Weed Management in Enhanced Glyphosate-Resistant Cotton

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ABSTRACT

Field experiments were conducted in 2003 and 2004 to evaluate glyphosate rates and timings on control of Palmer amaranth, devil's-claw, ivyleaf morningglory, and silverleaf nightshade in enhanced glyphosate-resistant cotton. Treatments based on cotton growth stage (CS) were compared to as-needed (ASN) treatments based on weed population and size. Palmer amaranth, devil's-claw, and silverleaf nightshade were controlled (> 90%) with postemergence (POST) treatments based on CS or ASN applications in both years. These weeds were controlled with glyphosate at 0.75 lb ae/A and no benefit was observed with an increased glyphosate rate. Ivyleaf morningglory control, in both years, improved with increased glyphosate rates to 1.5 lb ae/A. When the first application was delayed to 11-leaf cotton, three glyphosate applications at 1.5 lb ae/A were required to achieve control. Ivyleaf morningglory in 2003 was controlled with four glyphosate applications applied ASN beginning at two-leaf cotton and ending with the last treatment applied at 20-leaf cotton. In 2004 with increased rainfall and weed pressure, five applications of glyphosate at 1.5 lb ae/A were required for effective control (>90%).

KEYWORDS: *Amaranthus palmeri* S. Wats., cotton, devil's-claw, glyphosate rates, glyphosate timing, *Gossypium hirsutum* L., *Ipomoea hederacea* (L.) Jacq., ivyleaf morningglory, Palmer amaranth, *Proboscidea louisianica* (Mill.) Thellung, silverleaf nightshade, *Solanum elaeagnifolium* Cav., weed management systems.

Abbreviations: ASN, as-needed; cot, cotyledon; CS, crop stage; EB, early-bloom; fb, followed by; lf, leaf; PPI, preplant incorporated; PDIR, postemergence-directed; POST, postemergence.

INTRODUCTION

Glyphosate resistance in cotton was conferred by the incorporation of a 5-enolpyruvylshikimate-3-phosphate synthase (EC 2.5.1.19) gene cloned from

Agrobacterium sp. strain CP4 (CP4-EPSPS) (Johnson 1996). The expression of the CP4-EPSPS gene produces a glyphosate-resistant EPSPS enzyme which can overcome the inhibition of native EPSP synthase in the presence of glyphosate, allowing sufficient production of aromatic amino acids and secondary metabolites (Nida et al. 1996). This technology allows POST applications of glyphosate from emergence through the four-leaf stage of development and PDIR applications when cotton has five-leaves or more (Jones and Snipes 1999). The maximum glyphosate rate allowed for POST or PDIR applications is 0.75 lb ae/A. The CP4-EPSPS gene is not well expressed in male flower tissues (Chen et al. 2003; Pline et al. 2003), and glyphosate applied after the four-leaf stage can compromise reproductive development (Light et al. 2003). When late over-the-top applications were made, there have been performance and yield loss complaints in glyphosate-resistant cotton due to an increase in lower fruiting branch boll abortions and misshapen bolls (Ferreira et al. 1998; Vargas et al. 1998).

Due to the limitation of the current glyphosate-resistant cotton, an enhanced glyphosate- resistant genotype has been introduced. Roundup Ready® Flex cotton, event MON 88913, was created by transforming Coker 312 plant material using a disarmed *Agrobacterium tumefaciens* method and a CP4-EPSPS gene construct (Burns et al. 2004). The CP4-EPSPS protein as expressed in the Roundup Ready® Flex cotton is the same protein contained in the current glyphosate resistant cotton product (Burns et al. 2004). The CP4-EPSPS protein is expressed in both vegetative and reproductive tissues at levels necessary to provide resistance to glyphosate (Burns et al. 2004). Glyphosate applications at 1.5 and 2.25 lb ae/A at the 3-, 6-, 10-, and 14-lf stages did not affect yield or fiber quality compared to the non-treated control (May et al. 2004). Glyphosate is now registered for use in Roundup Ready® Flex cotton at rates up to 1.12 lb ae/A per application and a total of no more than 4.5 lb ae/A during the growing season (up to 60% open bolls). A total of 6.0 lb ae/A may be applied during the crop year.

