Chapter V

Control of Italian Ryegrass (*Lolium multiflorum*) in No-Till Corn[1]

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Abstract: Field experiments were conducted in Virginia in 2000 and 2001 to evaluate herbicide programs for control of Italian ryegrass in no-till corn establishment. Herbicide programs using transgenic corn hybrids were compared to standard programs that utilize nonselective herbicides in combination with high rates of triazine herbicides. Experiments were conducted in a split-plot, randomized complete block design with corn hybrid as the main plot and herbicide treatment as the subplot. Transgenic corn hybrids included glyphosate-, glufosinate-, sethoxydim-, and imidazolinone-tolerant lines. Italian ryegrass control and corn yields similar to standard treatments could be attained through with paraquat plus atrazine and by glyphosate applied at 840 and 1680 g ai/ha in

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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.

combination with either atrazine or rimsulfuron/thifensulfuron-methyl. In glyphosate-tolerant corn, early postemergence (EP) applications of glyphosate controlled Italian ryegrass, and yields were similar to yields of corn treated with standard preemergence (PRE) applications of glyphosate plus atrazine. The use of the glufosinate, imazethapyr plus imazapyr, or sethoxydim with the appropriate hybrids did not demonstrate potential for improved control of Italian ryegrass in comparison to traditional PRE treatments.

Nomenclature: Atrazine; glufosinate; glyphosate; imazapyr; imazethapyr; paraquat; sethoxydim; Italian ryegrass, *Lolium multiflorum* (Lam.) #[3] LOLMU; corn, *Zea mays* (L). ZEAMX.

Additional index words: Nicosulfuron, rimsulfruon, thifensulfuron-methyl; barley, *Hordeum vulgare* (L.); soybean, *Glycine max* (L.) Merr.; wheat, *Triticum aestivum* (L.).

Abbreviations: EP, early postemergence; fb, followed by; Imaze/imaza, Imazethapyr/imazapyr; IT, imadizolinone-tolerant; LL, liberty-link; LSD, least significant difference; PRE, preemergence; Rim/thifen, Rimsulfuron/thifensulfruon-methyl; RR, roundup-ready; SR, sethoxydim-resistant; WAT, weeks after treatment.

INTRODUCTION

In Virginia, Italian ryegrass [*Lolium multiflorum* (Lam.)] has become one of the most troublesome and difficult to control weeds in small grains, and in corn [*Zea mays* (L).] and soybean [*Glycine max* (L.) Merr.] grown in rotation with small grains. Italian ryegrass control has declined due to the development of resistance to diclofop-methyl, which has been the only treatment available for control in wheat [*Triticum aestivum* (L.)] and barley [*Hordeum vulgare* (L.)]. Lack of control in small grains has allowed Italian ryegrass to proliferate and become problematic in other cropping systems. The first occurrence of diclofop-resistance was documented in 1987 (Stanger and Appleby 1989). However, diclofop-resistance was not confirmed in Virginia until 1993 in Brunswick County (Heap 2002). In 1999, collections of Italian ryegrass biotypes from Virginia were screened for diclofop-resistance. Resistance was determined to be widespread and certain biotypes exhibited up to 16-fold resistance to the normal use rate of diclofop (Morozov et al. 1999). Italian ryegrass has reduced small grain yield by as much as 75 percent through competition for resources and by harvest impairment[1]. Inability to control Italian ryegrass and low small grain prices has led to a reduction in small grains hectarage planted in Virginia. During the period of 1996-2000, harvested wheat hectares decreased from 111,291 to 82,962 (VDACS 2000).

Italian ryegrass is difficult to control in no-till corn establishment, where high triazine herbicide rates or sequential applications of nonselective herbicides are frequently

[1] Hagood, E. S. and H. P. Wilson. 2000. Application for specific exemption in accordance with Section 18 of FIFRA to use Axiom herbicide to control Italian ryegrass in wheat. pp. 12

required for acceptable control prior to corn emergence. Cyanazine has controlled Italian ryegrass in no-till corn establishment; and cancellation of registration of this product further limits control options in corn. Davis (1986) stressed that success or failure of no-till corn depends on control of the vegetation at planting. No-till corn hectarage has also increased in Virginia, where 36% was planted without tillage in 1990 compared to 49% in 1998[2]. The current percentage of Virginia corn planted no-till is over three-times greater than the national average of 16%. Presently, nonselective burndown herbicides such as paraquat, and glyphosate are used to control vegetation existing at planting (Wilson et al. 1985).

