab	11,900	12,480
132	910 + 704	11,930 c	9,780 ab	11,680	11,590
Application timing[d]					
Early preplant		11,740 c	8,850 b	11,500 b	11,890 b
Preplant incorporated		13,970 a	9,410 ab	12,010 ab	12,170 ab
Preemergence		12,820 b	9,750 a	12,300 a	12,480 a
Nontreated control[e]		11,970	2,250[f]	8,730	11,290
Hand-weeded		13,980	9,450	12,510	12,360

[a] Means are compared within columns and those followed by a common letter are not different according to Pdiff option in SAS at the 5% level for herbicide treatment or application timing. In columns where letters are absent, no significant differences in the herbicide treatments occurred.

[b] Herbicide treatments are averaged over application methods.

[c] The premix formulation contains atrazine at 372 g ai/L, S-metolachlor at 288 g ai/L, and benoxacor.

[d] Data for application timings were averaged across herbicide treatments.

[e] Nontreated control and hand-weeded treatments were not included in the comparative analysis because they were not replicated between application timings.

[f] The low yield in the nontreated control at Dekalb in 1999 was due to intense competition from the presence of giant ragweed and high velvetleaf densities.

er in the season (Table 8). The combined rainfall for July and August was only 125 mm at Dekalb in 1999, whereas other environments received at least 155 mm. This environment also had competitive large-seeded broadleaf populations, with giant ragweed and high velvetleaf densities. Corn yields were numerically greater with any herbicide treatment than in the nontreated control, except with RPA 201772 at 132 g/ha plus atrazine at 910 g/ha + S-metolachlor at 704 g/ha at Dekalb in 1998. Corn yields were similar for all herbicide treatments at Urbana in both years. However, at Dekalb in 1998, the yields in treatments containing the RPA 201772 at the greatest rate (132 g/ha) were 8 and 16% less than yields in treatments with 26 and 78 g/ha of RPA 201772, respectively. The high rate of RPA 201772 may have injured corn plants, even where visible symptoms were not severe. Corn injury with RPA 201772 was negligible with all herbicide treatments at both locations in 1998 and 1999, so data are not presented. The greatest rate of RPA 201772 (132 g/ha) plus the full rate of atrazine + S-metolachlor caused less than 5% injury in every environment. Injury was less than 1% in any environment when RPA 201772 rates were 53 g/ha or less.

Corn yields differed with application timing in all environments. At Dekalb in 1998, the highest yields occurred in the PPI applications, which were 8 and 16% greater than PRE and EPP applications, respectively. At Dekalb in 1999 and at Urbana in both years, corn yields in treatments applied PRE were greater than EPP, but not different from treatments applied PPI.

RPA 201772 improved control of several broadleaf species when used in combination with the atrazine + S-metolachlor premix compared with the premix alone. Even the lowest rate of RPA 201772 (26 g/ha) increased weed control in some environments, but increasing the rate tended to improve control of broadleaf weeds, particularly the large-seeded species. Compared with the premix alone, the density of velvetleaf decreased with RPA 201772 rates from 26 to 78 g/ha combined with the premix, depending on environment and application timing. However, RPA 201772 had very little effect on grass control, where atrazine + S-metolachlor rates were a more important factor. Previous studies have demonstrated the benefit of tank-mixing herbicides with RPA 201772 to improve control on grasses and other species. In field studies by Geier and Stahlman (1998), control of puncturevine (*Tribulus terrestris* L.), green foxtail [*Setaria viridis* (L.) Beauv.], and Devil's-claw [*Proboscidea louisianica* (P. Mill.) Thell.] was improved with the addition of acetamide herbicides to RPA 201772, compared with the latter alone. Tank-mixtures of atrazine with RPA 201772 have also been shown to increase control of common sunflower (*Helianthus annuus* L.), giant ragweed, and common cocklebur (*Xanthium strumarium* L.) (Simkins et al. 1997).

Premix products have been studied including RPA 201772/acetochlor (EXP 31499A) and RPA 201772/atrazine (EXP 41430A) (Hartwig et al. 1997). However, there may be a benefit in tank-mixing the herbicides so the rates can be adjusted to maximize the control of the species present and reduce rates of the herbicides where appropriate.

The application timing of the herbicide treatments was a more important factor in corn yield than the herbicide rates. Application timings closer to planting provided better control of weeds under most environmental conditions. However, where precipitation was greatly reduced after PRE applications, the EPP and PPI applications were more effective. Wrucke et al. (1997) demonstrated that RPA 201772 applied PPI gave better weed control than RPA 201772 applied PRE only under dry conditions, but the PPI applications gave equal or less weed control where moisture was adequate. The same trend has been demonstrated with EPP and PPI applications of other herbicides (Buhler 1996, Johnson et al. 1997). Generally, herbicide combinations with RPA 201772 at low rates are likely to be more effective applied PRE than PPI or EPP.

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