Cotton producers throughout the Texas Southern High Plains must control many annual and perennial weeds that reduce crop yields each year. Residual herbicides applied preplant incorporated (PPI) and preemergence (PRE) are successful in managing early-season annual weeds such as Palmer amaranth (Keeling et al. 1997). However, as the residual soil activity declines, late-season control of Palmer amaranth escapes and other annual weeds including devil's-claw and ivyleaf morningglory becomes more difficult (Everitt et al. 2002; Keeling et al. 1997). These weeds compete with cotton, reducing yields, and complicating harvest. With the development of new crop herbicide resistance technologies, producers on the Texas High Plains have an opportunity to implement a variety of weed control strategies for improved annual and perennial weed management.

Glyphosate provides excellent control of Palmer amaranth, devil's-claw, and silverleaf nightshade; however, due to a limited application window and environmental conditions such as wind (causes drift) and rain (prevents equipment entering field), season-long control may be difficult (Everitt et al. 2002; Keeling et al. 1997). Glyphosate is marginally effective on annual morningglory (*Ipomoea* sp.) (Culpepper et al. 2001; Jordan et al. 1997) often requiring higher application rates and timely applications to achieve effective control (Jordan et al. 1997; McCloskey et al. 2004). Current weed management systems in glyphosate-resistant cotton provide producers with tools needed to control early-season weeds; however, late-season control requires the use of specialized sprayer equipment (Burns et al. 2004). With the introduction of Roundup Ready® Flex cotton, there is a need to determine optimum glyphosate rates and timing

that will provide the most efficient weed control. Therefore, field experiments were conducted to evaluate different weed control strategies for use in Roundup Ready® Flex cotton systems.

MATERIALS AND METHODS

Field experiments were conducted in 2003 at Lubbock and Hockley County, TX and in 2004 at Lubbock, TX. The soil type at the Lubbock location was an Acuff clay loam (Fine-loamy, mixed, thermic Aridic Paleustolls) with less than 1.0% organic matter and pH 7.4. The soil type at the Hockley County location was an Amarillo fine sandy loam (Fine-loamy, mixed, superactive, thermic Aridic Paleustalfs) with less than 1.0% organic matter and pH 7.5.

Cotton (Paymaster 2326 RR and MON 88913) was planted at a depth of 2 in. on 40-in. rows at a seeding rate of 15 lb/A and treated with aldicarb at 0.37 lb ai/A. In 2003, test was irrigated with 5.2 in. using an overhead using an overhead sprinkler irrigation system. All other tests were furrow-irrigated with 6 in. of supplemental water in 2003 and 2 in. in 2004.

A tractor-mounted compressed air sprayer or CO_2 -pressurized backpack sprayer calibrated to deliver 10 gallons per acre (GPA) was used for postemergence (POST) herbicide applications. The tractor sprayer was operated at 35 PSI with 110015 flat-fan nozzles at 3 MPH. A commercial standard treatment was used and required a hooded sprayer calibrated to deliver 10 GPA at a speed of 5 MPH. Percent weed control was estimated each week throughout the season using a scale of 0 to 100, with 0 equal to no control and 100 equaling complete control (Frans et al. 1986). Ratings were made approximately 3-, 60, and 100 days after planting (DAP), reflecting early-, mid-, and late-season control. Cotton lint was harvested in 2004 from both Roundup Ready® Flex varieties using a sample size of 2 rows (6.6 ft) by 6.6 ft. Samples were weighed and a 22 percent turnout was applied to seed cotton weight.