The development of genetically modified corn hybrids that tolerate POST applications of non-selective compounds has increased growers' options for Italian ryegrass control in no-till corn. These hybrids include glyphosate-tolerant, glufosinate-tolerant, imidazolinone-tolerant and sethoxydim-resistant corn hybrids. Previous research has indicated the potential for control of Italian grass species with paraquat, glufosinate, and glyphosate with or without triazine herbicides as either early preplant or PRE treatments (Wilson et al. 1985; Martin and Green 1999). Photosynthetic inhibiting herbicides applied in combination with these herbicides increased control of several annual grass species (Wilson and Worsham 1998). Others have described successful Italian grass control using herbicide treatments that included PRE and POST applications of glyphosate, glufosinate, sethoxydim or imidazolinone herbicides in herbicide-resistant

[2] Data provided by Conservation technology information center, http:www.ctic.purdue.edu/CTIC/CTIC.html

crops (Askew et al. 1999; York and Culpepper 1999; Spivey et al. 1999; Vencil 1999; Young 1999; Walker 1999; Kranz 1998; Rabaey 1996; Johnson et al. 2000).

As a result of the need to control Italian ryegrass in no-till corn and the lack of information on the effectiveness of various systems using genetically modified corn, additional information is needed. Therefore, the objective of this research was to investigate herbicide programs using transgenic corn hybrids for control of Italian ryegrass in no-till corn establishment.

Materials and Methods

Field experiments were established at two Virginia sites in 2000 and one site in 2001. In 2000, the locations included Amelia and Henrico counties. In 2001, the experiment was located in Amelia County. Amelia County experiments were conducted on an Appling sandy loam (*typic Hapludults*) with 1.7% organic matter and pH 6.4. The Henrico county experiment was conducted on a Pamunkey fine sandy loam (*ultic Hapludalfs*) with 1.8% organic matter and pH 6.3. These locations were chosen for heavy natural infestations of Italian ryegrass, and were also characterized by relatively low levels of infestation of other weed species.

Experiments were conducted in a split-plot, randomized complete block design containing four replications with corn hybrid as the main plot and herbicide treatment as the subplot. Transgenic corn hybrids included Dekalb[3] 626 RR, Dekalb 683 SR, Pioneer[4]

[3] Dekalb Genetics Corporation, Dekalb, Illinois 60115

33G28 LL, and Pioneer 32Z18 IMI. Hybrid designations of RR, SR, LL, and IMI refer to glyphosate-, sethoxydim-, glufosinate-, and imidazolinone-tolerance, respectively. Treatments applied to transgenic corn hybrids included glyphosate, sethoxydim, glufosinate, imazethapyr plus imazapyr, and paraquat. Each herbicide was applied at two rates with or without atrazine, alone or in a sequential treatment, and with or without rimsulfuron plus thifensulfuron-methyl, with the exception of paraquat, which was not applied sequentially. Sequential treatments applied to transgenic corn hybrids consisted only of glyphosate, sethoxydim, glufosinate, and imazethapyr plus imazapyr. These treatments were compared to standard treatments of paraquat or glyphosate applied at two rates with or without atrazine, cyanazine, and rimsulfuron plus thifensulfuron-methyl, and with or without a sequential treatment of nicosulfuron alone. The standard treatments were applied to the Dekalb 626 RR corn hybrid. The prepackage herbicide mixture of imazethapyr plus imazapyr commercially available as Lightning[5] contains imazethapyr and imazapyr in a 3:1 ratio. The prepackage herbicide mixture of rimsulfuron plus thifensulfuron-methyl, with the trade name of Basis[6] contains rimsulfuron plus thifensulfuron-methyl in a 2:1 ratio.

