To the Graduate Council:

I am submitting herewith a thesis written by Eric Walker entitled "Comparison of Herbicide Programs in Imidazolinone-Tolerant Corn ". I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant and Soil Sciences.

Thomas C Mueller

Thomas C. Mueller, Major Professor

We have read this thesis
and recommend its acceptance.

Robert M Hayes

Accepted for the Council:

Associate Vice Chancellor
and Dean of The Graduate School

COMPARISON OF HERBICIDE PROGRAMS IN IMIDAZOLINONE TOLERANT CORN

A

Thesis

Presented for

The Master of Science

Degree

The University of Tennessee, Knoxville

Eric Walker

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DEDICATION

To my parents, Eddie Ray and Joyce Walker, who have made their children the most important parts of their life, I dedicate this thesis.

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ABSTRACT

Field studies were conducted in 1998 at Jackson, Milan, Knoxville, and Spring Hill, Tennessee, to examine several herbicide programs for weed control in imidazolinone-tolerant corn. Field corn variety FFR 797 IMI was no-till or minimum-till planted at all locations. The treatments were replicated four times in a randomized block design. Treatments ranging from a PRE-only to PRE followed by postemergent (POST) to total POST applied to examine weed control, crop injury, and yield. Crop oil concentrate (COC) was combined with atrazine when applied POST, while nonionic surfactant was added to all other POST treatments. Visual evaluations were taken four weeks after treatment to evaluate control of broadleaf signalgrass (*Brachiaria platyphylla* (Griseb.) Nash), large crabgrass (*Digitaria sanguinalis* (L.) Scop), Palmer amaranth (*Amaranthus palmeri* (S.) Wats), pitted morningglory (*Ipomoea lacunosa* L.), and sicklepod (*Senna obtusifolia* (L.) Irwin and Barnaby). None of the treatments controlled sicklepod at Milan due to high population density (600-5000 plants/m^2). Imazethapyr + imazapyr + dicamba POST and atrazine + metolachlor PRE followed by prosulfuron + primisulfuron + nicosulfuron POST controlled these weeds while imazethapyr + imazapyr POST, imazethapyr + imazapyr + pendimethalin POST, and atrazine + metolachlor PRE followed by flumetsulam + clopyralid + nicosulfuron POST controlled all weeds >86% except Palmer amaranth (<67%). Imazethapyr + imazapyr + nicosulfuron POST failed to control Palmer amaranth and only controlled sicklepod 75% at Spring Hill. Atrazine + metolachlor PRE followed by nicosulfuron POST did not

control Palmer amaranth and pitted morningglory but controlled all other weeds. Atrazine + metolachlor PRE followed by dicamba POST failed to control broadleaf signalgrass and pitted morningglory, but controlled large crabgrass, Palmer amaranth, and sicklepod. Imazethapyr + imazapyr + atrazine POST controlled all weeds except pitted morningglory (71%), while atrazine + crop oil concentrate controlled the dicot weeds but had little monocot activity. Nicosulfuron + rimsulfuron + atrazine POST controlled broadleaf signalgrass and Palmer amaranth, but only partially controlled pitted morningglory control. Sicklepod was controlled at Knoxville but not at Spring Hill by the mixture of these three herbicides. Although atrazine + metolachlor PRE controlled broadleaf signalgrass and sicklepod at Knoxville, the treatment did not control all other weeds at Jackson and Spring Hill. Corn yields were reduced at Milan from sicklepod competition. Yields were also low for treatments that did not provide adequate large crabgrass and Palmer amaranth control. Slight corn injury was observed but did not appear to influence corn yields.

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CHAPTER 1

Literature Review

Weed control is a critical component of corn (*Zea mays*) production. Without proper weed control, corn yields are reduced (Hall et al., 1992). Furthermore, the critical period of weed control must be considered for maximum corn yield (Hall et al.,1992; Weaver and Tan, 1983). The critical period is the specific minimum period of time during which the crop must be free of weeds to prevent a loss in yield (Weaver and Tan, 1983). Two components of the critical period are the length of time weeds can remain in a crop before interference with crop growth and the length of time weed control is necessary to prevent crop yield loss (Hall et al.,1992; Weaver and Tan, 1983). Hall et al. (1992) reported that the beginning of the critical period in corn varied from the 3- to 14-leaf stage of corn development, and the end of the critical period ended on average at the 14-leaf stage. Hall et al. (1992) also stated that weed control measures need to last no longer than the 14-leaf stage (Hall et al.,1992).

Acceptable weed control in corn necessitates the use of herbicides in most cases. However, due to increasing environmental concerns and the development of weeds resistant to herbicide current herbicide programs are continually reexamined and new weed control options are explored. For example, the PRE herbicide atrazine offers good residual dicot weed control in corn (Sprague et al.,1997; Wicks et al.,1997). However, atrazine has potential for leaching which has leads ground and surface water contamination (Sprague et al., 1997). Also, biotypes of weeds resistant to atrazine have developed

(Wicks et al.,1997). For these and other reasons, new herbicides are developed and evaluated.

The imidazolinone herbicides have low mammalian toxicity, low environmental contamination risk, low volatility, and offer residual weed control (Monks et al.,1996). The imidazolinones are broad-spectrum herbicides which kill plants by inhibiting *acetolactate synthase* (ALS) , an essential enzyme for the biosynthesis of branched-chain amino acids, valine, leucine, and isoleucine, in plants (Sprague et al.,1997). These herbicides are used in several crops, including soybean [*Glycine max* (L.) Merr], peas , alfalfa, and peanuts (*Arachis hypogaea* L.), and in noncrop areas (Hart et al. 1991).

Imazethapyr is one of the imidazolinones frequently used in soybean, among other crops (Hart et al. 1991). Corn is commonly rotated with soybean; therefore, studies were conducted to determine the effect of imazethapyr carryover to corn (Krausz et al.,1992; Johnson et al., 1993; Walsh et al.,1993; Mills and Witt, 1989). Soybean herbicide trials showed that the imidazolinones controlled several weeds, including shattercane (*Sorghum bicolor* (L.) Moench) and (*Sorghum halepense*) (Newhouse et al., 1991). It was discovered that imazethapyr could injure corn (Mills and Witt, 1989; Johnson et al., 1993). However, some corn plants were more tolerant to imazethapyr than others, varying from 1- to 40-thousand-fold (Newhouse et al., 1991; Currie et al., 1995). Therefore, corn was selected for introducing imidazolinone tolerance (Newhouse et al., 1991). At least four alleles in two unlinked loci, containing several variations of genes coding for ALS, 11 of which have been identified, are known to code for ALS in corn (Newhouse et al., 1991; Currie et al., 1995). The XA17 gene, found on chromosome five, confers resistance to the imidazolinone, sulfonylurea, and sulfonamide herbicides (Newhouse et al., 1991; Currie et al., 1995; Boerboom and Lauer, 1997). Pioneer Hi-Bred International, Inc. marketed their imidazolinone-resistant (IR) hybrid with the XA17 gene in its homozygous form (Newhouse et al., 1991; Currie et al., 1995; Currie and Regehr, 1995; Boerboom and Lauer, 1997). Novartis marketed their hybrid with another gene in its homozygous form, which also exhibits tolerance to the aforementioned herbicides (Currie et al., 1995). Both the Pioneer IR hybrids and the Novartis hybrids involve the added expense of backcrossing their ALS-coding genes into both parents for homozygosity (Currie and Regehr, 1995). Unlike Pioneer and Novartis, Imperial Chemical Industries (ICI), now Zeneca, marketed their imidazolinone-tolerant (IT) hybrids with an unnamed and unplaced (as to chromosome position) gene in its heterozygous form (Currie et al., 1995; Currie and Regehr, 1995; Boerboom and Lauer, 1997). While this gene does confer imazethapyr resistance in its heterozygous form, it does not protect corn from the sulfonylurea or sulfonamide herbicides (Currie et al., 1995; Boerboom and Lauer, 1997).

Due to the added expense of maintaining homozygosity of ALS-coding genes for marginal imazethapyr resistance increases, IT hybrids have gained in popularity. Currie et al. (1995) reported that ALS from the ICI and Pioneer hybrids was resistant to imazethapyr. Currie and Regehr (1995) observed slight injury by imazethapyr at 140 g/ha (twice label rate) on a Pioneer IR hybrid crossed with a Pioneer normal hybrid, which was heterozygous for the resistance gene. The hybrid recovered by 5 WAT and yield was not reduced by 280 g/ha (four times the label rate) of imazethapyr. Wicks et al. (1997) observed no difference in corn injury between IR and IT corn.

With the introduction of IT corn, weed control options using imidazolinone herbicides became available to producers. One of these options is Lightning™, a broad spectrum, postemergence herbicide for use on IT or IR corn. Lightning™ is a premix of imazethapyr and imazapyr (Beardmore et al., 1991). Imazethapyr provides control of several monocot and dicot weeds (Mills and Witt, 1989; Sprague et al., 1997; Wicks et al., 1997). Imazapyr is a broad-spectrum herbicide that controls many annual and perennial monocot and dicot weeds (Beardmore et al., 1991).

Broadleaf signalgrass (*Brachiaria platyphylla* (Griseb.) Nash) is a spreading summer annual monocot found on the ten most troublesome weeds list of several states in the southeastern United States (Dowler, 1994; Mueller and Hayes, 1997). Broadleaf signalgrass is a problem weed in corn, soybean, and peanuts (Chamblee et al., 1982a). It is competitive, due in part to its tolerance to alachlor (Mueller and Hayes, 1997; Johnson and Coble, 1986; Chamblee et al., 1982b). Mueller and Hayes (1997) reported that alachlor, metolachlor, and dimethenamid controlled broadleaf signalgrass >80% for about 4 wk, while acetochlor had the most consistent control, with good control in no-till plots for 4 wk, and good control in tilled plots for 8 wk. Mueller and Hayes (1997) also reported that broadleaf signalgrass control was more complete in till than no-till plots, possibly because some herbicide may be immobilized by surface residue, making it unavailable for weed control (Banks and Robinson, 1982).