Ivyleaf morningglory. Studies were established in 2003 and 2004 in Hockley County, TX and Lubbock, TX, respectively. A natural infestation of ivyleaf morningglory was present in both years. Plot size was 4 rows (13 ft.) by 30 ft. in length. Trifluralin was applied at 0.75 lb ai/A and incorporated to a depth of 3 in. with a spring-tooth harrow before planting. Glyphosate was applied POST topical at 0.75 or 1.5 lb ae/A in three weed management systems based on crop growth stage (CS), as-needed (ASN: 0.4 to 0.8 in.), or a combination of CS and ASN (Table 1).

Palmer amaranth, devil's-claw and silverleaf nightshade. Experiments were established near Lubbock, TX in areas naturally infested with Palmer amaranth, devil's-claw and silverleaf nightshade in 2003 and 2004 (Table 2). Plot size was 8 rows (26.2 ft) by 30 ft in length. Trifluralin was applied at 0.75 lb ai/A and incorporated to a depth of 3 in. with a spring-tooth harrow before planting. Glyphosate was applied POST at 0.75 or 1.5 lb ae/A in three weed management systems based on CS, ASN, or a combination of CS and ASN.

Table 1. Postemergence-topical glyphosate application dates and crop and weed growth stages for ivyleaf morningglory control in 2003 and 2004[a].

	2003			2004		
Application	Date	Crop stage	Weed stage	Date	Crop stage	Weed stage
POST I	May 29[b]	cotyledon to 1 leaf	cotyledon	May 24[c]	1 leaf	2 leaf
POST II	N/A	N/A	N/A	Jun 1[b]	3 to 4 leaf	cotyledon to 2 leaf
POST III	Jun 11[b]	3 to 4 leaf	cotyledon to 2 leaf	N/A	N/A	N/A
POST IV	N/A	N/A	N/A	Jun 15[c]	6 to 8 leaf	cotyledon to 2 leaf
POST V	Jun 25[c]	8 leaf	cotyledon to 4 leaf	Jun 23[c]	10 to 12 leaf	cotyledon to 3 leaf
POST VI	Jul 1[c]	10 to 11 leaf	cotyledon to 4 leaf	Jul 1[c]	12 to 14 nodes	cotyledon to 4 leaf
POST VII	Jul 9[c]	11 to 12 leaf	cotyledon to 2 leaf	N/A	N/A	N/A
POST VII	Jul 30[c]	early bloom	cotyledon to 4 leaf	Jul 21[c]	early bloom	cotyledon to 4 leaf
POST IX	Sep 3[c]	peak bloom	cotyledon to 4 leaf	Aug 4[c]	peak bloom	cotyledon to 2 leaf

[a] Abbreviations: N/A, not applicable; POST, postemergence-topical.
[b] Glyphosate applied at 1.5 lb ai/A.
[c] Glyphosate applied at both 0.75 and 1.5 lb ai/A.

Table 2. Postemergence-topical glyphosate rate and timing treatments for Palmer amaranth, devil's-claw, and silverleaf nightshade control[a].

Applications 2003	Date	Crop stage	Palmer amaranth	Devil's-claw	Silverleaf nightshade
			in.		
POST I[b]	Jun 11	cotyledon to 1 leaf	0	0	4
POST II[c]	Jul 1	5 to 6 leaf	0	0 to 4	10
POST III[c]	Jul 11	6 to 8 leaf	0	4	1 to 7
POST IV[c]	Jul 15	10 to 11 leaf	6	4	6
POST V[c]	Jul 21	10 to 12 leaf	4	4	6
POSTVI[c]	Jul 29	early bloom	2	12	5
Applications 2004					
POST I[c]	May 24	2 leaf	0	cotyledon to 3	1 to 4
POST II[b]	Jun 1	3 to 4 leaf	0	3 to 4	1 to 6
POST III[c]	Jun 15	6 to 8 leaf	cotyledon to 1	cotyledon to 1	0.5 to 3
POST IV[c]	Jun 23	10 to 12 leaf	cotyledon to 3	cotyledon to 4	0.5 to 5
POST V[c]	Aug 4	early bloom	cotyledon to 12	cotyledon to 12	0.5 to 8

[a] Abbreviations: POST, postemergence-topical.
[b] Glyphosate applied at 1.5 lb ae/A.
[c] Glyphosate applied at both 0.75 and 1.5 lb ae/A.

