ECONOMIC EVALUATION OF LONG-TERM WEED CONTROL SYSTEMS AND OF PITTED MORNINGGLORY CONTROL SYSTEMS WITH GLYPHOSATE-TOLERANT COTTON

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TABLE OF CONTENTS

LIST OF TABLES

Table Page

INTRODUCTION

Chapters I and II of this dissertation are manuscripts to be submitted for publication in Weed Technology, a journal of the Weed Science Society of America, while chapter III is a manuscript to be submitted for publication in the Journal of Cotton Science, a journal of the Cotton Foundation.

Chapter I

Economic Evaluation of Long-Term Weed Control Systems Using Glyphosate-Tolerant Cotton (*Gossypium hirsutum*)

Economic Evaluation of Long-Term Weed Control Systems

Using Glyphosate-Tolerant Cotton (*Gossypium hirsutum*)

Abstract: Field experiments were conducted for 3 yr to evaluate weed control systems and their economics using glyphosate, standard herbicides, and a glyphosate-tolerant cotton cultivar. Treatment with glyphosate alone at the first postemergence timing (POST-1) controlled at least 85% of the johnsongrass, common cocklebur, silverleaf nightshade, and Palmer amaranth present 10 wk after planting (WAP). Soil-applied herbicides [such as pendimethalin or pyrithiobac followed by (fb) glyphosate 4 WAP] improved Palmer amaranth and devil's-claw control in 2 of 3 yr. Treatment with the pendimethalin preplant incorporated (PPI) fb prometryn plus pyrithiobac preemergence (PRE) fb quizalofop or pyrithiobac POST-1 did not consistently improve devil's-claw control when compared to glyphosate alone. Cotton treated with glyphosate POST-1 yielded 390, 700, and 250 kg lint/ha in 1998, 1999, and 2000, respectively. In 1998, treatment with pendimethalin PPI fb pyrithiobac PRE, glyphosate POST-1, and quizalofop POST-2 improved cotton lint yield over glyphosate alone, while in 1999 and 2000 cotton treated with glyphosate alone yielded equal to or greater than all other treatments. Glyphosate alone was the most economical treatment (costing ≤ $50/ha) and provided the largest net return for weed control in 2 of 3 yr and the largest return ratio in all years.

Nomenclature: Glyphosate; pendimethalin; prometryn; pyrithiobac; quizalofop; common cocklebur, *Xanthium strumarium* L. #[1] XANST; common lambsquarters, *Chenopodium album* L. # CHEAL; devil's-claw, *Proboscidea*

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[1]Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

louisianica (Mill.) Thellung # PROLO; johnsongrass, *Sorghum halepense* (L.) Pers. # SORHA; Palmer amaranth, *Amaranthus palmeri* S. Wats. # AMAPA; pitted morningglory, *Ipomoea lacunosa* L. # IPOLA; silverleaf nightshade, *Solanum elaeagnifolium* Cav. # SOLEL; yellow nutsedge, *Cyperus esculentus* L. # CYPES; cotton, *Gossypium hirsutum* L. 'Paymaster 1220 BG/RR'.

Abbreviations: fb, followed by; gly, glyphosate; pend, pendimethalin; POST-1, first postemergence application timing; POST-2, second postemergence application timing; PPI, preplant incorporated; PRE, preemergence; pro, prometryn; pyri, pyrithiobac; quiz, quizalofop; WAP, weeks after planting.

INTRODUCTION

The introduction of herbicide-tolerant crops has given producers new options for postemergence (POST) weed control. Prior to the introduction of glyphosate-tolerant cotton, early-season grass and broadleaf weed control was accomplished primarily by preplant incorporated (PPI) or preemergence (PRE) herbicides like trifluralin, metolachlor, fluometuron, and prometryn (Culpepper and York 1999; Keeling et al. 1999). POST weed control in cotton usually consisted of postemergence-directed sprays toward the base of the plant to avoid crop injury and yield reduction which was generally caused by over-the-top application of herbicides like MSMA and fluometuron (Shankle et al. 1996; Snipes et al. 1984). Producers prefer to apply herbicides over-the-top of cotton rather than POST-directing applications because of the slower application speed, a required height differential between the weed and crop, and the requirement for specialized application equipment. Glyphosate-tolerant cotton allows the application of glyphosate over-the-top of cotton with some limitations.

Glyphosate, a non-selective herbicide, controls many annual and perennial grass and broadleaf weeds that are common to agronomic crops. Cotton's normal intolerance to glyphosate was overcome by selection, insertion, and expression of a gene encoding a glyphosate-tolerant 5-enolpyruvylshikimate-3-phosphate synthase, the enzyme usually inhibited by glyphosate (Kishore et al. 1992; Thompson et al. 1987). Glyphosate can be applied safely over-the-top from emergence until the crop reaches the four-leaf stage, while subsequent applications must be POST-directed at the base of the plant. Glyphosate's lack of residual activity often results in the need for multiple applications or the application of a residual PPI or PRE herbicide for season-long control of weeds such as pitted morningglory, Palmer amaranth, and common cocklebur that may germinate and emerge throughout a single growing season (Culpepper and York 1998; Flint et al. 1999; Harris and Vencill 1999).