Large crabgrass (*Digitaria sanguinalis* (L.) Scop) is a summer annual distributed throughout the tropical and temperate regions of the world (King and Oliver, 1994). It is propagated by seed which can germinate over a 4- to 5-month period (King and Oliver, 1994; Chasm and Bingham, 1991). Therefore, herbicides that have short residual activity must be applied repeatedly to maintain control (Chasm and Bingham, 1991).

Palmer amaranth (*Amaranthus palmeri* (S.) Wats) is a dioecious annual herb common in agronomic crops (Mayo et al., 1995; Hayrack and Peterson, 1995). Mayo et al. (1995) stated that there were significant differences in herbicide control among pigweed species; therefore, species identification is critical for control. Palmer amaranth has rhombic-ovate to rhombic-lanceolate leaves, with petioles as long or longer than the blades, and have a poinsettia-like appearance from the 10-leaf stage until floral initiation (Mayo et al., 1995). Hayrack and Peterson (1995) reported ALS-resistant Palmer amaranth, surviving imazethapyr and thifensulfuron treatments up to 8x the label rate.

Pitted morningglory (*Ipomoea lacunosa* L.) is a summer annual which can cause increased lodging, reduce yields, and reduce efficiency of mechanical harvest (Barker et al., 1984) This species has become increasingly dominant due to decreased competition from weeds successfully controlled by soil-applied herbicides, which do not consistently control morningglories (Barker et al., 1994). Monks et al. (1996) reported that imazethapyr at 36 and 72 g/ha controlled entireleaf (*Ipomoea hederacea*) and pitted morningglory complex >86% in corn when applied 2 WAP.

Sicklepod (*Senna obtusifolia* (L.) Irwin and Barnaby), a non-nodulating leguminous annual weed, is also listed on the ten most troublesome weeds list of several states in the southeastern United States (Dowler, 1994). Sicklepod can germinate over a wide temperature range and can emerge from a soil depth of 12.5 cm (Teem et al., 1980; Miller and Griffin, 1994). Furthermore, sicklepod regrowth following POST herbicide applications may result in late season competition and seed production that can cause infestation in future years (Griffin et al., 1993). Monks et al. (1996) reported that imazethapyr did not control sicklepod >58% regardless of rate and application timing.

CHAPTER 2

Comparison of Postemergence Herbicide Programs in Imidazolinone-Tolerant Corn[1]

E.R. Walker, R.M. Hayes, G.N. Rhodes, Jr., and T.C. Mueller[2]

Abstract

Field studies were conducted in 1998 at four sites in Tennessee to examine several herbicide programs for weed control in imidazolinone-tolerant corn. No treatment controlled sicklepod (*Senna obtusifolia* (L.) Irwin and Barnaby) at Milan due to high population density (600-5000 plants/m^2). Imazethapyr + imazapyr + dicamba POST and atrazine + metolachlor PRE followed by prosulfuron + primisulfuron + nicosulfuron POST controlled all weeds evaluated, while imazethapyr + imazapyr POST, imazethapyr + imazapyr + pendimethalin POST, and atrazine + metolachlor PRE followed by flumetsulam + clopyralid + nicosulfuron POST controlled all weeds >86% except Palmer amaranth (*Amaranthus palmeri* (S.) Wats)(<67%). Imazethapyr + imazapyr + nicosulfuron POST gave 60% control of Palmer amaranth, while atrazine + metolachlor PRE followed by nicosulfuron POST failed to control Palmer amaranth and pitted morningglory (*Ipomoea lacunosa* L.). Atrazine + metolachlor PRE followed by dicamba POST did not control broadleaf signalgrass (*Brachiaria platyphylla* (Griseb.) Nash) and pitted morningglory, but gave >95% control of large crabgrass (*Digitaria sanguinalis* (L.) Scop) and Palmer amaranth. Imazethapyr +

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imazapyr + atrazine POST controlled all weeds except pitted morningglory (71%), while atrazine + crop oil concentrate controlled the dicot weeds but showed little monocot activity. Nicosulfuron + rimsulfuron + atrazine POST controlled all weeds 70-97% except sicklepod at Spring Hill (66%). Atrazine + metolachlor PRE controlled broadleaf signalgrass and sicklepod at Knoxville, but failed to control other weeds. Corn yields were reduced where large crabgrass, Palmer amaranth, and sicklepod population density was high. Slight corn injury was observed but did not appear to influence corn yields.

Nomenclature: Atrazine, 6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine; clopyralid, 3,6-dichloro-2-pyridinecarboxylic acid; dicamba, 3,6-dichloro-2-methoxy-benzoic acid; flumetsulam, *N*-(2,6-difluorophenyl)-5-methyl[1,2,4]triazolo[1,5-*a*]pyrimidine-2-sulfonylamide; imazapyr, (±)-(2)-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-pyridinecarboxylic acid; imazethapyr, (2)-[4,5-dihydro-4-methyl-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxylic acid; metolachlor, 2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl)acetamide; nicosulfuron, 2-[[[[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonyl]amino]sulfonyl]-*N*,*N*-dimethyl-3-pyridinecarboxamide; pendimethalin, *N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine; primisulfuron, methyl 2-[[[[4,6-bis(difluoromethoxy)-2-pyrimidinyl]amino]carbonyl]amino]sulfonyl]benzoate; prosulfuron, 1-(4-methoxy-6-methyl-triazin-2-yl)-3-[2-(3,3,3-trifluoropropyl)-phenyl-sulfonyl]-urea; rimsulfuron, *N*-[[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonyl]-3-(ethylsulfonyl)-2-

pyridinesulfonamide, broadleaf signalgrass, *Brachiaria platyphylla* (Griseb.) Nash; large crabgrass, *Digitaria sanguinalis* (L.) Scop.; Palmer amaranth, *Amaranthus palmeri* (S.) Wats; pitted morningglory, *Ipomoea lacunosa* L.; sicklepod, *Senna obtusifolia* (L.) Irwin and Barnaby.

Abbreviations: IT, imidazolinone-tolerant; ALS, acetolactate synthase; PRE, preemergence; POST, postemergence; WAT, weeks after postemergence treatment; DAP, days after planting; NIS, nonionic surfactant; COC, crop oil concentrate; WAP, weeks after planting.

Introduction

Weed control is critical in corn (*Zea mays*) production. Without proper weed control, corn yields are reduced (Hall et al., 1992). Furthermore, the critical period of weed control must be considered for maximum corn yield (Hall et al.,1992; Weaver and Tan, 1983). Hall et al. (1992) reported that the beginning of the critical period in corn varied from the 3- to 14-leaf stage of corn development, and the critical period ended on average at the 14-leaf stage. Hall et al. (1992) also stated that weed control measures need to last no longer than the 14-leaf stage (Hall et al.,1992).

Acceptable weed control in corn necessitates the use of herbicides in most cases. However, due to increasing environmental concerns and the development of weeds resistant to herbicides, current herbicide programs are continually reexamined and new weed control options are explored.

One of these weed control options is the imidazolinone herbicides. The imidazolinones have low mammalian toxicity, little risk of environmental contamination, low volatility, and offer residual weed control (Monks et al.,1996).

The imidazolinones are broad-spectrum herbicides which kill plants by inhibiting *acetolactate synthase* (ALS), an essential enzyme for the biosynthesis of the branched-chain amino acids valine, leucine, and isoleucine in plants (Sprague et al.,1997). These herbicides are used in several crops, including soybean, peas, alfalfa, and peanuts, and in noncrop areas (Hart et al. 1991).

Imazethapyr is one of the imidazolinones frequently used in soybean production (Hart et al. 1991). Studies revealed that imazethapyr carryover could injure corn, which is commonly rotated with soybean (Krausz et al.,1992; Johnson et al.; Walsh et al.,1993; Mills and Witt, 1989). However, some corn plants were more tolerant to imazethapyr than others, varying from 1 to 40 thousand-fold (Newhouse et al., 1991; Currie et al., 1995). Therefore, imidazolinone-tolerant (IT) corn was developed (Newhouse et al., 1991).

At least four alleles in two unlinked loci, containing several variations of genes coding for ALS, are known to code for ALS in corn (Newhouse et al., 1991). Several companies developed hybrids with genes exhibiting tolerance to the imidazolinone herbicides. The imidazolinone-resistant hybrids contain a gene which codes for ALS in its homozygous form and confers resistance to the imidazoline, sulfonylurea, and sulfonamide herbicides (Newhouse et al., 1991; Currie et al., 1995; Boerboom and Lauer, 1997). Hybrids containing a gene which codes for ALS in its heterozygous form are imidazolinone-tolerant (IT) hybrids. IT corn is resistant to imazethapyr, but it is susceptible to sulfonylurea or sulfonylamide herbicides (Currie et al, 1995). Imidazolinone-resistant corn hybrids involve the added expense of maintaining homozygosity of ALS-coding genes for marginal imazethapyr resistance increases. As a result of this, and its comparable resistance to imidazolinones, IT corn has gained in popularity.

With the introduction of IT corn, weed control options using imidazolinone herbicides became available to producers. One of these options is a premix of 52.5% imazethapyr + 17.5% imazapyr used at 63 g/ha (Beardmore et al., 1991). Imazethapyr controls several monocot and dicot weeds (Mills and Witt, 1989; Sprague et al., 1997; Wicks et al., 1997), Imazapyr is a broad-spectrum herbicide that controls many annual and perennial monocot and dicot weeds (Beardmore et al., 1991).

Broadleaf signalgrass (*Brachiaria platyphylla* (Griseb.) Nash) is a spreading summer annual monocot found on the ten most troublesome weeds list of several states in the southeastern United States (Dowler, 1994; Mueller and Hayes, 1997). Mueller and Hayes (1997) reported that broadleaf signalgrass control was more complete in tilled than in no-till plots. Furthermore, they found that acetochlor, metolachlor, and dimethenamid provided >80% broadleaf signalgrass control for 4 weeks, with acetochlor controlling broadleaf signalgrass approximately 4 weeks in no-till plots and approximately 8 weeks in tilled plots (Mueller and Hayes, 1997).