All experiments were arranged as a randomized block design with a factorial arrangement with three replications. Data were subjected to an analysis of variance, and means were separated using Fisher's protected LSD test at the 5% probability level. Percent weed control data were arcsine transformed before analysis for stability; however, non-transformed data are presented mean separation based on transformed data.

RESULTS AND DISCUSSION

Ivyleaf Morningglory Control.

A weed management system by rate interaction was not observed for early- or mid-season ivyleaf morningglory control in 2003; therefore, data were averaged over weed management systems within rates and over rates within weed management systems. A weed management system by rate interaction was observed for late-season ivyleaf morningglory control in 2003; therefore, data were not averaged across weed management system or rate. A weed management system by rate interaction was not observed for early-season ivyleaf morningglory control assessments in 2004; therefore, data were averaged over weed management systems within rates and within rates over weed management systems. A weed management system by rate interaction was observed for mid- and late-season ivyleaf morningglory.

Early-season ivyleaf morningglory control was greater following glyphosate at 1.5 lb ae/A (81%) than at 0.75 lb ae/A (72%) rate and control was similar among systems (Table 3). Effective mid-season ivyleaf morningglory control (96 to 98%) was observed in all weed management systems (94 to 99%) following both glyphosate rates. In other research, late-season ivyleaf morningglory control was improved with increased glyphosate rates, regardless of weed management system (Jordan et al. 1997; McCloskey et al. 2004). Glyphosate POST applied in CS/ASN and ASN systems controlled ivyleaf morningglory better than glyphosate POST applied in the CS system at both rates.

Application timing was essential for achieving effective ivyleaf morningglory control. Rainfall from January to March totaled 0.5 in. with an additional 7.4 in. recorded throughout the growing season (Apr to Sep). Due to the dry early-season, ivyleaf morningglory emergence was reduced, which decreased the need for early-season ASN applications. More effective control was achieved with the same amount of glyphosate when applied based upon weed density and size (Table 3).

Similar early-season ivyleaf morningglory control (89 to 91%) was achieved with all weed management systems (Table 4). Glyphosate at 1.5 lb ae/A controlled ivyleaf morningglory 94%, which was greater than the 85% control achieved with glyphosate at 0.75 lb ae/A. Mid-season control was not different between weed management systems at each glyphosate rate. However, glyphosate at 1.5 lb ae/A achieved greater ivyleaf morningglory control than glyphosate at 0.75 lb ae/A in the ASN and CS/ASN weed management systems. Effective late-season control (98%) was achieved with glyphosate at 1.5 lb ae/A applied five times in the CS/ASN and ASN weed management systems (Table 4). Regardless of rate, three glyphosate applications in the CS weed management system failed to provide 75% ivyleaf morningglory control.

Similar to 2003, environmental conditions in 2004 affected ivyleaf morningglory emergence and control. Above average rainfall was recorded with January to March rainfall totaling 5.3 in. and a growing season (Apr to Sep) total of 16.7 in. Due to these conditions, early-season CS applications were more beneficial than in 2003 (Tables 3 to

Table 3. Effect of glyphosate rate and weed management system on ivyleaf morningglory control in 2003[a].

Evaluation timing	Weed management system	Rate[b] 0.75		1.5		avg	
		——— % ———					
early-season	CS (2 leaf)	70		83		77	A[c]
	CS/ASN (2 leaf)	73		79		76	A
	ASN[d]	N/A		N/A		N/A	
	avg	72	Y[e]	81	X		
mid-season	CS (2 fb 7 fb 11 leaf)	99		99		99	A
	CS/ASN (2 fb 7 leaf)	97		98		98	A
	ASN (11 leaf)	91		97		94	A
	avg	96	X	98	X		
late-season	CS (2 fb 7 fb 11 leaf)	55	b[f]y[g]	65	bx	60	
	CS/ASN (2 fb 7 fb 17 fb 19 leaf)	89	ay	99	ax	94	
	ASN (11 fb 17 fb 19 leaf)	87	ay	97	ax	92	
	avg	77		87			