In 1996, pyrithiobac[2] was registered for both PRE and POST over-the-top broadleaf weed control in cotton (Smith et al. 1997). Unlike glyphosate, there is no limitation for over-the-top application of pyrithiobac. Pyrithiobac controls many broadleaf weeds that are a problem in Oklahoma cotton production. Palmer amaranth, pitted morningglory, and devil's-claw are controlled with POST applications of pyrithiobac; however, many annual grasses, johnsongrass, and silverleaf nightshade are not controlled. The presence of grass weeds would necessitate the application of a graminicide in combination with pyrithiobac or a separate application which would be more expensive than a single glyphosate application. Graminicides may be tank-mixed with pyrithiobac, but antagonism of grass weed control may be observed when acetolactate synthase (ALS) inhibiting herbicides like pyrithiobac are tank-mixed with graminicides (Jordan et al. 1993; Tredaway et al. 1998;

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[2]Staple® herbicide product label. Dupont Agricultural Products. Walker's Mill, Banley Mill Plaza, Wilmington, DE 19898-0038.

Palmer et al. 1999).

High production costs combined with low cotton prices have made all production decisions, especially weed control, increasingly important. The most cost-effective weed control option when considering a conventional vs. a glyphosate-tolerant cotton system will depend on factors such as high yield potential, weed spectrum, herbicide costs, and technology fees. The objectives of this research are to evaluate the efficacy and economics of various weed control systems using glyphosate, traditional herbicides, and a glyphosate-tolerant cotton cultivar over a 3-yr period.

MATERIALS AND METHODS

Field experiments were established in 1998, 1999, and 2000 at the South Central Research Station near Chickasha, OK. The soil type was a Reinach silt loam (a coarse-silty, mixed, superactive, thermic Pachic Haplustoll) with a pH of 6.5 and a 0.5% organic matter content. A weed population was already present at the study location; and it included predominantly johnsongrass, devil's-claw, silverleaf nightshade, common cocklebur, and Palmer amaranth; however, smaller populations of pitted morningglory, yellow nutsedge, and common lambsquarters were also present.

Prior to disking and bedding the study area each year, 112 kg/ha of 46-0-0 was applied. This N fertilizer rate was based on soil test values and yield-goal related recommendations for Oklahoma. PPI herbicides were applied to preformed beds and incorporated with a rolling cultivator on April 16, May 6, and April 25 in three respective years. At the time of herbicide incorporation, beds were reformed. Each year, 'Paymaster 1220 BG/RR' cotton was planted at 14 seed/m of row with rows spaced 1.0 m apart. Planting and PRE application dates were May 19, May 20, and May 22, in 1998, 1999, and 2000, respectively. Plots were 12 rows wide and 30 m long with 0.5 m removed from each end shortly before harvest to reduce the end-row effect; thus, harvested row length was 29 m.

The experimental design was a randomized complete block with 16 herbicide treatments replicated four times. Treatments were applied to the same plots in all 3 yr of the experiment. All applications were made with a tractor-mounted, compressed-air sprayer calibrated to deliver 140 L/ha at 260 kPa. Herbicides (and their rates) included: pendimethalin (1.4 kg ai/ha) or no PPI herbicide; prometryn (2.2 kg ai/ha), pyrithiobac (0.05 kg ai/ha), a tank-mixture of prometryn plus pyrithiobac (2.2 + 0.05 kg/ha), or no PRE herbicide; and glyphosate (1.1 kg ai/ha), pyrithiobac (0.07 kg ai/ha), quizalofop (0.09 kg ai/ha applied once or 0.05 kg ai/ha sequential POST), or no POST over-the-top herbicide. A nonionic surfactant[3] at 0.25% (v/v) was included with pyrithiobac POST, while a crop oil concentrate[4] at 1% (v/v) was included with quizalofop POST.

To simulate applications a producer would likely make in-season, several planned POST applications were not required or the order of application was adjusted based on weeds present at the time of application; hence, these adjustments resulted in fewer than the intended 16 treatments, because some of the 16 were duplications. This duplication resulted in nine different treatments in 1998 and seven which were different in 1999 and 2000. In the last 2 yr, duplication of the treatments pendimethalin PPI fb prometryn PRE fb pyrithiobac POST-1 (Treatments 4 and 7) and pendimethalin PPI fb prometryn plus pyrithiobac

[3]Latron AG-98 contains 80% alkylaryl polyoxyethylene glycol. Rohm and Haas Co., Philadelphia, PA 19106.

[4]Agridex, a heavy range paraffin base petroleum oil, polyol fatty acid esters, and polyethoxylated derivatives. Helena Chemical Co., 6075 Poplar Ave., Suite 500, Memphis, TN 38119.

PRE fb pyrithiobac POST-1 (Treatments 5 and 6) resulted in seven treatments because pyrithiobac was moved to a POST-1 application (replacing quizalofop) because broadleaf weeds were present. In 1998, johnsongrass populations warranted a single glyphosate or quizalofop application POST-1 or a split application of quizalofop POST-1 and POST-2. In 1999 and 2000, broadleaf weeds were predominant; therefore, glyphosate or pyrithiobac was applied POST-1 instead of quizalofop. Only one POST application was required for season-long weed control in 1999 and 2000 due to late-season drought and the resulting lack of weed germination and emergence.