Large crabgrass (*Digitaria sanguinalis* (L.) Scop) is a summer annual distributed throughout the tropical and temperate regions of the world (King and Oliver, 1994). It is propagated by seed which can germinate over a 4- to 5-

month period (King and Oliver, 1994; Chasm and Bingham, 1991). Therefore, herbicides that have short residual activity may not provide full-season control (Chasm and Bingham, 1991).

Palmer amaranth (*Amaranthus palmeri* (S.) Wats) is a dioecious annual herb common in agronomic crops (Mayo et al., 1995; Hayrack and Peterson, 1995). Mayo et al. (1995) stated that there were significant differences in herbicide control among pigweed species; therefore, species identification is critical for control. Hayrack and Peterson (1995) reported ALS-resistant Palmer amaranth, surviving imazethapyr and thifensulfuron treatments up to 8 times the normal application dosage.

Pitted morningglory (*Ipomoea lacunosa* L.) is a summer annual which can cause increased lodging, reduce yields, and reduce efficiency of mechanical harvest (Barker et al., 1984) This species has become increasingly dominant due to decreased competition from weeds successfully controlled by soil-applied herbicides, which do not consistently control morningglory species (Barker et al., 1994).

Sicklepod (*Senna obtusifolia* (L.) Irwin and Barnaby), a non-nodulating leguminous annual weed, is also listed on the ten most troublesome weeds list of several states in the southeastern United States (Dowler, 1994). Sicklepod can germinate over a wide temperature range and can emerge from a soil depth of 12.5 cm (Teem et al., 1980; Miller and Griffin, 1994). Furthermore, sicklepod regrowth following POST herbicide applications may result in late season competition and seed production that can cause infestation in future years

(Griffin et al., 1993). Monks et al. (1996) reported that imazethapyr at 36 and 72 g/ha provided <58% sicklepod control.

With the introduction of herbicide-tolerant hybrids and a wide variety of herbicides to choose from, corn producers have many options for weed control. Therefore, it is important that producers know which herbicide programs offer adequate weed control and good crop safety, which will allow maximum corn yields. The objectives of this research were to evaluate efficacy of several herbicide programs on broadleaf signalgrass, large crabgrass, Palmer amaranth, pitted morningglory, and sicklepod. These are all troublesome weeds in field corn in the southeast United States. Additionally, this research examined stunting, discoloration, and overall corn injury and assessed herbicide influence on yield.

Materials and Methods

Field studies were conducted in 1998 at Jackson (southwest), Milan (northwest), Knoxville (east), and Spring Hill (central), TN (Figure 1). The studies used a randomized block design with four replications of each treatment. Plots consisted of four rows spaced 76 cm apart and 9 m in length, except in Knoxville, where plot rows were 7.6 m in length. Untreated weedy and weed-free control plots were also included at each location.

Field corn variety FFR 797 IMI, an IT variety was no-till planted at Jackson, Milan, and Spring Hill, and minimum-till planted at Knoxville (Table 1). By using an IT-variety, comparison could be made between imidazolinone herbicides and other herbicide classes. Corn was planted at Milan on April 30 and PRE

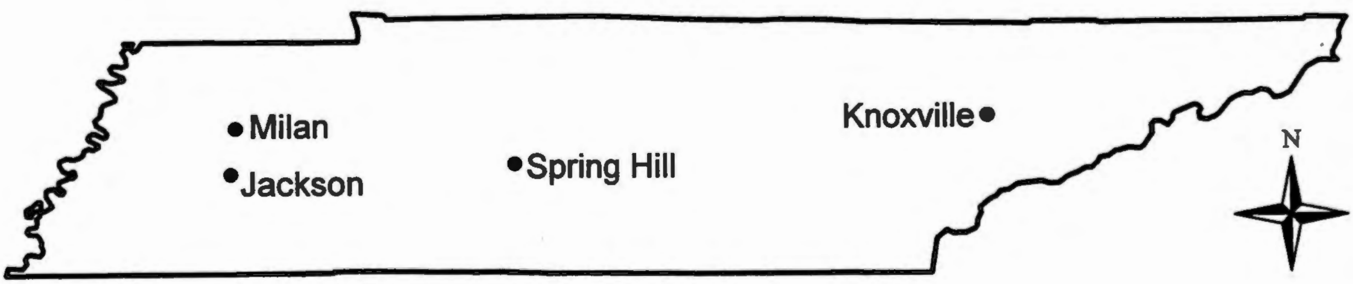

Figure 1. Field study locations in Tennessee in 1998.

Table 1. Locations, corn planting dates, seed rates, PRE and POST application dates, corn plant and weed stage at POST application, and weed density for field studies in 1998.

Location	Planting date	Seed (No./ha)	PRE date	POST date	Corn stage at POST appl.	Corn height at POST appl. (cm)	Weeds evaluated	Weed stage at POST appl.	Weed ht. at POST appl. (cm)	Weed density (No./m^2)
Jackson	May 14	67000	May 14	May 22	3-leaf	10	broadleaf	3-leaf	5	1300-4500
							signalgrass	0-1 leaf	2	0-50
							pitted morningglory	4-leaf	5	1000-3300
							Palmer amaranth			
Milan	May 15	67000	April 30	May 28	5-leaf	25	broadleaf signalgrass	5-leaf	10	300-1800
							sicklepod	2-leaf	8	600-5000
Knoxville	May 15	64000	May 15	June 4	6-leaf	29	broadleaf signalgrass	6-leaf	10	40-65
							sicklepod	3-leaf	15	1350
Spring Hill	May 5	62000	May 5	May 25	6-leaf	25	large crabgrass	3-leaf	10	600-3200
							sicklepod	2-leaf	5	200

treatments were applied. However, these corn plants were damaged by wildlife, and as a result corn was replanted on May 15. A pyrethroid insecticide was applied at planting for cutworm control at each location. POST treatments were applied before corn exceeded a height of 30 cm and before weeds exceeded a height of 10 cm (Tables 1 and 2).

Stand counts were taken two to three weeks after planting. Visual evaluations on a scale of 0 to 100 were made for weed control (Table 2) and corn injury, with 100 indicating complete weed control or complete crop kill. Weed biomass data was also collected. A 76 cm by 91 cm area between the two center rows of each plot was harvested. The weeds were immediately weighed for a total weed freshweight, then sorted by species and weighed to determine the individual weed species biomass. Weeds in the weed-free plot were controlled with atrazine + metolachlor at 1823 + 1411 g/ha PRE followed by dicamba + nicosulfuron at 290 + 35 g/ha POST and hand-removal as required.

The middle two rows of each plot in all trials were harvested. Weights were adjusted to the 15.5% moisture level (Table 3). Data were subjected to analysis of variance and means were separated with an LSD at the 5% level.

Results and Discussion

Stand counts showed no herbicide effect on crop density (data not shown). Slight corn injury was observed at some locations, but did not reduce yields at any location (data not shown). Weed biomass data was not as sensitive to display treatment differences as visual weed control evaluations. However, the biomass data was consistent with weed control evaluations (data not shown).

Table 2. Control of broadleaf signalgrass, large crabgrass, Palmer amaranth, pitted morningglory, and sicklepod by herbicide programs for field corn in 1998.

Treatment[a]	Rate	Appl. timing	Jackson - 4 WAT[c]			Milan - 3 WAT[c]		Knoxville - 4 WAT[c]		Spring Hill - 4 WAT[c]	
			Palmer amaranth	broadleaf signalgrass	pitted morningglory	broadleaf signalgrass	sicklepod	broadleaf signalgrass	sicklepod	sicklepod	large crabgrass
	g ai/ha		%								
Weedy check			0d	0d	0f	0d	0g	0d	0c	0d	0d
Weed-free			99a	99a	99a	99a	99a	99a	99a	99a	99a
Imazethapyr Imazapyr	47 16	POST POST	64c	96a	92abc	96a	59bc	87ab	96ab	89ab	90ab
Imazethapyr Imazapyr Atrazine	47 16 840	POST POST POST	99a	97a	71cde	97a	59bc	92ab	96ab	86ab	96a
Imazethapyr Imazapyr Nicosulfuron	47 16 26	POST POST POST	60c	99a	91abc	98a	68bc	81ab	97ab	75abc	99a
Imazethapyr Imazapyr Dicamba	47 16 280	POST POST POST	96a	93a	85a-d	97a	46cde	66b	91ab	87ab	99a
Imazethapyr Imazapyr Pendimethalin	47 16 1386	POST POST POST	54c	97a	97ab	95a	66bc	87ab	91ab	82abc	99a
Atrazine, Metolachlor Nicosulfuron	1823 1411 35	PRE PRE POST	58c	96a	59e	99a	36def	99a	91ab	82abc	97a
Atrazine Metolachlor Dicamba	1823 1411 280	PRE PRE POST	97a	53c	68de	65b	33ef	99a	95ab	77abc	97a
Atrazine Metolachlor	1823 1411	PRE PRE	0d	5d	0f	30c	15fg	99a	90b	60c	97a
Nicosulfuron Rimsulfuron Atrazine	13 13 850	POST POST POST	97a	96a	76b-e	88a	58bcd	70ab	91ab	66bc	74b
Atrazine COC (ml/ha)	2240 383	POST POST	99a	61b	98a	85ab	74b	38c	96ab	80abc	50c
Atrazine Metolachlor Prosulfuron Primisulfuron Nicosulfuron	1823 1411 20 20 26	PRE PRE POST POST POST	83ab	94a	95ab	97a	55bcd	99a	94ab	85abc	99a
Atrazine Metolachlor Flumetsulam Clopyralid Nicosulfuron	1823 1411 52 140 26	PRE PRE POST POST POST	66bc	95a	95ab	98a	70b	99a	98ab	94a	98a
LSD (0.05)			18	8	21	23	22	28	8	22	19

[a]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.
[c]WAT, weeks after postemergence treatment.

Table 3. Corn yield of FFR 797 IMI at 4 locations as influenced by herbicide treatments and weed control in 1998 in Tennessee[a].