[a] Abbreviations: ASN, as-needed; avg, average; CS, crop stage; fb, followed by; N/A, not applicable.
[b] Rate = lb ae/A.
[c] Weed management system means followed by the same upper case letter (A, B, C) are not significantly different (P=0.05) using Fisher's Protected LSD.
[d] Ivyleaf morningglory emergence was limited by dry conditions; therefore, no applications were required in the ASN weed management system.
[e] Rate means followed by the same upper case letter (X, Y, Z) are not significantly different (P=0.05) using Fisher's Protected LSD.
[f] Weed management system means within a rate followed by the same lower case letter (a, b, c) are not significantly different (P=0.05) using Fisher's Protected LSD.
[g] Rate means within a weed management system followed by the same lower case letter (x, y, z) are not significantly different (P=0.05) using Fisher's Protected LSD.

4). However, to achieve season-long control, additional ASN applications were necessary to control ivyleaf morningglory. An increase in glyphosate rate improved ivyleaf morningglory control.

Palmer amaranth, devil's-claw, and silverleaf nightshade control.

A weed management system by rate interaction was not observed for early or late-season Palmer amaranth, devil's-claw or silverleaf nightshade control or for Palmer amaranth mid-season. A weed management system by rate interaction was observed in mid-season silverleaf nightshade control; therefore, data were not averaged over weed management system or rate.

Table 4. Effect of glyphosate rate and weed management system on ivyleaf morningglory control in 2004[a].

Evaluation timing	Weed management system	Rate[b] 0.75		Rate[b] 1.5		avg	
		%		%		%	
early-season	CS (1 fb 7 leaf)	89		92		91	A[c]
	CS/ASN (1 fb 7 leaf)	85		94		90	A
	ASN (1 fb 7 leaf)	82		96		89	A
	avg	85	Y[d]	94	X		
mid-season	CS (1 fb 7 fb 11 leaf)	89	a[e]x[f]	96	ax	93	
	CS/ASN (1 fb 7 leaf fb 13 node)	85	ay	96	ax	91	
	ASN (1 fb 7 leaf fb 13 node)	79	ay	94	ax	87	
	avg	84		95			
late-season	CS (1 fb 7 fb 11 leaf)	73	bx	79	bx	76	
	CS/ASN (1 fb 7 leaf fb 13 node fb EB fb PB)	86	ay	98	ax	92	
	ASN (1 fb 7 leaf fb 13 node fb EB fb PB)	80	aby	98	ax	89	
	avg	80		92			

[a] Abbreviations: ASN, as-needed; avg, average; CS, crop stage; EB, early bloom; fb, followed by; PB, peak bloom.
[b] Rate = lb ae/A.
[c] Weed management system means followed by the same upper case letter (A, B, C) are not significantly different (P=0.05) using Fisher's Protected LSD.
[d] Rate means followed by the same upper case letter (X, Y, Z) are not significantly different (P=0.05) using Fisher's Protected LSD.
[e] Weed management system means within a rate followed by the same lower case letter (a, b, c) are not significantly different (P=0.05) using Fisher's Protected LSD.
[f] Rate means within a weed management system followed by the same lower case letter (x, y, z) are not significantly different (P=0.05) using Fisher's Protected LSD.

Palmer amaranth was controlled at least 99% throughout the season regardless of application timing or rate (Table 5). All weed management systems effectively controlled devil's-claw at least 99%, with the exception of glyphosate at 0.75 lb ae/A applied mid-season in the ASN weed management system (85%). Glyphosate at 1.5 lb ae/A controlled silverleaf nightshade 81%, which was greater than 74% control following glyphosate at 0.75 lb ae/A. Similar to mid-season devil's-claw control, a difference in silverleaf nightshade control was observed in the ASN weed management system. Regardless of rate, three glyphosate applications controlled at late-season silverleaf nightshade at least 93% (Table 5). These results show that an increase in glyphosate rate did not improve control of these weeds. This data supports Croon et al. (2003) who

Table 5. Effect of glyphosate rate and timing on Palmer amaranth, devil's-claw, and silverleaf nightshade control 2003[a].