In all 3 yr, the POST-1 application was made at 4 wk after planting (WAP) when cotton was in two-to-four leaf growth stage and was 8- to 15-cm tall. The POST-2 application in 1998 was made at 6 WAP when cotton was in the six-to-eight leaf growth stage and was 20- to 30-cm tall. Weed densities, heights, and growth stages at the time of POST application are listed in Table 1. In addition to chemical weed control, all plots were cultivated one time each year 6 WAP.

Weed control and cotton injury were visually determined 10 WAP based on a rating scale of 0 (no effect) to 100% (death of weed or crop). Cotton was harvested on October 27, October 21, and November 16 in the three respective years. The center four rows of each plot were harvested with a commercial two-row brush-roller stripper followed by weighing, collection of a "grab" sample, deburring that sample, and ginning to determine lint percentage and lint yield/plot (then converted into kilograms/hectare). Five-year moving average cotton lint prices of $1.39/kg in 1998, $1.43/kg in 1999, and $1.26/kg in 2000 (Oklahoma Agricultural Statistics Service 2000), along with current herbicide prices from an Oklahoma chemical supplier[5] were used to calculate the variable costs of weed control and adjusted net returns for economic comparisons of treatments. Cost was calculated as $8.10/ha per application based on estimates published in Oklahoma (Kletke 1996). Adjusted net return was calculated as total return (average price times yield) minus variable cost minus total return for the untreated check. Variable costs included the cost of herbicides, adjuvants, applications, and a seed technology fee of $13.30/ha that was assessed only when glyphosate was applied. A return ratio was calculated for each treatment by dividing its net return by its variable cost. The return ratio represents the increased return for each dollar spent on weed control.

As a result of treatment duplication, unequal numbers of observations per mean resulted; therefore, data were subjected to analyses of variance using Proc Mixed, and least squares means were calculated (SAS 1999). Treatment means were separated by Fisher's protected LSD at $P = 0.05$. Treatment by year interactions were significant; hence, data from each year are presented separately.

RESULTS AND DISCUSSION

Cotton injury was not observed in 1998, 1999, or 2000 10 WAP with any of the herbicides (data not shown).

Weed Control. All herbicide combinations controlled johnsongrass at least 84%, regardless of year; however, most treatments controlled johnsongrass ≥ 90% 10 WAP (Table 2). Glyphosate alone POST-1 controlled johnsongrass 99, 99, and 97% in 1998, 1999, and 2000, respectively. Glyphosate alone POST-1 (Treatment 1) or pendimethalin PPI fb glyphosate POST-1 (Treatment 2) controlled johnsongrass equally in all 3 yr of this

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[5]Estes Incorporated. Price list. 1819 NW Fifth, Oklahoma City, OK 73106.

experiment (Table 2). In 1998, glyphosate alone POST-1 (Treatment 1) controlled johnsongrass better than Treatments 3, 4, 5, and 7 statistically; however, all treatments controlled johnsongrass at least 84% which would be considered acceptable at 10 WAP by many producers. In 1999 and 2000, quizalofop treatments were not applied due to the low johnsongrass populations in those plots. Previous research has shown that quizalofop controls johnsongrass when applied alone and that pendimethalin is effective for seedling johnsongrass control (Ferreira and Coble 1994; Johnson and Frans 1991; McWhorter 1977).

Devil's-claw control 10 WAP was less in 1998 than in 1999 and 2000 with glyphosate alone POST-1 (Treatment 1) or following pendimethalin PPI (Treatment 2) (≤ 38% in 1998 compared to at least 87% in 1999 and 2000) (Table 2). Lower johnsongrass densities in 1999 and 2000 may have contributed to better devil's-claw control. In 1999 and 2000, all treatments that contained glyphosate or pyrithiobac POST controlled devil's-claw at least 87% (Table 2). Treatment 3 did not contain glyphosate or pyrithiobac and did not control devil's-claw > 28% in 1999 or 2000. Poor devil's-claw control was also observed in Texas with trifluralin or pendimethalin PPI followed by prometryn (Dotray et al. 1999; Keeling et al. 1999). The addition of pyrithiobac POST-1 in Treatment 4 improved control over Treatment 3 from 28 to 99% in 1999 and from 25 to 98% in 2000. This agrees with other research demonstrating that pyrithiobac controls devil's-claw effectively (Dotray et al. 1996; Prostko and Chandler 1998).

Common cocklebur and silverleaf nightshade control at 10 WAP was ≥ 95% with glyphosate POST-1 in all years (Tables 2 and 3). Other researchers have reported that glyphosate controls common cocklebur and silverleaf nightshade (Flint et al. 1999; Westerman and Murray 1994). Common cocklebur control with Treatment 1 was not improved with the addition of PPI or PRE herbicides, regardless of year (Table 2). The addition of pyrithiobac POST-1 in Treatment 4 improved common cocklebur control over Treatment 3 from 26 to 94% in 1999 and from 46 to 78% in 2000. Drier conditions at the time of PRE application in 1999 and 2000, resulted in the lack of PRE herbicide activation. This lack of herbicide activation could explain the poor common cocklebur control since the benefits of the PRE herbicides were not realized. The large number of common cocklebur not controlled by PRE herbicides in 1999 and 2000 made a POST application imperative.