Individual plots were 3.1 m wide and 9.1 m long containing four corn rows. The center 1.8 m of each plot containing the two center corn rows were treated, leaving a 1.2 m non-sprayed area containing two corn rows between each treated plot. Herbicide treatments were applied using a CO_2 backpack sprayer at a volume of 210 L/ha with flat-

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[4] Pioneer Hi-Bred International, Inc. P. O. Box 256, Johnston, Iowa 50131-0256

[5] American Cyanamid Company, One campus drive, Parsippany, NJ. 07054

[6] E. I. du Pont de Nemours and Company, Walker's Mill, Banley Mill Plaza, Wilmington, DE. 19898

fan spray tips[7]. The glyphosate product[8] contained its own surfactant and was applied without an additional surfactant. Glufosinate was applied with 3.4 kg/ha of ammonium sulfate. Sethoxydim was applied with 1.0% V/V crop oil concentrate. All other herbicide treatments contained 0.5% V/V nonionic surfactant[9]. Corn was planted with a population of 69,200 seed per hectare in 76 cm rows using a two-row no-till planter[10] in both years at the Amelia County location. The Amelia County location was fertilized with 154 kg/ha of nitrogen when the corn was 8 to 10 cm tall. In the Henrico county trial, treatments were evaluated in the absence of a corn crop.

Herbicide efficacy ratings were made throughout the growing season. A 0-100 rating scale was used, where 0 was equal to the Italian ryegrass population observed in the control plots and 100 was equal to complete Italian ryegrass control. The two center corn rows of each plot were harvested by hand at maturity, and grain moisture and yields were determined for each plot. Weed control ratings and corn yields were subjected to analysis of variance and means were separated using the least significant difference (LSD) test at the 5% level of probability. To determine significance of main and interaction effects for herbicide treatment and year, and for corn hybrid and year, factorial analyses were also performed.

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[7] Teejet 8003 flat fan spray nozzles, Spraying Systems Co., North Ave. Wheaton, IL. 60188

[8] Roundup Ultra, Monsanto Co., 800 N. Lindbergh Blvd., St. Louis, MO. 63167

[9] X-77, non-ionic surfactant, Valent USA Corp. 1333 N. California Blvd., Walnut Creek, CA. 94596

[10] Almaco planter, 99 M Avenue, Nevada, Iowa 50201

Results and Discussion

Significant effects of herbicide treatment on Italian ryegrass control and corn yield occurred in all experiments. Homogeneity of variance evaluation indicated significant interaction effects of location with respect to weed control and corn yield variables. For this reason, data are presented individually for each location.

Italian ryegrass control with either single or sequential herbicide applications was poor to fair with glufosinate, imazethapyr plus imazapyr or sethoxydim in Amelia County in 2000 (Table 1). Glufosinate, imazethapyr plus imazapyr, and sethoxydim provided 8, 49, and 65% control at 8 wk after treatment (WAT) with single applications, and 50, 35, and 68 % control with sequential applications, respectively.

Glyphosate applied alone at either 840 or 1680 g ai/ha provided 87 and 98% Italian ryegrass control at 8 WAT, and provided 99% control with sequential early postemergence (EP) application after corn emergence (Table 1). Similar results with regard to the effects of single versus sequential herbicide applications occurred in the Henrico location and in the Amelia County in 2001 (Data not presented). In both locations glyphosate provided significantly greater control than glufosinate, imazethapyr plus imazapyr or sethoxydim. Sequential glyphosate treatments provided 97 and 100% control in Henrico county in 2000 and Amelia county in 2001, respectively.

Application of glufosinate, imazethapyr plus imazapyr or sethoxydim in combination with 1680 g ai/ha of atrazine and/or 26 g ai/ha of rimsulfuron plus thifensulfuron-methyl resulted in unacceptable control of Italian ryegrass at both 2 WAT and 8 WAT at all locations. Representative data from the Henrico location are contained in Table 2.

Significant increases in Italian ryegrass control occurred only when 26 g ai/ha of rimsulfuron plus thifensulfuron-methyl was added to 267 g ai/ha imazethapyr plus imazapyr or 213 g ai/ha of sethoxydim, where control increased from 20 to 60%, and from 54 to 70%, respectively, at 8 WAT. Only 8 and 11% Italian ryegrass control was observed at 8 WAT with glufosinate and glufosinate plus rimsulfuron plus thifensulfuron-methyl, respectively. Similar levels of Italian ryegrass control occurred in the Amelia County experiments with glufosinate, imazethapyr plus imazapyr or sethoxydim in combination with atrazine and/or rimsulfuron plus thifensulfuron-methyl (Data not presented).