Treatment[b]	Rate	Appl. timing	Jackson	Milan	Knoxville	Spring Hill
	g ai/ha		kg/ha[c]			
Weedy check			2570d	3760bc	5180c	2460c
Weed-free			6810abc	6490a	10110a	8960ab
Imazethapyr	47	POST	5820c	4870abc	8950ab	8210ab
Imazapyr	16	POST				
Imazethapyr	47	POST	6790abc	6200ab	10570a	9730a
Imazapyr	16	POST				
Atrazine	840	POST				
Imazethapyr	47	POST	6380bc	5080abc	8880ab	8800ab
Imazapyr	16	POST				
Nicosulfuron	26	POST				
Imazethapyr	47	POST	7370ab	5210abc	9870ab	8290ab
Imazapyr	16	POST				
Dicamba	280	POST				
Imazethapyr	47	POST	6360bc	5740ab	6900bc	9250a
Imazapyr	16	POST				
Pendimethalin	1386	POST				
Atrazine	1823	PRE	6880abc	5500ab	8460ab	9120ab
Metolachlor	1411	PRE				
Nicosulfuron	35	POST				
Atrazine	1823	PRE	6790abc	4540abc	8220abc	9950a
Metolachlor	1411	PRE				
Dicamba	280	POST				
Atrazine	1823	PRE	3590d	2780c	8000abc	8180ab
Metolachlor	1411	PRE				
Nicosulfuron	13	POST	7990a	5740ab	9600ab	8760ab
Rimsulfuron	13	POST				
Atrazine	850	POST				
Atrazine	2240	POST	6750abc	4310abc	8340ab	7240b
COC (ml/ha)	383	POST				
Atrazine	1823	PRE	6500c	5340abc	7630abc	9400a
Metolachlor	1411	PRE				
Prosulfuron	20	POST				
Primisulfuron	20	POST				
Nicosulfuron	26	POST				
Atrazine	1823	PRE	6080c	6740a	9180ab	9350a
Metolachlor	1411	PRE				
Flumetsulam	52	POST				
Clopyralid	140	POST				
Nicosulfuron	26	POST				
LSD (0.05)			1082	2268	3010	1664

[a]Corn yields were adjusted to 15.5% moisture level.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.
[c]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.

For ease of discussion, only visual weed control evaluations made 3 WAT at Milan and 4 WAT at Jackson, Knoxville, and Spring Hill will be presented (Table 2).

Programs for IT corn only. Imazethapyr + imazapyr applied POST controlled broadleaf signalgrass >86%, large crabgrass 90%, and pitted morningglory 92% (Table 2). This combination gave >88% sicklepod control at Knoxville and Spring Hill, but only 59% sicklepod control at Milan (Table 2), partly due to high sicklepod population (600-5000 plants/m^2) (Table 1). The treatment controlled Palmer amaranth 64% at Jackson, which contributed to lower corn yields at Jackson (Table 3) where Palmer amaranth density was 1000-3300 plants/m^2 (Table 1). Corn yields for this treatment at the other locations were equal to the weed-free check (Table 3).

When atrazine was tank-mixed with imazethapyr + imazapyr, complete Palmer amaranth control was achieved, as well as excellent broadleaf signalgrass and large crabgrass control (>91% and 96%, respectively), and >85% sicklepod control, except at Milan where this treatment did not fully control sicklepod (59%). The addition of atrazine to imazethapyr + imazapyr decreased pitted morningglory control to 71% at Jackson, possibly by contact activity of atrazine interfering with the systemic activity of imazethapyr and imazapyr (Table 2). Corn yields at each location for this treatment were equal to the weed-free check (Table 3).

The combination of imazethapyr + imazapyr + nicosulfuron applied POST controlled broadleaf signalgrass 81 to 99% and large crabgrass 99%. Likewise, this treatment controlled pitted morningglory 91%. While this treatment controlled sicklepod 97% at Knoxville, <80% control at Spring Hill and Milan suggests that one should consider using another combination if sicklepod pressure exists (Table 2). Palmer amaranth control was <60% and corn yields were reduced at Jackson, while yields at the other locations were equal to the weed-free check (Tables 2 and 3).

The addition of dicamba to imazethapyr + imazapyr applied POST provided dicot control with 85% pitted morningglory control, 96% Palmer amaranth control, and >86% sicklepod control at Jackson and Spring Hill. Sicklepod control at Milan was only 46%. This treatment also controlled large crabgrass 99% and broadleaf signalgrass 92% at Jackson and Milan, but only 66% at Knoxville (Table 2). However, yields at all locations equaled the yields of the weed-free checks (Table 3).

Imazethapyr + imazapyr + pendimethalin applied POST controlled large crabgrass 99% and broadleaf signalgrass >86%. Likewise, the combination controlled pitted morningglory 97% and sicklepod >81% at Knoxville and Spring Hill. The combination only controlled sicklepod 66% at Milan (Table 2). A weakness of this treatment was Palmer amaranth control (54%), which reduced corn yields at Jackson (Tables 2 and 3). Corn yields in this treatment at Milan and Spring Hill equaled those of the weed-free check, but less than the weed-free check at Knoxville (Table 3).

Based on the data, if a producer has only a broadleaf signalgrass or large crabgrass problem, imazethapyr + imazapyr should provide adequate control, and there is no significant benefit of adding a grass herbicide such as nicosulfuron. Likewise, imazethapyr + imazapyr should provide adequate control of sicklepod and pitted morningglory without additional herbicides. A major weakness of imazethapyr + imazapyr is the lack of Palmer amaranth control. If Palmer amaranth is present, atrazine or dicamba could be added to the combination to achieve control. A disadvantage of all treatments containing imazethapyr + imazapyr is that an IT corn must be used with these herbicides to avoid crop injury. All treatments in the studies which do not contain imazethapyr + imazapyr can be used with any corn variety.

Programs for IT or non-IT varieties. Atrazine + metolachlor applied PRE followed by nicosulfuron applied POST controlled broadleaf signalgrass >95% and large crabgrass >96% at all locations (Table 2). Sicklepod control was >81% at Knoxville and Spring Hill, while the combination achieved only 36% sicklepod control at Milan. This treatment did not fully control Palmer amaranth and pitted morningglory (60%) (Table 2). Although this treatment did not achieve adequate dicot weed control at all locations, yields were equal to yields obtained from the weed-free checks at all locations (Table 3).

Atrazine + metolachlor applied PRE followed by dicamba applied POST controlled Palmer amaranth (>97%) and large crabgrass (>97%), while achieving only 68% pitted morningglory control. Although the treatment controlled broadleaf signalgrass in Knoxville (>99%), control at Jackson and Milan was <66%. Sicklepod control was 95% at Knoxville and 77% at Spring Hill, but only 33% in Milan (Table 2). However, yields from this treatment equaled those of the weed-free checks (Table 3).

Atrazine + metolachlor applied PRE did not control Palmer amaranth and pitted morningglory. This treatment did not control sicklepod (15%) and broadleaf signalgrass (<31%) at Jackson and Milan, but controlled broadleaf signalgrass >99% and sicklepod >90% at Knoxville. Large crabgrass control was 97%. However, atrazine + metolachlor applied PRE did not control Palmer amaranth and pitted morningglory (Table 2). As a result of poor overall weed control at Jackson and Milan, yields were low. However, yields from this treatment equaled those of the weed-free checks in Knoxville and Spring Hill (Table 3).

Nicosulfuron + rimsulfuron + atrazine applied POST controlled Palmer amaranth 97%, while achieving only 76% pitted morningglory control and 74% large crabgrass control. The treatment controlled broadleaf signalgrass 87% in Jackson and Milan, while providing only 70% control in Knoxville. The combination controlled sicklepod 91% in Knoxville, while controlling sicklepod >70% at Spring Hill or Milan (Table 2). Yields from this treatment were equal to yields from the weed-free checks (Table 3).

Atrazine + crop oil concentrate applied POST controlled Palmer amaranth 99%, pitted morningglory 98%, and sicklepod > 79%, except in Milan, where the treatment provided 74% sicklepod control. The treatment achieved only 50% large crabgrass control at Spring Hill and <62% broadleaf signalgrass control in Jackson and Knoxville. However, this treatment provided 85% broadleaf signalgrass control in Milan (Table 2). Yields from this combination equaled those of the weed-free checks (Table 3). Atrazine + crop oil concentrate applied

POST controlled dicot weeds, but did not control monocot weeds (Table 2). Another disadvantage of this treatment is that consistent, annual application of this treatment to the same field could select for triazine-resistant weeds. Also, environmental concerns over atrazine, such as ground water contamination, make the future of this herbicide uncertain.

Atrazine + metolachlor applied PRE followed by a POST application of prosulfuron + primisulfuron + nicosulfuron provided >82% of all weeds evaluated, except sicklepod in Milan, where the combination only controlled sicklepod 55% (Table 2). Yields equaled those of the weed-free checks at all locations except Jackson, where this treatment provided less control of Palmer amaranth than some of the other treatments, although differences in Palmer amaranth control were not significant (Tables 2 and 3).

Similarly, atrazine + metolachlor applied PRE followed by flumetsulam + clopyralid + nicosulfuron controlled broadleaf signalgrass, large crabgrass, pitted mornningglory >93%. The treatment provided 70% sicklepod control in Milan and only 66% Palmer amaranth control (Table 2). Poor Palmer amaranth control contributed to reduced corn yields at Jackson, whereas at all other locations yields from this combination were equal to yields of the weed-free checks (Table 3).

There are many herbicide program options available to producers which will adequately control the problem weeds evaluated in this test with no apparent reduction in corn yield. Based on these treatments (Table 2),if a corn field is infested with broadleaf signalgrass, imazethapyr + imazapyr POST (in IT corn), atrazine + metolachlor PRE followed by nicosulfuron POST, and nicosulfuron + rimsulfuron + atrazine POST should provide adequate control. Imazethapyr + imazapyr POST is also an effective treatment for controlling large crabgrass if an IT corn variety is used. Likewise, atrazine + metolachlor PRE should also control this species. Palmer amaranth control can be achieved by atrazine + metolachlor followed dicamba POST, nicosulfuron + rimsulfuron + atrazine POST, or atrazine + COC POST. In IT corn only, imazethapyr + imazapyr + either atrazine or dicamba POST should also control Palmer amaranth, although the contribution of imazethapyr + imazapyr to the control of this species appears to be negligible. If pitted morningglory or sicklepod pressure exists, imazethapyr + imazapyr POST (in IT corn) or atrazine + COC POST should control these species. Atrazine + metolachlor PRE followed by either primisulfuron + prosulfuron + nicosulfuron or flumetsulam + clopyralid + nicosulfuron POST should also control pitted morningglory and sicklepod.