There were no differences in silverleaf nightshade control with any treatments in 1998 (Table 3). POST application of pyrithiobac following pendimethalin PPI and prometryn PRE (Treatment 4) did not improve silverleaf nightshade control over pendimethalin PPI followed by prometryn PRE alone (Treatment 3) in 1999 or 2000. This could be expected since pyrithiobac does not control perennials such as silverleaf nightshade. All treatments that contained glyphosate POST-1 controlled silverleaf nightshade at least 96% in 1999 and 2000 (Table 3).

Palmer amaranth population was not uniform in 1998, thus, control was not evaluated. In 1999, all herbicides combinations controlled Palmer amaranth at least 96% 10 WAP (Table 3). Glyphosate alone controlled Palmer amaranth only 85% in 2000. Application of pendimethalin PPI or PRE application of prometryn, pyrithiobac, or a tank-mixture of prometryn plus pyrithiobac increased control to at least 99%; however, each of these treatments are individually labeled for Palmer amaranth control.

Lint Yield. Cotton treated with pendimethalin PPI followed by pyrithiobac PRE fb glyphosate POST-1 and quizalofop POST-2 (Treatment 8) yielded 480 kg/ha in 1998, which was not different than Treatment 2 (Table 4). However, cotton yields were different in 1998 when comparing the conventional treatments (Treatments 3, 4, 5, 6, and 7) to Treatment

8. Pendimethalin fb glyphosate increased cotton lint yield numerically at least 30 kg/ha over glyphosate applied alone in 1998. This increase in cotton yield can be attributed to early-season control of seedling johnsongrass in plots treated with pendimethalin PPI. Culpepper and York (1998) also reported lower cotton yield with glyphosate applied once in the absence of a soil-applied herbicide than when glyphosate followed a soil-applied herbicide.

In 1999 and 2000, cotton treated with glyphosate alone yielded 700 and 250 kg/ha, respectively, which was equal to or greater than all other treatments (Table 4). The addition of a soil-applied herbicide followed by glyphosate did not improve control of any of the predominant weed species in this experiment and subsequently did not result in higher cotton yield in 1999 or 2000. The small rainfall amounts received in 1999 and 2000 throughout July and August contributed to dry conditions that inhibited the germination and emergence of weed populations both mid and late-season. Since the lack of soil moisture inhibited weed germination and emergence, the residual benefits of soil-applied herbicides were not realized in 1999 or 2000; therefore, one glyphosate application controlled weeds and yielded equal to or better than treatments containing soil-applied herbicides. Cotton yield was lower in 2000 than in 1998 or 1999 for all treatments. The absence of a measurable rainfall from July 22 to September 24 was the key limiting factor for cotton yield in 2000.

Adjusted Net Return and Return Ratio. There was no statistical difference in adjusted net return from Treatments 1, 2, 4, or 8, in 1998 (Table 5). In all 3 yr, treatment with glyphosate POST-1 alone or following pendimethalin PPI resulted in adjusted net returns greater than or equal to all other treatments while having the lowest treatment cost (Table 5). In 1998, glyphosate POST-1 had an adjusted net return of \$353/ha with a treatment cost of \$40/ha this was not different than the adjusted net return and herbicide cost from Treatment 2 which was $360/ha and $74/ha. However, glyphosate applied alone increased adjusted net return $147/ha in 1999 and $95/ha in 2000 over Treatment 2 (Table 5). The predominance of seedling johnsongrass in 1998 (4 to 5/m^2) increased the importance of pendimethalin PPI compared to lower seedling johnsongrass populations in 1999 and 2000 (1 to 3 and 1 to 2/m^2).

Glyphosate alone POST-1 had the highest return ratio, regardless of year (Table 6). The return ratio (increased return for each dollar spent on weed control) for glyphosate alone was 8.83 in 1998, 14.64 in 1999, and 6.37 in 2000. This ratio was at least 3.12 higher than any other treatment, thus indicating that for every dollar spent on weed control glyphosate alone provided at least a 312% increase in return over all other treatments. Pendimethalin PPI followed by glyphosate POST-1 and glyphosate alone POST-1 had a higher return ratio than any non-glyphosate treatment.

These data agree with previous glyphosate-tolerant cotton research demonstrating that soil-applied herbicides were not always necessary for weed control (Bloodworth et al. 1997). However, in situations with high weed populations or when conditions favor longer emergence periods soil-applied herbicides are beneficial in delaying emergence and reducing the competitive ability of weeds (Adcock and Banks 1991; Holloway and Shaw 1995). This delayed emergence or reduction of competitive ability allows producers greater flexibility in applying POST over-the-top herbicides. However, this flexibility is limited due to application restrictions in a glyphosate-tolerant system. In this research, the presence of difficult-to-control weeds coupled with dry conditions late-season made the application of glyphosate alone POST-1 the most cost-effective treatment.

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Table 1. Weed densities, heights, and growth stages at postemergence application in the untreated check.