Evaluation timing	Weed management system	Palmer amaranth Rate[b] 0.75		1.5		avg		Devil's-claw Rate 0.75		1.5		avg		Silverleaf nightshade Rate 0.75		1.5		avg	
		%																	
early-season	CS (2 leaf)	100		100		100	A[c]	100		100		100	A	73		80		77	A
	CS/ASN (2 leaf)	100		100		100	A	100		100		100	A	76		80		78	A
	ASN (2 leaf)	100		100		100	A	100		100		100	A	73		82		78	A
	avg	100	X[d]	100	X			100	X	100	X			74	Y	81	X		
mid-season	CS (2 fb 7 fb 12 leaf)	100		100		100	A	100	a[e]x[f]	99	ax	99		94	ax	97	ax	96	
	CS/ASN (2 fb 5[g] fb 10 leaf)	100		100		100	A	99	ax	100	ax	99		93	ax	93	ax	93	
	ASN (2 fb 5 leaf)	99		100		99	A	85	by	99	ax	92		85	by	93	ax	89	
	avg	100	X	100	X			95		99				91		94			
late-season	CS (2 fb 7 fb 12 leaf)	100		100		100	A	100		100		100	A	95		98		97	A
	CS/ASN (2 fb 5[g] fb 10 leaf)	99		99		99	A	100		100		100	A	94		92		93	A
	ASN (2 fb 5 fb 14 leaf)	99		99		99	A	100		100		100	A	97		96		97	A
	avg	99	X	99	X			100	X	100	X			95	X	95	X		

[a] Abbreviations: ASN, as-needed; avg, average; CS, crop stage; fb, followed by.
[b] Rate = lb ae/A.
[c] Weed management system means followed by the same upper case letter (A, B, C) are not significantly different (P=0.05) using Fisher's Protected LSD.
[d] Rate means followed by the same upper case letter (X, Y, Z) are not significantly different (P=0.05) using Fisher's Protected LSD.
[e] Weed management system means within a rate followed by the same lower case letter (a, b, c) are not significantly different (P=0.05) using Fisher's Protected LSD.
[f] Rate means within a weed management system followed by the same lower case letter (x, y, z) are not significantly different (P=0.05) using Fisher's Protected LSD.
[g] 5 leaf application at 0.75 lb ae/A only..

Table 6. Effect of glyphosate rate and timing on Palmer amaranth, devil's-claw, and silverleaf nightshade control 2004[a].

Evaluation timing	Weed management system	Palmer amaranth Rate[b] 0.75		1.5		avg		Devil's-claw Rate 0.75		1.5		avg		Silverleaf nightshade Rate 0.75		1.5		avg	
		%																	
early-season	CS (2 leaf)	100		100		100	A[c]	99		98		99	A	72		80		76	A
	CS/ASN (2 leaf)	100		100		100	A	100		100		100	A	70		68		69	A
	ASN (2 leaf)	100		100		100	A	98		100		99	A	73		83		78	A
	avg	100	X[d]	100	X			99	X	99	X			72	X	77	X		
mid-season	CS (2 fb 7 fb 11 leaf)	100		99		99	A	99		98		99	A	92	a[e]y[f]	99	ax	96	
	CS/ASN (2 fb 11 leaf)	100		100		100	A	99		99		99	A	83	by	95	ax	89	
	ASN (2 fb 11 leaf)	100		100		100	A	99		99		99	A	86	by	95	ax	91	
	avg	100	X	100	X			99	X	99	X			87		96			
late-season	CS (2 fb 7 fb 11 leaf)	99		99		99	A	99		99		99	A	97		99		98	A
	CS/ASN (2 fb 11 leaf fb early bloom)	99		99		99	A	100		100		100	A	92		94		93	A
	ASN (2 fb 11 leaf fb early bloom)	99		99		99	A	100		100		100	A	96		96		96	A
	avg	99	X	99	X			99	X	99	X			95	X	96	X		