A producer can expect similar results from using imidazolinones with IT corn varieties compared to using other herbicide programs on conventional corn varieties if broadleaf signalgrass, large crabgrass, pitted morningglory, or sicklepod pressure exists. If a combination of these weeds are present, imazethapyr + imazapyr POST in IT corn should give broad spectrum control of these weeds, an advantage provided by none of the other treatments. However, if Palmer amaranth is present, atrazine or dicamba should be included with imidazolinones to order to control this species. IT corn + imidazolinone herbicide use also may be a benefit on areas which disallow atrazine use due to labeling restrictions. Also, IT corn use (with no atrazine PRE) allows farmers to plant soybean if the corn stand fails. A benefit of rotating IT corn with conventional varieties is that this allows rotation of modes of action, which will decrease selection for herbicide-resistant weeds.

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APPENDIX

Table A1. Rainfall on 1998 field studies.

DAP	Jackson	Milan[a]	Knoxville	Spring Hill
	mm			
-5	0	43	1	8
-4	34	0	5	14
-3	0	0	0	0
-2	0	0	0	5
-1	0	0	0	0
0	0	0	0	0
1	0	0	0	0
2	0	0	0	46
3	0	0	0	1
4	0	0	0	0
5	0	0	0	12
6	0	0	0	1
7	0	12	26	0
8	T	0	0	0
9	0	0	0	0
10	0	0	0	0
11	0	0	1	0
12	T	37	30	0
13	21	2	1	0
14	0	1	0	0
15	T	0	0	0
16	T	0	0	0
17	0	0	75	5
18	0	0	27	0
19	0	0	1	0
20	0	28	0	0
21	0	40	17	0
22	29	1	22	10
23	10	0	0	3
24	0	0	0	0
25	0	T	1	0
26	3	3	27	0
27	T	0	9	5
28	9	8	1	0
29	2	8	3	0
30	19	0	0	6
31	0	0	12	103
32	0	0	0	5
33	0	0	1	0
34	0	0	0	0
35	0	19	6	12
36	2	2	1	1
37	2	27	0	19
38	2	17	2	1
39	4	0	10	20
40	0	0	0	25
41	0	0	0	4
42	0	0	0	0
43	0	0	0	0
44	0	0	0	0
45	0	0	0	3
46	0	3	0	7
47	T	0	12	3
48	0	0	0	0
49	13	0	10	0
50	0	0	0	0

[a]PRE was applied -15 DAP, 18 mm rainfall.

Table A2. Soils data for 1998 field studies.

Location	Soil texture	Series	Soil description
Jackson	silt loam	Loring	Fine-silty, mixed, thermic Oxyaquic Fragiudalf
Milan	silt loam	Grenada	Fine-silty, mixed, thermic Glossic Fragiudalf
Knoxville	silt loam	Sequatchie	Fine-loamy, siliceous, thermic Humic Hapludult
Spring Hill	silt loam	Maury	Fine, mixed, mesic Typic Paleudalf

Table A3. Stand counts of FFR 797 IMI as influenced by PRE herbicide treatments[a].

Treatment[b]	Rate	Appl. timing	Jackson		Milan		Knoxville		Spring Hill	
			L	R	L	R	L	R	L	R
	g ai/ha		plants/row[c]							
Weedy check			42c	44ab	30ab	32ab	40a	36bc	39a	34a
Weed-free			45abc	45ab	35a	33ab	39a	33c	37a	34a
Imazethapyr Imazapyr	47 16	POST POST	43bc	42b	32ab	32ab	41a	40abc	37a	34a
Imazethapyr Imazapyr Atrazine	47 16 840	POST POST POST	43bc	42b	35a	34a	42a	37abc	36a	31a
Imazethapyr Imazapyr Nicosulfuron	47 16 26	POST POST POST	46abc	46ab	27b	30ab	38a	43a	38a	34a
Imazethapyr Imazapyr Dicamba	47 16 280	POST POST POST	44bc	42b	32ab	26b	41a	33c	39a	31a
Imazethapyr Imazapyr Pendimethalin	47 16 1386	POST POST POST	44bc	45ab	33ab	32ab	39a	42ab	41a	33a
Atrazine Metolachlor Nicosulfuron	1823 1411 35	PRE PRE POST	49a	44ab	33ab	30ab	36a	41ab	39a	32a
Atrazine Metolachlor Dicamba	1823 1411 280	PRE PRE POST	43bc	44ab	32ab	30ab	41a	41ab	38a	33a
Atrazine Metolachlor	1823 1411	PRE PRE	47ab	48a	31ab	27ab	40a	38abc	34a	37a
Nicosulfuron Rimsulfuron Atrazine	13 13 850	POST POST POST	47ab	46ab	32ab	33ab	37a	42ab	38a	34a
Atrazine COC (ml/ha)	2240 383	POST POST	45abc	43b	34a	32ab	41a	41ab	37a	37a
Atrazine Metolachlor Prosulfuron Primisulfuron Nicosulfuron	1823 1411 20 20 26	PRE PRE POST POST POST	45abc	43ab	33ab	33ab	38a	39abc	44a	39a
Atrazine Metolachlor Flumetsulam Clopyralid Nicosulfuron	1823 1411 52 140 26	PRE PRE POST POST POST	44abc	41b	31ab	31ab	40a	43ab	34a	28a
LSD (0.05)			5	6	6	8	7	7	8	12

[a]Means followed by the same letters are not significantly different (P ≤ 0.05) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.
[c]Stand counts were taken in the left and right center rows of each plot.

Table A4. Broadleaf signalgrass control at Jackson[a].

Treatment[b]	Rate	Appl. timing	1 WAT[c]	2 WAT[c]	4 WAT[c]	8 WAT[c]
	g ai/ha		%			
Weedy check			0e	0d	0d	0c
Weed-free			99a	99a	99a	99a
Imazethapyr	47	POST	83b	96a	96a	99a
Imazapyr	16	POST				
Imazethapyr	47	POST	85b	94a	97a	99a
Imazapyr	16	POST				
Atrazine	840	POST				
Imazethapyr	47	POST	81bc	98a	99a	99a
Imazapyr	16	POST				
Nicosulfuron	26	POST				
Imazethapyr	47	POST	84b	92a	93a	98a
Imazapyr	16	POST				
Dicamba	280	POST				
Imazethapyr	47	POST	85b	98a	97a	99a
Imazapyr	16	POST				
Pendimethalin	1386	POST				
Atrazine	1823	PRE	89ab	98b	96a	95a
Metolachlor	1411	PRE				
Nicosulfuron	35	POST				
Atrazine	1823	PRE	84b	71b	53c	30b
Metolachlor	1411	PRE				
Dicamba	280	POST				
Atrazine	1823	PRE	15d	21c	5d	0c
Metolachlor	1411	PRE				
Nicosulfuron	13	POST	83b	95a	96a	98a
Rimsulfuron	13	POST				
Atrazine	850	POST				
Atrazine	2240	POST	69c	68b	61b	49b
COC (ml/ha)	383	POST				
Atrazine	1823	PRE	89ab	96a	94a	95a
Metolachlor	1411	PRE				
Prosulfuron	20	POST				
Primisulfuron	20	POST				
Nicosulfuron	26	POST				
Atrazine	1823	PRE	81bc	93a	95a	96a
Metolachlor	1411	PRE				
Flumetsulam	52	POST				
Clopyralid	140	POST				
Nicosulfuron	26	POST				
LSD (0.05)			13	13	8	21

[a]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.
[c]WAT, weeks after postemergence treatment.

Table A5. Palmer amaranth control at Jackson[a].

Treatment[b]	Rate	Appl. timing	1 WAT[c]	2 WAT[c]	4 WAT[c]	8 WAT[c]
	g ai/ha		%[c]			
Weedy check			0g	0g	0d	0e
Weed-free			99a	99a	99a	99a
Imazethapyr	47	POST	80cde	73cde	64c	46d
Imazapyr	16	POST				
Imazethapyr	47	POST	91abc	99a	99a	99a
Imazapyr	16	POST				
Atrazine	840	POST				
Imazethapyr	47	POST	76de	75cde	60c	75bc
Imazapyr	16	POST				
Nicosulfuron	26	POST				
Imazethapyr	47	POST	86bde	99a	96a	97a
Imazapyr	16	POST				
Dicamba	280	POST				
Imazethapyr	47	POST	75de	69de	54c	40d
Imazapyr	16	POST				
Pendimethalin	1386	POST				
Atrazine	1823	PRE	74e	64e	58c	53d
Metolachlor	1411	PRE				
Nicosulfuron	35	POST				
Atrazine	1823	PRE	94ab	99a	97a	99a
Metolachlor	1411	PRE				
Dicamba	280	POST				
Atrazine	1823	PRE	18f	18f	0d	0e
Metolachlor	1411	PRE				
Nicosulfuron	13	POST	94ab	98ab	97a	97a
Rimsulfuron	13	POST				
Atrazine	850	POST				
Atrazine	2240	POST	95ab	99a	99a	99a
COC (ml/ha)	383	POST				
Atrazine	1823	PRE	86bcd	85bc	83ab	91ab
Metolachlor	1411	PRE				
Prosulfuron	20	POST				
Primisulfuron	20	POST				
Nicosulfuron	26	POST				
Atrazine	1823	PRE	86bcd	79cd	66bc	60cd
Metolachlor	1411	PRE				
Flumetsulam	52	POST				
Clopyralid	140	POST				
Nicosulfuron	26	POST				
LSD (0.05)			12	14	18	21

[a]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.
[c]WAT, weeks after postemergence treatment.

Table A6.. Pitted morningglory control at Jackson[a].