Year, time, and species[a]	Weed density	Weed height	Weed stage
	no./m^2	cm	leaf no.
1998			
POST-1			
SORHA	4-5	15-25	3-5
SOLEL	1-2	7-9	6-8
PROLO	2-4	12-17	5-9
XANST	1-2	12-17	5-7
AMAPA	1	11	4-6
POST-2			
SORHA	4-5	30-40	7-9
SOLEL	1-2	20-25	8-10
PROLO	2-4	19-30	8-12
XANST	1-2	25-30	10-16
AMAPA	1	30	8-12
1999			
POST-1			
SORHA	1-3	15-20	3-6
SOLEL	1-2	7-10	4-5
PROLO	3-4	10-19	4-8
XANST	1-2	15-19	4-8
AMAPA	5-6	3-10	4-6
2000			
POST-1			
SORHA	1-2	10-25	3-5
SOLEL	2-3	10-15	7-10
PROLO	1-2	5-15	3-6
XANST	1-2	10-17	4-8
AMAPA	5-10	20-25	6-10

[a]Abbreviations: POST-1, first postemergence timing; POST-2, second postemergence timing; AMAPA, Palmer amaranth; PROLO, devil's-claw; SOLEL, silverleaf nightshade; SORHA, johnsongrass; XANST, common cocklebur; WAP, weeks after planting. In 1999 and 2000 only one POST application was made.

Table 2. Control of johnsongrass, devil's-claw, and common cocklebur 10 wk after planting with herbicide programs in glyphosate-tolerant cotton.

Trt. No.	Trt.[a,b]	Obs.	Rate	Timing	SORHA[a] 1998	PROLO 1998	XANST 1998
			kg ai/ha		%		
1	Gly	(16)	1.1	POST-1	99a[c]	25bc	97a
2	Pend fb		1.4	PPI			
	gly	(16)	1.1	POST-1	99a	38b	93a
3	Pend fb		1.4	PPI			
	pro fb		2.2	PRE			
	quiz	(4)	0.09	POST-2	88b	0c	55c
4	Pend fb		1.4	PPI			
	pro fb		2.2	PRE			
	quiz	(4)	0.09	POST-1	94b	0c	60c
5	Pend fb		1.4	PPI			
	pro +		2.2				
	pyri fb		0.05	PRE			
	quiz	(4)	0.09	POST-1	91b	0c	83ab
6	Pend fb		1.4	PPI			
	pro +		2.2				
	pyri fb		0.05	PRE			
	quiz fb		0.05	POST-1			
	quiz	(4)	0.05	POST-2	95a	69a	75bc

Trt. No.	Trt.	Obs.	Rate	Timing	SORHA '99	SORHA '00	PROLO '99	PROLO '00	XANST '99	XANST '00
			kg ai/ha		%					
1	Same as 1998				99a	97a	87b	100a	99a	98a
2	Same as 1998				99a	100a	94a	98a	98a	96a
3	Pend fb		1.4	PPI						
	pro	(4)	2.2	PRE	84c	85c	28c	25b	26b	46c
4	Pend fb		1.4	PPI						
	pro fb		2.2	PRE						
	pyri	(8)	0.07	POST-1	95b	97ab	99a	98a	94a	78b
5	Pend fb		1.4	PPI						
	pro +		2.2							
	pyri fb		0.05	PRE						
	pyri	(8)	0.07	POST-1	99a	100a	96a	97a	92a	94a
6	Same as Trt. No. 5 in 1999 and 2000.									

Table 2. Continued.

Trt. No.	Trt.[a,b]	Obs.	Rate	Timing	SORHA[a] 1998	PROLO 1998	XANST 1998
			kg ai/ha		%		
7	Pend fb		1.4	PPI			
	pro fb		2.2	PRE			
	quiz fb		0.05	POST-1			
	quiz	(4)	0.05	POST-2	84c[c]	0c	30d
8	Pend fb		1.4	PPI			
	pyri fb		0.05	PRE			
	gly fb		1.1	POST-1			
	quiz	(8)	0.09	POST-2	99a	96a	93ab
9	Untrt Chk	(4)			0d	0c	0d

Trt. No.	Trt.	Obs.	Rate	Timing	SORHA '99	SORHA '00	PROLO '99	PROLO '00	XANST '99	XANST '00
			kg ai/ha		%					
7	Same as Trt. No. 4 in 1999 and 2000.									
8	Pend fb		1.4	PPI						
	pyri fb		0.05	PRE						
	gly	(8)	1.1	POST-1	100a	100a	98a	100a	98a	98a
9	Untrt Chk	(4)			0d	0d	0d	0c	0c	0d

[a]Abbreviations: Gly, glyphosate; pend, pendimethalin; pro, prometryn; pyri, pyrithiobac; quiz, quizalofop; fb, followed by; Obs., observations per mean; PPI, preplant incorporated; PRE, preemergence; POST-1, first postemergence timing; POST-2, second postemergence timing; Trt No., treatment number; Trt., treatment; Untrt Chk, untreated check; SORHA, johnsongrass; PROLO, devil's-claw; XANST, common cocklebur.

[b]Crop oil concentrate at 1% v/v was included with quizalofop POST, while nonionic surfactant at 0.25% v/v was included with pyrithiobac POST.

[c]Means within the same column followed by the same letter were not significantly different as determined by Fisher's protected LSD test at P = 0.05. LSD's vary from treatment pair to treatment pair because of the different number of observations per mean.

Table 3. Control of silverleaf nightshade and Palmer amaranth 10 wk after planting with herbicide programs in glyphosate-tolerant cotton.