[a] Abbreviations: ASN, as-needed; avg, average; CS, crop stage; fb, followed by.
[b] Rate = lb ae/A.
[c] Weed management system means followed by the same upper case letter (A, B, C) are not significantly different (P=0.05) using Fisher's Protected LSD.
[d] Rate means followed by the same upper case letter (X, Y, Z) are not significantly different (P=0.05) using Fisher's Protected LSD.
[e] Weed management system means within a rate followed by the same lower case letter (a, b, c) are not significantly different (P=0.05) using Fisher's Protected LSD.
[f] Rate means within a weed management system followed by the same lower case letter (x, y, z) are not significantly different (P=0.05) using Fisher's Protected LSD.

reported that an increase in glyphosate rate may be less important than timely applications.

All weed management systems controlled Palmer amaranth and devil's-claw 90-100%, regardless of application timing or rate (Table 6). Three glyphosate applications at 0.75 lb ae/A in the CS weed management system provided greater mid-season silverleaf nightshade control (92%) than two applications in the CS/ASN (83%) and ASN (86%) systems. No differences in silverleaf nightshade control were observed across weed management systems with the highest glyphosate rate. All weed management systems and rates effectively controlled silverleaf nightshade at least 93% with three glyphosate applications.

These data show that Palmer amaranth, devil's-claw, and silverleaf nightshade can be controlled season-long when glyphosate is applied at 0.75 lb ae/A based upon either CS or ASN application timings (Table 6). Previous research by Dotray and Keeling (1996) reported that a fall application of glyphosate at 0.75 lb ae/A provided effective long-term control of silverleaf nightshade. Keeling et al. (1999) reported that an additional PDIR glyphosate application improved season-long control of silverleaf nightshade.

Yield data were not collected in 2003 due to USDA regulations requiring the test area to be destroyed due to a breach in the borders surrounding the test area. In 2004, glyphosate rate and weed management system had no effect on cotton lint yield. When averaged across rates within weed management systems, cotton lint yields ranged from 533 to 553 lb/A. When averaged across weed management systems within rates, cotton lint yield was at least 539 lb/A (Table 7). This yield was likely due to effective weed control in all weed management systems.

Table 7. Effect of glyphosate rate and timing on cotton lint yield in 2004[a].

	Rate[b]		
Weed management system	0.75	1.5	avg
	lb/A		
	56	53	55 A
CS (2 fb 7 fb 11 leaf)	8	8	3 [c]
CS/ASN (2 fb 11 leaf fb early	57	51	54
bloom)	7	6	7 A
	50	56	53
ASN (2 fb 11 leaf fb early bloom)	2	2	3 A
	54 X	53	
avg	9 [d]	9 X	

[a] Abbreviations: ASN, as-needed; avg, average; CS, crop stage; followed by.
[b] Rate = lb ae/A
[c] Weed management system means followed by the same upper case letter (A, B, C) are not significantly different (P=0.05) using Fisher's Protected LSD.
[d] Rate means followed by the same upper case letter (X, Y, Z) are not significantly different (P=0.05) using Fisher's Protected LSD.

These results indicate that glyphosate rate and timing were essential to effectively control ivyleaf morningglory. Early-season applications made based on CS timings were unnecessary in 2003 due to a lack of early-season rainfall, however in 2004 these timings were beneficial as well as two additional ASN late-season applications. Late-season control also demonstrated the importance of increasing glyphosate rate from 0.75 to 1.5

lb ae/A. Glyphosate applied at 1.5 lb ae/A controlled ivyleaf morningglory at least 97% in 2003 and 98% in 2004 season-long when applications were made based on weed growth stage.

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