In the Henrico experiment, paraquat alone rapidly desiccated the above ground portion of Italian ryegrass, and control of 83 and 88% occurred with application of 526 or 885 g ai/ha, respectively, at 2 WAT (Table 2). Italian ryegrass regrowth occurred in subsequent weeks, however, and control decreased to 47 and 55% at 8 WAT with 526 or 885 g ai/ha of paraquat, respectively (Table 2). Italian ryegrass was controlled 91% at 8 WAT when paraquat at 526 g ai/ha was combined with atrazine, due to both foliar and root absorption of atrazine. Reductions in Italian ryegrass control occurred when rimsulfuron plus thifensulfuron-methyl was added to the 526 g ai/ha paraquat treatment, where control was reduced from 83 to 54% and 47 to 26% at 2 WAT and 8 WAT, respectively (Table 2). Glyphosate at 1680 g ai/ha controlled Italian ryegrass 84 and 98% at 2 and 8 WAT, respectively (Table 2). These levels of control were significantly higher than those afforded by the 840 g ai/ha rate of glyphosate alone or in combination with 1680 g ai/ha of atrazine at both evaluation timings. The addition of 26 g ai/ha of rimsulfuron plus thifensulfruon-methyl to 840 g ai/ha of glyphosate increased Italian ryegrass control from

44 to 69% and 64 to 96% at 2 and 8 WAT, respectively (Table 2). Similar results were observed in the Amelia county experiments with respect to paraquat and glyphosate containing treatments (Data not presented).

Comparisons of standard PRE paraquat treatments containing cyanazine with paraquat treatments applied with other residual compounds in Amelia county in 2001 indicated that treatments without cyanazine at either 1120or 2240 g ai/ha resulted in significantly lower Italian ryegrass control at both 2 WAT and 6 WAT (Table 3). Only the addition of 35 g ai/ha of nicosulfuron applied EP following a PRE application of paraquat at 526 g ai/ha and atrazine at 1680 g ai/ha controlled Italian ryegrass equivalent to treatments of paraquat plus atrazine, and cyanazine at 8 WAT (Table 3). Reductions in Italian ryegrass control were once again noted for all evaluation timings when any treatment containing paraquat was combined with rimsulfuron plus thifensulfuron-methyl (Table 3).

Standard PRE glyphosate treatments in Amelia county in 2001 resulted in a 10% increase in Italian ryegrass control at 2 WAT when 26 g ai/ha of rimsulfuron plus thifensulfuron-methyl was added to 840 g ai/ha glyphosate compared to glyphosate at 840 g ai/ha in combination with 1680 g ai/atrazine (Table 4). Italian ryegrass control by 8 WAT with any treatment containing glyphosate was 93% or greater and no significant effects of any additions to glyphosate treatments occurred. Similar results occurred in the Amelia county experiment in 2000, where Italian ryegrass control was 88 and 98% at 8 WAT when glyphosate was applied alone at 840 g ai/ha or in combination with rimsulfuron plus thifensulfuron-methyl, respectively (Data not presented). The combination of 840 g ai/ha of glyphosate and 1680 g ai/ha of atrazine resulted in 96% Italian ryegrass control. In 2000 in Henrico county, however, a greater than 30%

increase in ryegrass control occurred at 8 WAT when 26 g ai/ha of rimsulfuron/thifensulfuron-methyl was added to 840 g ai/ha of glyphosate compared to glyphosate applied alone or in combination with atrazine.

Comparisons of yields within individual hybrids for Amelia County in 2000 are contained in Table 5. Statistical comparisons between hybrids could not be performed because yield differences could result from either level of Italian ryegrass control or from yield traits of specific hybrids. In 2000, corn yield increased when glyphosate, glufosinate, and imazethapyr plus imazapyr treatments were combined with atrazine and/or rimsulfuron plus thifensulfuron-methyl compared to yield with any of these herbicides applied alone (Table 5). Corn yield also increased in the sethoxydim-resistant hybrid when 213 g ai/ha of sethoxydim was combined with atrazine compared to sethoxydim applied alone or in a sequential application. However, no difference in yield occurred when sethoxydim was combined with rimsulfuron plus thifensulfuron-methyl compared to sethoxydim applied alone (Table 5). Similar results to those observed in the sethoxydim-resistant hybrid occurred when paraquat treatments were applied to the glyphosate-resistant corn hybrid (Table 5). Corn yield in the Amelia experiments was much greater in 2000 than 2001 due to drought in 2001. However, trends associated with increases in yield due to the addition of residual herbicides or sequential applications were generally observed within individual hybrids in 2001 (Data not presented).