Trt. No.	Trt.[a,c]	Obs.	Rate	Timing	SOLEL[a] 1998	Trt. No.	Trt.	Obs.	Rate	Timing	SOLEL '99	SOLEL '00	AMAPA[b] '99	AMAPA[b] '00
			kg ai/ha		%				kg ai/ha		%			
1	Gly	(16)	1.1	POST-1	95a[d]	1	Same as 1998				99a	99a	96b	85b
2	Pend fb		1.4	PPI		2	Same as 1998							
	gly	(16)	1.1	POST-1	79a						96ab	98a	100a	99a
3	Pend fb		1.4	PPI		3	Pend fb		1.4	PPI				
	pro fb		2.2	PRE			pro	(4)	2.2	PRE	79ab	71c	99a	99a
	quiz	(4)	0.09	POST-2	74a									
4	Pend fb		1.4	PPI		4	Pend fb		1.4	PPI				
	pro fb		2.2	PRE			pro fb		2.2	PRE				
	quiz	(4)	0.09	POST-1	99a		pyri	(8)	0.07	POST-1	100a	81bc	100a	100a
5	Pend fb		1.4	PPI		5	Pend fb		1.4	PPI				
	pro +		2.2				pro +		2.2					
	pyri fb		0.05	PRE			pyri fb		0.05	PRE				
	quiz	(4)	0.09	POST-1	65a		pyri	(8)	0.07	POST-1	88b	85a-c	100a	100a
6	Pend fb		1.4	PPI		6	Same as Trt. No. 5 in 1999 and 2000.							
	pro +		2.2											
	pyri fb		0.05	PRE										
	quiz fb		0.05	POST-1										
	quiz	(4)	0.05	POST-2	96a									

Table 3. Continued.

Trt. No.	Trt.[a,c]	Obs.	Rate	Timing	SOLEL[a] 1998	Trt. No.	Trt.	Obs.	Rate	Timing	SOLEL '99	SOLEL '00	AMAPA[b] '99	AMAPA[b] '00
			kg ai/ha		—%—				kg ai/ha		%			
7	Pend fb		1.4	PPI		7	Same as Trt. No. 4 in 1999 and 2000.							
	pro fb		2.2	PRE										
	quiz fb		0.05	POST-1										
	quiz	(4)	0.05	POST-2	84a[d]									
8	Pend fb		1.4	PPI		8	Pend fb		1.4	PPI				
	pyri fb		0.05	PRE			pyri fb		0.05	PRE				
	gly fb		1.1	POST-1			gly	(8)	1.1	POST-1	100a	99ab	100a	100a
	quiz	(8)	0.09	POST-2	91a									
9	Untrt Chk	(4)			0b	9	Untrt Chk	(4)			0c	0d	0c	0c

[a]Abbreviations: Gly, glyphosate; pend, pendimethalin; pro, prometryn; pyri, pyrithiobac; quiz, quizalofop; fb, followed by; Obs., observations per mean; PPI, preplant incorporated; PRE, preemergence; POST-1, first postemergence timing; POST-2, second postemergence timing; Trt No., treatment number; Trt., treatment; Untrt Chk, untreated check; SOLEL, silverleaf nightshade; AMAPA, Palmer amaranth.

[b]Palmer amaranth was not evaluated in 1998 because the population was not uniform.

[c]Crop oil concentrate at 1% v/v was included with quizalofop POST, while nonionic surfactant at 0.25% v/v was included with pyrithiobac POST.

[d]Means within the same column followed by the same letter were not significantly different as determined by Fisher's protected LSD test at P = 0.05. LSD's vary from treatment pair to treatment pair because of the different number of observations per mean.

Table 4. Cotton lint yield resulting from treatment with various herbicides in a glyphosate-tolerant system.

Trt. No.	Trt.[a,b]	Obs.	Rate	Timing	Cotton lint yield 1998	Trt. No.	Trt.	Obs.	Rate	Timing	Cotton lint yield 1999	2000
			kg ai/ha		—kg/ha—				kg ai/ha		—kg/ha—	
1	Gly	(16)	1.1	POST-1	390b[c]	1	Same as 1998				700a	250a
2	Pend fb		1.4	PPI		2	Same as 1998					
	gly	(16)	1.1	POST-1	420a-c						630b	200a
3	Pend fb		1.4	PPI		3	Pend fb		1.4	PPI		
	pro fb		2.2	PRE			pro	(4)	2.2	PRE	260c	90c
	quiz	(4)	0.09	POST-2	280cd							
4	Pend fb		1.4	PPI		4	Pend fb		1.4	PPI		
	pro fb		2.2	PRE			pro fb		2.2	PRE		
	quiz	(4)	0.09	POST-1	380bc		pyri	(8)	0.07	POST-1	580b	260a
5	Pend fb		1.4	PPI		5	Pend fb		1.4	PPI		
	pro +		2.2				pro +		2.2			
	pyri fb		0.05	PRE			pyri fb		0.05	PRE		
	quiz	(4)	0.09	POST-1	320bc		pyri 8		0.07	POST-1	590b	230a
6	Pend fb		1.4	PPI		6	Same as Trt. No. 5 in 1999 and 2000.					
	pro +		2.2									
	pyri fb		0.05	PRE								
	quiz fb		0.05	POST-1								
	quiz	(4)	0.05	POST-2	370b-d							

Table 4. Continued.