Treatment[b]	Rate	Appl. timing	2 WAT[c]	4 WAT[c]	8 WAT[c]
	g ai/ha		%		
Weedy check			0f	0f	0e
Weed-free			99a	99a	99a
Imazethapyr	47	POST	96abc	92abc	90ab
Imazapyr	16	POST			
Imazethapyr	47	POST	64cde	71cde	70bc
Imazapyr	16	POST			
Atrazine	840	POST			
Imazethapyr	47	POST	77abcd	91abc	91ab
Imazapyr	16	POST			
Nicosulfuron	26	POST			
Imazethapyr	47	POST	69abcde	85abcd	79abc
Imazapyr	16	POST			
Dicamba	280	POST			
Imazethapyr	47	POST	89abcd	97ab	92ab
Imazapyr	16	POST			
Pendimethalin	1386	POST			
Atrazine	1823	PRE	65bcde	59e	26d
Metolachlor	1411	PRE			
Nicosulfuron	35	POST			
Atrazine	1823	PRE	63de	68de	66c
Metolachlor	1411	PRE			
Dicamba	280	POST			
Atrazine	1823	PRE	40e	0f	0e
Metolachlor	1411	PRE			
Nicosulfuron	13	POST	79abcd	76bcde	75bc
Rimsulfuron	13	POST			
Atrazine	850	POST			
Atrazine	2240	POST	94abcd	98a	99a
COC (ml/ha)	383	POST			
Atrazine	1823	PRE	97ab	95ab	88abc
Metolachlor	1411	PRE			
Prosulfuron	20	POST			
Primisulfuron	20	POST			
Nicosulfuron	26	POST			
Atrazine	1823	PRE	97ab	95ab	87abc
Metolachlor	1411	PRE			
Flumetsulam	52	POST			
Clopyralid	140	POST			
Nicosulfuron	26	POST			
LSD (0.05)			33	21	23

[a]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.
[c]WAT, weeks after postemergence treatment.

Table A7. Broadleaf signalgrass control at Milan[a].

Treatment[b]	Rate	Appl. timing	1 WAT[c]	2 WAT[c]	3 WAT[c]	8 WAT[c]
	g ai/ha		%			
Weedy check			0d	0d	0d	0c
Weed-free			99a	99a	99a	99a
Imazethapyr	47	POST	87abc	92ab	96a	93a
Imazapyr	16	POST				
Imazethapyr	47	POST	99a	98a	97a	99a
Imazapyr	16	POST				
Atrazine	840	POST				
Imazethapyr	47	POST	95ab	93ab	98a	99a
Imazapyr	16	POST				
Nicosulfuron	26	POST				
Imazethapyr	47	POST	99a	97ab	97a	99a
Imazapyr	16	POST				
Dicamba	280	POST				
Imazethapyr	47	POST	90abc	92ab	95a	87a
Imazapyr	16	POST				
Pendimethalin	1386	POST				
Atrazine	1823	PRE	99a	99a	99a	97a
Metolachlor	1411	PRE				
Nicosulfuron	35	POST				
Atrazine	1823	PRE	74c	74b	65b	67b
Metolachlor	1411	PRE				
Dicamba	280	POST				
Atrazine	1823	PRE	76bc	25c	30c	6c
Metolachlor	1411	PRE				
Nicosulfuron	13	POST	77bc	88ab	88a	83ab
Rimsulfuron	13	POST				
Atrazine	850	POST				
Atrazine	2240	POST	87abc	85ab	85ab	98a
COC (ml/ha)	383	POST				
Atrazine	1823	PRE	95ab	98a	97a	97a
Metolachlor	1411	PRE				
Prosulfuron	20	POST				
Primisulfuron	20	POST				
Nicosulfuron	26	POST				
Atrazine	1823	PRE	99a	97ab	98a	99a
Metolachlor	1411	PRE				
Flumetsulam	52	POST				
Clopyralid	140	POST				
Nicosulfuron	26	POST				
LSD (0.05)			19	24	23	18

[a]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.
[c]WAT, weeks after postemergence treatment.

Table A8. Sicklepod control at Milan[a].

Treatment[b]	Rate	Appl. timing	1 WAT[c]	2 WAT[c]	3 WAT[c]	8 WAT[c]
	g ai/ha		%			
Weedy check			0f	0f	0g	0f
Weed-free			99a	99a	99a	99a
Imazethapyr	47	POST	66bcd	70bcd	59bc	43cde
Imazapyr	16	POST				
Imazethapyr	47	POST	66bcd	65bcd	59bc	45bcde
Imazapyr	16	POST				
Atrazine	840	POST				
Imazethapyr	47	POST	70bcd	74bc	68bc	58bcd
Imazapyr	16	POST				
Nicosulfuron	26	POST				
Imazethapyr	47	POST	56de	56cde	46cde	29e
Imazapyr	16	POST				
Dicamba	280	POST				
Imazethapyr	47	POST	75bc	74bc	66bc	51bcde
Imazapyr	16	POST				
Pendimethalin	1386	POST				
Atrazine	1823	PRE	48e	44e	36def	41de
Metolachlor	1411	PRE				
Nicosulfuron	35	POST				
Atrazine	1823	PRE	55de	51de	33ef	35de
Metolachlor	1411	PRE				
Dicamba	280	POST				
Atrazine	1823	PRE	10f	18f	15fg	0f
Metolachlor	1411	PRE				
Nicosulfuron	13	POST	75bc	69bcd	58bcd	54b-e
Rimsulfuron	13	POST				
Atrazine	850	POST				
Atrazine	2240	POST	81b	81ab	74b	69b
COC (ml/ha)	383	POST				
Atrazine	1823	PRE	64cd	66bcd	55bcd	40de
Metolachlor	1411	PRE				
Prosulfuron	20	POST				
Primisulfuron	20	POST				
Nicosulfuron	26	POST				
Atrazine	1823	PRE	66bcd	78b	70b	68bc
Metolachlor	1411	PRE				
Flumetsulam	52	POST				
Clopyralid	140	POST				
Nicosulfuron	26	POST				
LSD (0.05)			16	21	22	25

[a]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.
[c]WAT, weeks after postemergence treatment.

Table A9. Broadleaf signalgrass control at Knoxville[a].

Treatment[b]	Rate	Appl. timing	2 WAT[c]	4 WAT[c]	8 WAT[c]
	g ai/ha		%		
Weedy check			0d	0d	0c
Weed-free			99a	99a	99a
Imazethapyr	47	POST	84ab	87ab	95a
Imazapyr	16	POST			
Imazethapyr	47	POST	84ab	92ab	97a
Imazapyr	16	POST			
Atrazine	840	POST			
Imazethapyr	47	POST	71ab	81ab	99a
Imazapyr	16	POST			
Nicosulfuron	26	POST			
Imazethapyr	47	POST	65bc	66b	90a
Imazapyr	16	POST			
Dicamba	280	POST			
Imazethapyr	47	POST	89ab	87ab	97a
Imazapyr	16	POST			
Pendimethalin	1386	POST			
Atrazine	1823	PRE	98a	99a	99a
Metolachlor	1411	PRE			
Nicosulfuron	35	POST			
Atrazine	1823	PRE	97a	99a	99a
Metolachlor	1411	PRE			
Dicamba	280	POST			
Atrazine	1823	PRE	97a	99a	99a
Metolachlor	1411	PRE			
Nicosulfuron	13	POST	64bc	70ab	98a
Rimsulfuron	13	POST			
Atrazine	850	POST			
Atrazine	2240	POST	39c	38c	38b
COC (ml/ha)	383	POST			
Atrazine	1823	PRE	99a	99a	99a
Metolachlor	1411	PRE			
Prosulfuron	20	POST			
Primisulfuron	20	POST			
Nicosulfuron	26	POST			
Atrazine	1823	PRE	96a	99a	99a
Metolachlor	1411	PRE			
Flumetsulam	52	POST			
Clopyralid	140	POST			
Nicosulfuron	26	POST			
LSD (0.05)			27	27	18

[a]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.
[c]WAT, weeks after postemergence treatment.

Table A10. Sicklepod control at Knoxville[a].

Treatment[b]	Rate	Appl. timing	2 WAT[c]	4 WAT[c]	8 WAT[c]
	g ai/ha		%		
Weedy check			0d	0c	0d
Weed-free			99a	99a	99a
Imazethapyr	47	POST	90abc	96ab	93bc
Imazapyr	16	POST			
Imazethapyr	47	POST	93ab	96ab	91bc
Imazapyr	16	POST			
Atrazine	840	POST			
Imazethapyr	47	POST	84bc	97ab	89c
Imazapyr	16	POST			
Nicosulfuron	26	POST			
Imazethapyr	47	POST	93ab	91ab	94bc
Imazapyr	16	POST			
Dicamba	280	POST			
Imazethapyr	47	POST	90abc	91ab	92bc
Imazapyr	16	POST			
Pendimethalin	1386	POST			
Atrazine	1823	PRE	94ab	91ab	90c
Metolachlor	1411	PRE			
Nicosulfuron	35	POST			
Atrazine	1823	PRE	97a	95ab	91bc
Metolachlor	1411	PRE			
Dicamba	280	POST			
Atrazine	1823	PRE	95a	90b	88c
Metolachlor	1411	PRE			
Nicosulfuron	13	POST	81c	91ab	90c
Rimsulfuron	13	POST			
Atrazine	850	POST			
Atrazine	2240	POST	84bc	96ab	90c
COC (ml/ha)	383	POST			
Atrazine	1823	PRE	97a	94ab	91bc
Metolachlor	1411	PRE			
Prosulfuron	20	POST			
Primisulfuron	20	POST			
Nicosulfuron	26	POST			
Atrazine	1823	PRE	97a	98ab	97ab
Metolachlor	1411	PRE			
Flumetsulam	52	POST			
Clopyralid	140	POST			
Nicosulfuron	26	POST			
LSD (0.05)			10	8	6

[a]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.
[c]WAT, weeks after postemergence treatment.

Table A11. Large crabgrass control at Spring Hill[a].