Yield of glyphosate-resistant corn in response to Italian ryegrass control in Amelia County in 2000 did not differ between standard glyphosate and paraquat treatments containing atrazine with or without cyanazine or an EP application of nicosulfuron (Table 6). In 2001, however, there was a significant decrease in corn yield when glyphosate at

840 g ai/ha was combined with 1680 g ai/ha of atrazine compared to any other treatment containing a higher rate of glyphosate with atrazine and with or without cyanazine, or with an EP application of nicosulfuron (Table 6.) This result was not expected because Italian ryegrass control at 8 WAT was 93% with 840 g ai/ha of glyphosate combined with 1680 g ai/ha of atrazine at this location. The lower yield could possibly be a result of lower Italian ryegrass control levels at 2 WAT, which could have reduced early corn growth, relative to growth with the higher rate of glyphosate combined with atrazine. No difference in corn yield between paraquat containing treatments occurred in 2001 in Amelia County.

Italian ryegrass control and corn yields similar to standard treatments containing cyanazine could be realized with paraquat in combination with atrazine, or glyphosate applied at 840 and 1680 g ai/ha in combination with either atrazine or rimsulfuron plus thifensulfuron-methyl. Paraquat treatments in combination with rimsulfuron plus thifensulfuron-methyl reduced Italian ryegrass control compared to control with paraquat alone. Antagonistic effects from the combination of paraquat with rimsulfuron plus thifensulfuron-methyl have not been previously described. However, antagonism of paraquat activity has been noted due to the application of bentazon (Wehtje 1992), metribuzin plus chlorimuron, imazaquin (Hydrick and Shaw 1994), and amine salts of growth regulator herbicides (O'Donovan and O'Sullivan 1982). Increasing paraquat rate overcame these antagonistic effects (Hydrick and Shaw 1994; O'Donovan and O'Sullivan 1982). ^{14}C studies with bentazon indicated that each herbicide inhibited the foliar penetration of the other (Wehtje 1992). This could also explain the reduction in

Italian ryegrass control with the combination of paraquat plus rimsulfuron plus thifensulfuron-methyl.

The use of glyphosate-tolerant corn appeared to be advantageous due to the ability to apply EP treatments of glyphosate after corn emergence for the control of Italian ryegrass. Corn yield did not significantly increase, however, compared to yield with standard PRE applications of glyphosate plus atrazine. The use of the other transgenic hybrids does not appear to add any potential benefit for the control of Italian ryegrass.

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Table 1. Effect of single or sequential herbicide applications on Italian ryegrass control in no-till corn in Virginia in Amelia County, 2000.

Herbicide	Rate	Timing	Control of Italian Ryegrass[a]	
			2 WAT[b]	8 WAT[c]
	g ai/ha		%	
Glufosinate	291	PRE	8	8
Glufosinate	493	PRE	6	0
Glufosinate fb glufosinate	291 fb 291	PRE fb EP	10	50
Imazethapyr/imazapyr	627	PRE	4	49
Imaze/imaza fb imaze/imaza	627 fb 627	PRE fb EP	4	35
Sethoxydim	213	PRE	11	65
Sethoxydim	314	PRE	20	69
Sethoxydim fb sethoxydim	213 fb 213	PRE fb EP	13	68
Glyphosate	840	PRE	68	87

Glyphosate	1680	PRE	84	98
Glyphosate fb glyphosate	840 fb 840	PRE fb EP	76	99
LSD (0.05)			12	15

[a] Indicates visual ryegrass control (0-100%).

[b] Abbreviation: WAT, weeks after treatment; fb, followed by; imaze/imaza, imazethapyr plus imazapyr.