Trt. No.	Trt.[a,b]	Obs.	Rate	Timing	Cotton lint yield 1998
			kg ai/ha		—kg/ha—
7	Pend fb		1.4	PPI	
	pro fb		2.2	PRE	
	quiz fb		0.05	POST-1	
	quiz	(4)	0.05	POST-2	290d[c]
8	Pend fb		1.4	PPI	
	pyri fb		0.05	PRE	
	gly fb		1.1	POST-1	
	quiz	(8)	0.09	POST-2	480a
9	Untrt Chk	(4)			0d

Trt. No.	Trt.	Obs.	Rate	Timing	Cotton lint yield 1999	2000
			kg ai/ha		—kg/ha—	
7	Same as Trt. No. 4 in 1999 and 2000.					
8	Pend fb		1.4	PPI		
	pyri fb		0.05	PRE		
	gly	(8)	1.1	POST-1	610b	250a
9	Untrt Chk	(4)			160c	0c

[a]Abbreviations: Gly, glyphosate; pend, pendimethalin; pro, prometryn; pyri, pyrithiobac; quiz, quizalofop; fb, followed by; Obs., observations per mean; PPI, preplant incorporated; PRE, preemergence; POST-1, first postemergence timing; POST-2, second postemergence timing; Trt No., treatment number; Trt., treatment; Untrt Chk, untreated check.

[b]Crop oil concentrate at 1% v/v was included with quizalofop POST, while nonionic surfactant at 0.25% v/v was included with pyrithiobac POST.

[c]Means within the same column followed by the same letter were not significantly different as determined by Fisher's protected LSD test at P = 0.05. LSD's vary from treatment pair to treatment pair because of the different number of observations per mean.

Table 5. Adjusted net return and herbicide cost from selected herbicides in a glyphosate-tolerant cotton system in 1998, 1999, and 2000.

Trt. No.	Trt.[b,c]	Obs.	Rate	Timing	Adjusted net return (Cost)[a] 1998	Trt. No.	Trt.	Obs.	Rate	Timing	Adjusted net return (Cost) 1999	Adjusted net return (Cost) 2000
			kg ai/ha		——$/ha——				kg ai/ha		——$/ha——	
1	Gly	(16)	1.1	POST-1	353a[d] (40)	1	Same as 1998				732a (50)	274a (43)
2	Pend fb		1.4	PPI		2	Same as 1998					
	gly	(16)	1.1	POST-1	360a (74)						585b (87)	179b (72)
3	Pend fb		1.4	PPI		3	Pend fb		1.4	PPI		
	pro fb		2.2	PRE			pro	(4)	2.2	PRE	58c (89)	37c (76)
	quiz	(4)	0.09	POST-2	113bc (128)							
4	Pend fb		1.4	PPI		4	Pend fb		1.4	PPI		
	pro fb		2.2	PRE			pro fb		2.2	PRE		
	quiz	(4)	0.09	POST-1	256ab (128)		pyri	(8)	0.07	POST-1	430cd (178)	176b (146)
5	Pend fb		1.4	PPI		5	Pend fb		1.4	PPI		
	pro +		2.2				pro +		2.2			
	pyri fb		0.05	PRE			pyri fb		0.05	PRE		
	quiz	(4)	0.09	POST-1	118bc (188)		pyri	(8)	0.07	POST-1	377c (238)	101bc (192)
6	Pend fb		1.4	PPI		6	Same as Trt. No. 5 in 1999 and 2000.					
	pro +		2.2									
	pyri fb		0.05	PRE								
	quiz fb		0.05	POST-1								
	quiz	(4)	0.05	POST-2	183b (195)							

Table 5. Continued.

Trt. No.	Trt.[b,c]	Obs.	Rate	Timing	Adjusted net return (Cost)[a] 1998	Trt. No.	Trt.	Obs.	Rate	Timing	Adjusted net return (Cost) 1999	2000
			kg ai/ha		———$/ha———				kg ai/ha		———$/ha———	
7	Pend fb		1.4	PPI		7	Same as Trt. No. 4 in 1999 and 2000.					
	pro fb		2.2	PRE								
	quiz fb		0.05	POST-1								
	quiz	(4)	0.05	POST-2	129bc[d] (136)							
8	Pend fb		1.4	PPI		8	Pend fb		1.4	PPI		
	pyri fb		0.05	PRE			pyri fb		0.05	PRE		
	gly fb		1.1	POST-1			gly	(8)	1.1	POST-1	343a (183)	500cd (154)
	quiz	(8)	0.09	POST-2	343a (183)							
9	Untrt Chk	(4)			0c (0)	9	Untrt Chk	(4)			0e (0)	0c (0)

[a]Adjusted net return is the difference between total return (price times yield) minus variable cost, minus total return for the untreated check. Values in parentheses represent herbicide, adjuvant, application, and seed technology fee (if applicable) for each program.

[b]Abbreviations: Gly, glyphosate; pend, pendimethalin; pro, prometryn; pyri, pyrithiobac; quiz, quizalofop; fb, followed by; Obs., observations per mean; PPI, preplant incorporated; PRE, preemergence; POST-1, first postemergence timing; POST-2, second postemergence timing; Trt No., treatment number; Trt., treatment; Untrt Chk, untreated check.

[c]Crop oil concentrate at 1% v/v was included with quizalofop POST, while nonionic surfactant at 0.25% v/v was included with pyrithiobac POST.

[d]Means within the same column followed by the same letter were not significantly different as determined by Fisher's protected LSD test at P = 0.05. LSD's vary from treatment pair to treatment pair because of the different number of observations per mean.