Treatment[b]	Rate	Appl. timing	1 WAT[c]	2 WAT[c]	4 WAT[c]	8 WAT[c]
	g ai/ha		%[c]			
Weedy check			0e	0d	0d	0c
Weed-free			99a	99a	99a	99a
Imazethapyr Imazapyr	47 16	POST POST	83b	87a	90ab	87a
Imazethapyr Imazapyr Atrazine	47 16 840	POST POST POST	73bc	86a	96a	87a
Imazethapyr Imazapyr Nicosulfuron	47 16 26	POST POST POST	74bc	90a	99a	98a
Imazethapyr Imazapyr Dicamba	47 16 280	POST POST POST	86ab	92a	99a	96a
Imazethapyr Imazapyr Pendimethalin	47 16 1386	POST POST POST	73bc	89a	99a	98a
Atrazine Metolachlor Nicosulfuron	1823 1411 35	PRE PRE POST	99a	84a	97a	83a
Atrazine Metolachlor Dicamba	1823 1411 280	PRE PRE POST	99a	99a	97a	97a
Atrazine Metolachlor	1823 1411	PRE PRE	98a	99a	97a	93a
Nicosulfuron Rimsulfuron Atrazine	13 13 850	POST POST POST	55d	66b	74b	43b
Atrazine COC (ml/ha)	2240 383	POST POST	63cd	38c	50c	16c
Atrazine Metolachlor Prosulfuron Primisulfuron Nicosulfuron	1823 1411 20 20 26	PRE PRE POST POST POST	99a	97a	99a	97a
Atrazine Metolachlor Flumetsulam Clopyralid Nicosulfuron	1823 1411 52 140 26	PRE PRE POST POST POST	99a	99a	98a	89a
LSD (0.05)			14	16	19	20

[a]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.
[c]WAT, weeks after postemergence treatment.

Table A12. Sicklepod control at Spring Hill[a].

Treatment[b]	Rate	Appl. timing	1 WAT[c]	2 WAT[c]	4 WAT[c]	8 WAT[c]
	g ai/ha		%[c]			
Weedy check			0c	0f	0d	0e
Weed-free			99a	99a	99a	99a
Imazethapyr	47	POST	87a	86abcd	89ab	58cd
Imazapyr	16	POST				
Imazethapyr	47	POST	88a	86abcd	86ab	64bcd
Imazapyr	16	POST				
Atrazine	840	POST				
Imazethapyr	47	POST	90a	81cd	75abc	58cd
Imazapyr	16	POST				
Nicosulfuron	26	POST				
Imazethapyr	47	POST	90a	85bcd	87ab	56cd
Imazapyr	16	POST				
Dicamba	280	POST				
Imazethapyr	47	POST	91a	85bcd	82ab	56cd
Imazapyr	16	POST				
Pendimethalin	1386	POST				
Atrazine	1823	PRE	91a	84bcd	82ab	50cd
Metolachlor	1411	PRE				
Nicosulfuron	35	POST				
Atrazine	1823	PRE	95a	89abcd	77abc	64bcd
Metolachlor	1411	PRE				
Dicamba	280	POST				
Atrazine	1823	PRE	68b	56e	60c	39d
Metolachlor	1411	PRE				
Nicosulfuron	13	POST	83ab	76d	66bc	63bcd
Rimsulfuron	13	POST				
Atrazine	850	POST				
Atrazine	2240	POST	96a	91abc	80abc	92ab
COC (ml/ha)	383	POST				
Atrazine	1823	PRE	96a	91abc	85abc	80abc
Metolachlor	1411	PRE				
Prosulfuron	20	POST				
Primisulfuron	20	POST				
Nicosulfuron	26	POST				
Atrazine	1823	PRE	96a	96ab	94a	79abc
Metolachlor	1411	PRE				
Flumetsulam	52	POST				
Clopyralid	140	POST				
Nicosulfuron	26	POST				
LSD (0.05)			16	11	22	27

[a]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.
[c]WAT, weeks after postemergence treatment.

Table A13. Stunting and discoloration at Jackson[a].

Treatment[b]	Rate	Appl. timing	1 WAT[c]	2 WAT[c]	4 WAT[c]	1 WAT[c]	2 WAT[c]	4 WAT[c]
	g ai/ha			Stunting			Discoloration	
					%[c]			
Weedy check			0c	0c	1ab	0b	0c	0b
Weed-free			34a	4abc	0b	2b	6b	0b
Imazethapyr Imazapyr	47 16	POST POST	8bc	1bc	0b	1b	0c	0b
Imazethapyr Imazapyr Atrazine	47 16 840	POST POST POST	11bc	4abc	1ab	1b	1c	1ab
Imazethapyr Imazapyr Nicosulfuron	47 16 26	POST POST POST	11bc	1bc	1ab	5b	4bc	1ab
Imazethapyr Imazapyr Dicamba	47 16 280	POST POST POST	19b	4bc	0b	7b	4bc	1ab
Imazethapyr Imazapyr Pendimethalin	47 16 1386	POST POST POST	8bc	6abc	0b	0b	0c	1ab
Atrazine Metolachlor Nicosulfuron	1823 1411 35	PRE PRE POST	5c	3bc	0b	0b	1c	0b
Atrazine Metolachlor Dicamba	1823 1411 280	PRE PRE POST	3c	1bc	0b	1b	0c	0b
Atrazine Metolachlor	1823 1411	PRE PRE	4c	1bc	5b	1b	0c	1ab
Nicosulfuron Rimsulfuron Atrazine	13 13 850	POST POST POST	5c	7ab	1ab	0b	2bc	0b
Atrazine COC (ml/ha)	2240 383	POST POST	11bc	10a	3ab	21a	13a	3a
Atrazine Metolachlor Prosulfuron Primisulfuron Nicosulfuron	1823 1411 20 20 26	PRE PRE POST POST POST	9bc	1bc	0b	0b	0c	0b
Atrazine Metolachlor Flumetsulam Clopyralid Nicosulfuron	1823 1411 52 140 26	PRE PRE POST POST POST	7bc	5abc	3ab	7b	1c	0b
LSD (0.05)			14	6	4	7	5	2

[a]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.
[c]WAT, weeks after postemergence treatment.

Table A14. Stunting and discoloration at Milan[a].

Treatment[b]	Rate	Appl. timing	1 WAT[c]	2 WAT[c]	3 WAT[c]	1 WAT[c]	2 WAT[c]	3 WAT[c]
	g ai/ha		Stunting			Discoloration		
			%					
Weedy check			0a	0b	0b	0a	0b	0b
Weed-free			4a	0b	0b	4a	3ab	3ab
Imazethapyr	47	POST	3a	2ab	3a	3a	7a	5a
Imazapyr	16	POST						
Imazethapyr	47	POST	0a	0b	0b	0a	5ab	3ab
Imazapyr	16	POST						
Atrazine	840	POST						
Imazethapyr	47	POST	0a	0b	0b	0a	0b	1ab
Imazapyr	16	POST						
Nicosulfuron	26	POST						
Imazethapyr	47	POST	4a	0b	0b	0a	0b	0b
Imazapyr	16	POST						
Dicamba	280	POST						
Imazethapyr	47	POST	3a	0b	0b	3a	4ab	4ab
Imazapyr	16	POST						
Pendimethalin	1386	POST						
Atrazine	1823	PRE	0a	0b	0b	0a	1b	0b
Metolachlor	1411	PRE						
Nicosulfuron	35	POST						
Atrazine	1823	PRE	4a	0b	0b	3a	0b	0b
Metolachlor	1411	PRE						
Dicamba	280	POST						
Atrazine	1823	PRE	1a	3a	3a	1a	2ab	4ab
Metolachlor	1411	PRE						
Nicosulfuron	13	POST	1a	0b	0b	1a	4ab	0b
Rimsulfuron	13	POST						
Atrazine	850	POST						
Atrazine	2240	POST	3a	0b	0b	4a	5ab	3ab
COC (ml/ha)	383	POST						
Atrazine	1823	PRE	0a	0b	0b	3a	2ab	5a
Metolachlor	1411	PRE						
Prosulfuron	20	POST						
Primisulfuron	20	POST						
Nicosulfuron	26	POST						
Atrazine	1823	PRE	0a	0b	0b	0a	0b	0b
Metolachlor	1411	PRE						
Flumetsulam	52	POST						
Clopyralid	140	POST						
Nicosulfuron	26	POST						
LSD (0.05)			5	3	2	4	6	5

[a]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.
[c]WAT, weeks after postemergence treatment.

Table A15. Overall injury at Knoxville[a].

Treatment[b]	Rate	Appl. timing	2 WAT[c]	4 WAT[c]	8 WAT[c]
	g ai/ha		%		
Weedy check			0a	0b	0a
Weed-free			0a	0b	0a
Imazethapyr	47	POST	0a	0b	1a
Imazapyr	16	POST			
Imazethapyr	47	POST	0a	0b	0a
Imazapyr	16	POST			
Atrazine	840	POST			
Imazethapyr	47	POST	0a	0b	1a
Imazapyr	16	POST			
Nicosulfuron	26	POST			
Imazethapyr	47	POST	0a	0b	1a
Imazapyr	16	POST			
Dicamba	280	POST			
Imazethapyr	47	POST	0a	0b	3a
Imazapyr	16	POST			
Pendimethalin	1386	POST			
Atrazine	1823	PRE	0a	0b	0a
Metolachlor	1411	PRE			
Nicosulfuron	35	POST			
Atrazine	1823	PRE	0a	3a	1a
Metolachlor	1411	PRE			
Dicamba	280	POST			
Atrazine	1823	PRE	0a	0b	0a
Metolachlor	1411	PRE			
Nicosulfuron	13	POST	0a	0b	0a
Rimsulfuron	13	POST			
Atrazine	850	POST			
Atrazine	2240	POST	0a	0b	0a
COC (ml/ha)	383	POST			
Atrazine	1823	PRE	0a	0b	1a
Metolachlor	1411	PRE			
Prosulfuron	20	POST			
Primisulfuron	20	POST			
Nicosulfuron	26	POST			
Atrazine	1823	PRE	0a	0b	0a
Metolachlor	1411	PRE			
Flumetsulam	52	POST			
Clopyralid	140	POST			
Nicosulfuron	26	POST			
LSD (0.05)			0	1	2

[a]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.
[c]WAT, weeks after postemergence treatment.