[c] Sequential treatment applied 6 weeks after initial treatment.

Table 2. Effect of the addition of residual herbicides to preemergence herbicide applications on Italian ryegrass control in no-till corn in Virginia in Henrico County, 2000

Herbicide	Rate	Timing	Control of Italian Ryegrass[a]	
			2 WAT	8 WAT
	g ai/ha		%	
Glufosinate	291	PRE	8	8
Glufosinate	493	PRE	6	10
Glufosinate	291	PRE	15	17
+ atrazine	1680	PRE		
Glufosinate	291	PRE	29	11
+ rim/thifen[b]	26	PRE		
Glufosinate	291	PRE	38	23
+ atrazine	1680	PRE		
+ rim/thifen	26	PRE		
Imazethapyr/imazapyr	627	PRE	31	20
Imazethapyr/imazapyr	627	PRE	36	17
+ atrazine	1680	PRE		
Imazethapyr/imazapyr	627	PRE	49	60
+ rim/thifen	26	PRE		
Imazethapyr/imazapyr	627	PRE	33	20
+ atrazine	1680	PRE		

+ rim/thifen	26	PRE		
Sethoxydim	213	PRE	50	54
Sethoxydim	314	PRE	48	54
Sethoxydim	213	PRE	39	51
+ atrazine	1680	PRE		
Sethoxydim	213	PRE	54	70
+ rim/thifen	26	PRE		
Sethoxydim	213	PRE	46	40
+ atrazine	1680	PRE		
+ rim/thifen	26	PRE		
Glyphosate	840	PRE	44	64
Glyphosate	1680	PRE	81	84
Glyphosate	840	PRE	46	62
+ atrazine	1680	PRE		
Glyphosate	840	PRE	69	96
+ rim/thifen	26	PRE		
Glyphosate	840	PRE	46	92
+ atrazine	1680	PRE		
+ rim/thifen	26	PRE		
Paraquat	526	PRE	83	47
Paraquat	885	PRE	88	55
Paraquat	526	PRE	90	91

+ atrazine	1680	PRE		
Paraquat	526	PRE	54	26
+ rim/thifen	26	PRE		
Paraquat	526	PRE	65	70
+ atrazine	1680	PRE		
+ rim/thifen	26	PRE		
LSD (0.05)			13	16

[a] Indicates visual ryegrass control (0-100%).

[b] Abbreviation: Rim/thifen, Rimsulfuron/thifensulfuron-methyl; WAT, weeks after treatment.

Table 3. Italian ryegrass control with high and low rates of preemergence paraquat with selected residual compounds and with or without postemergence nicosulfuron[a] in Amelia County, 2001.

Treatment	Rate	Timing	Control of Italian Ryegrass		
			2 WAT	6 WAT	8 WAT
	g ai/ha		%		
Paraquat	526	PRE	79	78	75
+ atrazine	1680	PRE			
Paraquat	526	PRE	38	33	30
+ rim/thifen[b]	26	PRE			
Paraquat	526	PRE	55	54	55
+ atrazine	1680	PRE			
+ rim/thifen	26	PRE			
Paraquat	526	PRE	92	94	95
+ atrazine	1680	PRE			
+ cyanazine	1120	PRE			
Paraquat	885	PRE	98	100	100

+ atrazine	2240	PRE			
+ cyanazine	2240	PRE			
Paraquat	526	PRE	78	90	99
+ atrazine fb nicosulfuron	1680 fb 35	PRE fb EP			
LSD (0.05)			8	12	12

[a] Early postemergence applications applied six weeks after initial treatment.

[b] Abbreviation: Rim/thifen, Rimsulfuron/thifensulfuron-methyl; WAT, weeks after treatment; fb, followed by.

Table 4. Italian ryegrass control with high and low rates of preemergence glyphosate with selected residual compounds and with or without postemergence nicosulfuron or sequential glyphosate application[a] in Amelia County, 2001.

Treatment	Rate	Timing	Control of Italian Ryegrass		
			2 WAT	6 WAT	8 WAT
	g ai/ha		%		
Glyphosate	840	PRE	74	94	93
+ atrazine	1680	PRE			
Glyphosate	840	PRE	84	98	98
+ rim/thifen[b]	26	PRE			
Glyphosate	840	PRE	84	99	99
+ atrazine	1680	PRE			
+ rim/thifen	26	PRE			
Glyphosate	840	PRE	64	93	93
+ atrazine	1680	PRE			
+ cyanazine	1120	PRE			
Glyphosate	1680	PRE	76	98	99

+ atrazine	2240	PRE			
+ cyanazine	2240	PRE			
Glyphosate	840	PRE	70	90	98
+ atrazine fb nicosulfuron	1680 fb 35	PRE fb EP			
Glyphosate fb glyphosate	840 fb 840	PRE fb EP	74	85	100
LSD (0.05)			8	12	12

[a] Early postemergence applications applied six weeks after initial treatment.

[b] Abbreviation: Rim/thifen, Rimsulfuron/thifensulfuron-methyl; WAT, weeks after treatment; fb, followed by.

Table 5. Effect of herbicide treatments on corn yield within hybrids in Amelia County in 2000.[a]

Treatment[c]	Rate	Timing	Glyphosate	Glufosinate	Sethoxydim	Imaze/imaz	Paraquat
			---------- Preemergence Treatments[b] ----------				
	g ai/ha		840	291	213	627	526
			---------- Corn yield[e] ----------				
			---------- kg / ha ----------				
Alone			7120	4100	4780	5380	-
+ Atrazine	840	PRE	9520	5410	6750	7650	9520
+ Rim/thifen	26	PRE	9520	6220	4800	8910	8600
+ Rim/thifen	26	PRE	10200	4590	5710	9610	10430
+ atrazine	1680	PRE					
fb Sequential[f]		EP	10010	4730	4590	7760	-
+ Atrazine	1680	PRE	10810	6400	6200	9790	-
fb sequential		EP					
Control			3100	3820	3780	3870	4850
LSD (0.05)			2410	1600	1510	2790	1820

[a] Dashes indicate that this treatment was not evaluated.

[b] Glyphosate, Glufosinate, Sethoxydim, Imazethapyr/imazapyr and Paraquat applied to Dekalb 626 RR, Pioneer 33G28 LL, Dekalb 683 SR, Pioner 32Z18 IMI, and Dekalb 626 RR hybrids, respectively.

[c] Early postemergence treatment was applied six weeks after initial treatment.

[d] Abbreviations: Imaze/imaza, Imazethapyr/imazapyr; Rim/thifen, Rimsulfuron/thifensulfuron-methyl; fb, followed by.

[e] Yield calculated at 13 percent moisture.

[f] Sequential treatment was applied six weeks after initial treatment and is identical to PRE treatment applied alone.

Table 6. Yield differences due to standard glyphosate and paraquat treatments for the control of Italian ryegrass in 2000 and 2001 in Amelia County[a].

Treatment	Rate	Timing	Corn Yield 2000	Corn Yield 2001
	g ai/ha		kg/ha[b]	
Glyphosate	840	PRE	9530	4940
+ atrazine	1680	PRE		
Glyphosate	1680	PRE	10400	8860
+ atrazine	1680	PRE		
Glyphosate	840	PRE	9790	8600
+ atrazine	1680	PRE		
+ cyanazine	1120	PRE		
Glyphosate	1680	PRE	10750	6030
+ atrazine	2240	PRE		
+ cyanazine	2240	PRE		
Glyphosate	840	PRE	10020	7280

+ atrazine fb[c] nicosulfuron	1680 fb 35	PRE fb EP[d]		
Paraquat	526	PRE	9520	6980
+ atrazine	1680	PRE		
Paraquat	526	PRE	10270	7990
+ atrazine	1680	PRE		
+ cyanazine	1120	PRE		
Paraquat	885	PRE	9870	6800
+ atrazine	2240	PRE		
+ cyanazine	2240	PRE		
Paraquat	526	PRE	9530	6900
+ atrazine fb nicosulfuron	1680 fb 35	PRE fb EP		
Control			4070	810
LSD (0.05)			2050	2960

[a] Treatments in both years applied to Dekalb 626 RR hybrid.

[b] Yields calculated at 13.0 percent moisture.

[c] Abbreviations: fb, followed by.

[d] Early postemergence treatment was applied six weeks after initial treatment.