Table A16. Stunting and discoloration at Spring Hill[a].

Treatment[b]	Rate	Appl. timing	1 WAT[c]	2 WAT[c]	4 WAT[c]	1 WAT[c]	2 WAT[c]	4 WAT[c]
	g ai/ha			Stunting			Discoloration	
					%			
Weedy check			3ab	0a	10a	0a	0a	0a
Weed-free			8ab	0a	0b	0a	3a	0a
Imazethapyr Imazapyr	47 16	POST POST	5ab	1a	3b	3a	0a	0a
Imazethapyr Imazapyr Atrazine	47 16 840	POST POST POST	3ab	1a	3b	0a	0a	0a
Imazethapyr Imazapyr Nicosulfuron	47 16 26	POST POST POST	5ab	2a	5ab	0a	1a	0a
Imazethapyr Imazapyr Dicamba	47 16 280	POST POST POST	9a	4a	9a	4a	0a	0a
Imazethapyr Imazapyr Pendimethalin	47 16 1386	POST POST POST	0b	4a	2b	0a	0a	0a
Atrazine Metolachlor Nicosulfuron	1823 1411 35	PRE PRE POST	1ab	0a	1b	0a	0a	0a
Atrazine Metolachlor Dicamba	1823 1411 280	PRE PRE POST	3ab	1a	1b	0a	0a	0a
Atrazine Metolachlor	1823 1411	PRE PRE	1ab	2a	1b	0a	0a	0a
Nicosulfuron Rimsulfuron Atrazine	13 13 850	POST POST POST	3ab	5a	0b	1a	1a	0a
Atrazine COC (ml/ha)	2240 383	POST POST	1ab	0a	1b	0a	0a	0a
Atrazine Metolachlor Prosulfuron Primisulfuron Nicosulfuron	1823 1411 20 20 26	PRE PRE POST POST POST	4ab	2a	1b	0a	1a	0a
Atrazine Metolachlor Flumetsulam Clopyralid Nicosulfuron	1823 1411 52 140 26	PRE PRE POST POST POST	3ab	0a	0b	0a	0a	0a
LSD (0.05)			7	4	5	4	3	0

[a]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.
[c]WAT, weeks after postemergence treatment.

Table A17. Weed biomass at Jackson[a].

Treatment[b]	Rate	Appl. timing	Total	broadleaf signalgrass	Palmer amaranth	pitted morningglory
	g ai/ha		g/m²			
Weedy check			1882a	1550a	168ab	7b
Weed-free			0c	0c	0b	0b
Imazethapyr Imazapyr	47 16	POST POST	747b	747b	0b	0b
Imazethapyr Imazapyr Atrazine	47 16 840	POST POST POST	81bc	0b	0b	29ab
Imazethapyr Imazapyr Nicosulfuron	47 16 26	POST POST POST	243bc	217b	0b	0b
Imazethapyr Imazapyr Dicamba	47 16 280	POST POST POST	37bc	0b	2b	3b
Imazethapyr Imazapyr Pendimethalin	47 16 1386	POST POST POST	511bc	509b	0b	0b
Atrazine Metolachlor Nicosulfuron	1823 1411 35	PRE PRE POST	362bc	295b	13b	39ab
Atrazine Metolachlor Dicamba	1823 1411 280	PRE PRE POST	698bc	0b	233a	13ab
Atrazine Metolachlor	1823 1411	PRE PRE	2240a	1966a	42b	50a
Nicosulfuron Rimsulfuron Atrazine	13 13 850	POST POST POST	24bc	0b	0b	23ab
Atrazine COC (ml/ha)	2240 383	POST POST	737b	0b	136ab	2b
Atrazine Metolachlor Prosulfuron Primisulfuron Nicosulfuron	1823 1411 20 20 26	PRE PRE POST POST POST	34bc	23b	0b	3b
Atrazine Metolachlor Flumetsulam Clopyralid Nicosulfuron	1823 1411 52 140 26	PRE PRE POST POST POST	737b	717b	10b	2b
LSD (0.05)			736	755	182	43

[a]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.

Table A18. Weed biomass at Milan[a].

Treatment[b]	Rate	Appl. timing	Total	broadleaf signalgrass	sicklepod
	g ai/ha		g/m²		
Weedy check			2192a	1031a	0b
Weed-free			0f	0d	0b
Imazethapyr Imazapyr	47 16	POST POST	404c-f	362cd	2b
Imazethapyr Imazapyr Atrazine	47 16 840	POST POST POST	339def	317cd	0b
Imazethapyr Imazapyr Nicosulfuron	47 16 26	POST POST POST	433c-f	270cd	0b
Imazethapyr Imazapyr Dicamba	47 16 280	POST POST POST	934bc	908ab	0b
Imazethapyr Imazapyr Pendimethalin	47 16 1386	POST POST POST	378c-f	349cd	2b
Atrazine Metolachlor Nicosulfuron	1823 1411 35	PRE PRE POST	424c-f	420bcd	0b
Atrazine Metolachlor Dicamba	1823 1411 280	PRE PRE POST	963bc	620abc	18b
Atrazine Metolachlor	1823 1411	PRE PRE	1225b	359cd	155a
Nicosulfuron Rimsulfuron Atrazine	13 13 850	POST POST POST	407c-f	239cd	26b
Atrazine COC (ml/ha)	2240 383	POST POST	627cde	223cd	0b
Atrazine Metolachlor Prosulfuron Primisulfuron Nicosulfuron	1823 1411 20 20 26	PRE PRE POST POST POST	925bcd	343cd	58ab
Atrazine Metolachlor Flumetsulam Clopyralid Nicosulfuron	1823 1411 52 140 26	PRE PRE POST POST POST	171ef	155cd	0b
LSD (0.05)			587	532	118

[a]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.

Table A19. Weed biomass at Knoxville[a].

Treatment[b]	Rate	Appl. timing	Total	broadleaf signalgrass	sicklepod
	g ai/ha		g/m²		
Weedy check			477a	96a	71b
Weed-free			14b	0b	0b
Imazethapyr	47	POST	14b	14b	0b
Imazapyr	16	POST			
Imazethapyr	47	POST	4b	4b	0b
Imazapyr	16	POST			
Atrazine	840	POST			
Imazethapyr	47	POST	21b	11b	0b
Imazapyr	16	POST			
Nicosulfuron	26	POST			
Imazethapyr	47	POST	43b	18b	0b
Imazapyr	16	POST			
Dicamba	280	POST			
Imazethapyr	47	POST	53b	28b	0b
Imazapyr	16	POST			
Pendimethalin	1386	POST			
Atrazine	1823	PRE	85b	4b	0b
Metolachlor	1411	PRE			
Nicosulfuron	35	POST			
Atrazine	1823	PRE	14b	0b	0b
Metolachlor	1411	PRE			
Dicamba	280	POST			
Atrazine	1823	PRE	64b	7b	0b
Metolachlor	1411	PRE			
Nicosulfuron	13	POST	39b	25b	0b
Rimsulfuron	13	POST			
Atrazine	850	POST			
Atrazine	2240	POST	150b	0b	174a
COC (ml/ha)	383	POST			
Atrazine	1823	PRE	7b	4b	0b
Metolachlor	1411	PRE			
Prosulfuron	20	POST			
Primisulfuron	20	POST			
Nicosulfuron	26	POST			
Atrazine	1823	PRE	7b	0b	0b
Metolachlor	1411	PRE			
Flumetsulam	52	POST			
Clopyralid	140	POST			
Nicosulfuron	26	POST			
LSD (0.05)			236	43	95

[a]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.

Table A20. Weed biomass at Spring Hill[a].

Treatment[b]	Rate	Appl. timing	Total	broadleaf signalgrass	sicklepod
	g ai/ha		g/m²		
Weedy check			1522a	939a	19b
Weed-free			0c	0d	0b
Imazethapyr	47	POST	18c	7d	7b
Imazapyr	16	POST			
Imazethapyr	47	POST	44c	4d	4b
Imazapyr	16	POST			
Atrazine	840	POST			
Imazethapyr	47	POST	13c	0d	7b
Imazapyr	16	POST			
Nicosulfuron	26	POST			
Imazethapyr	47	POST	23c	0d	4b
Imazapyr	16	POST			
Dicamba	280	POST			
Imazethapyr	47	POST	36c	7d	15b
Imazapyr	16	POST			
Pendimethalin	1386	POST			
Atrazine	1823	PRE	166bc	10cd	128a
Metolachlor	1411	PRE			
Nicosulfuron	35	POST			
Atrazine	1823	PRE	42c	4d	18b
Metolachlor	1411	PRE			
Dicamba	280	POST			
Atrazine	1823	PRE	74c	2d	14b
Metolachlor	1411	PRE			
Nicosulfuron	13	POST	472b	428b	15b
Rimsulfuron	13	POST			
Atrazine	850	POST			
Atrazine	2240	POST	398b	364bc	2b
COC (ml/ha)	383	POST			
Atrazine	1823	PRE	21c	2d	2b
Metolachlor	1411	PRE			
Prosulfuron	20	POST			
Primisulfuron	20	POST			
Nicosulfuron	26	POST			
Atrazine	1823	PRE	59c	3d	4b
Metolachlor	1411	PRE			
Flumetsulam	52	POST			
Clopyralid	140	POST			
Nicosulfuron	26	POST			
LSD (0.05)			317	354	94

[a]Means followed by the same letters are not significantly different ($P \leq 0.05$) according to the LSD test.
[b]All treatments contain 0.25% (v/v) nonionic surfactant except atrazine + crop oil concentrate.

VITA

Eric Ray Walker was born in Springfield, Tennessee, on November 21, 1973. He is the son of Eddie Ray and Joyce Walker. He graduated from Springfield High School in May of 1992. He entered Austin Peay State University in the Fall of 1992 and completed a Bachelor of Science degree in Agricultural Science in May of 1996. He entered the University of Tennessee, Knoxville in August 1996 as a graduate student in Plant and Soil Sciences. He received a Master of Science degree in May of 1999.

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