Table 6. Return ratio from selected herbicides in a glyphosate-tolerant cotton system in 1998, 1999, and 2000.

Trt. No.	Trt.[b,c]	Obs.	Rate	Timing	Return ratio[a] 1998	Trt. No.	Trt.	Obs.	Rate	Timing	Return ratio 1999	2000
			kg ai/ha						kg ai/ha			
1	Gly	(16)	1.1	POST-1	8.83a[d]	1	Same as 1998				14.64a	6.37a
2	Pend fb		1.4	PPI		2	Same as 1998					
	gly	(16)	1.1	POST-1	4.86b						6.72b	2.49b
3	Pend fb		1.4	PPI		3	Pend fb		1.4	PPI		
	pro fb		2.2	PRE			pro	(4)	2.2	PRE	0.65d-f	0.49c
	quiz	(4)	0.09	POST-2	0.88c							
4	Pend fb		1.4	PPI		4	Pend fb		1.4	PPI		
	pro fb		2.2	PRE			pro fb		2.2	PRE		
	quiz	(4)	0.09	POST-1	2.00c		pyri	(8)	0.07	POST-1	2.42d	1.21c
5	Pend fb		1.4	PPI		5	Pend fb		1.4	PPI		
	pro +		2.2				pro +		2.2			
	pyri fb		0.05	PRE			pyri fb		0.05	PRE		
	quiz	(4)	0.09	POST-1	0.63c		pyri	(8)	0.07	POST-1	1.58d	0.53c
6	Pend fb		1.4	PPI		6	Same as Trt. No. 5 in 1999 and 2000.					
	pro +		2.2									
	pyri fb		0.05	PRE								
	quiz fb		0.05	POST-1								
	quiz	(4)	0.05	POST-2	0.94c							

Table 6. Continued.

Trt. No.	Trt.[b,c]	Obs.	Rate	Timing	Return ratio[a] 1998	Trt. No.	Trt.	Obs.	Rate	Timing	Return ratio 1999	Return ratio 2000
			kg ai/ha						kg ai/ha			
7	Pend fb		1.4	PPI		7	Same as Trt. No. 4 in 1999 and 2000.					
	pro fb		2.2	PRE								
	quiz fb		0.05	POST-1								
	quiz	(4)	0.05	POST-2	0.95c[d]							
8	Pend fb		1.4	PPI		8	Pend fb		1.4	PPI		
	pyri fb		0.05	PRE			pyri fb		0.05	PRE		
	gly fb		1.1	POST-1			gly	(8)	1.1	POST-1	1.87c	3.25bc
	quiz	(8)	0.09	POST-2	1.87c							
9	Untrt Chk	(4)			0c	9	Untrt Chk	(4)			0f	0c

[a]Return ratio equals the increased return per dollar of weed control cost.

[b]Abbreviations: Gly, glyphosate; pend, pendimethalin; pro, prometryn; pyri, pyrithiobac; quiz, quizalofop; fb, followed by; Obs., observations per mean; PPI, preplant incorporated; PRE, preemergence; POST-1, first postemergence timing; POST-2, second postemergence timing; Trt No., treatment number; Trt., treatment; Untrt Chk, untreated check.

[c]Crop oil concentrate at 1% v/v was included with quizalofop POST, while nonionic surfactant at 0.25% v/v was included with pyrithiobac POST.

[d]Means within the same column followed by the same letter were not significantly different as determined by Fisher's protected LSD test at P = 0.05. LSD's vary from treatment pair to treatment pair because of the different number of observations per mean.

Chapter II

Weed Population Dynamics in a Three-Year Glyphosate-Tolerant Cotton (*Gossypium hirsutum*) System

Weed Population Dynamics in a Three-Year Glyphosate-Tolerant Cotton (*Gossypium hirsutum*) System

Abstract: Field experiments were conducted for 3 yr to measure weed population shifts when using glyphosate and a glyphosate-tolerant cotton cultivar compared with conventional herbicides commonly used in Oklahoma and an untreated check. Weed population shifts were observed in both treated and untreated plots. In the untreated check, weed populations shifted from predominantly seedling johnsongrass in 1998 to Palmer amaranth in 2000. Treatment with glyphosate alone at the first postemergence application timing (POST-1) resulted in decreased populations of devil's-claw, silverleaf nightshade, and common cocklebur; however, Palmer amaranth, johnsongrass, pitted morningglory, and yellow nutsedge populations increased slightly over the 3-yr period. The conventional herbicide treatment of pendimethalin preplant incorporated (PPI) followed by (fb) prometryn plus pyrithiobac preemergence (PRE) fb either quizalofop POST-1 and POST-2 in 1998 or pyrithiobac POST-1 in 1999 and 2000 decreased all predominant species in this experiment except silverleaf nightshade over 3 yr. A small increase was observed in pitted morningglory and yellow nutsedge populations in plots treated with glyphosate. This indicates that selection for weed populations not controlled or only controlled marginally (≤50%) can result in pronounced species shifts in as few as 3 yr of repeated application.

Nomenclature: Glyphosate; pendimethalin; prometryn; pyrithiobac; quizalofop; common cocklebur, *Xanthium strumarium* L. #[1] XANST; common

[1]Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

lambsquarters, *Chenopodium album* L. # CHEAL; devil's-claw, *Proboscidea louisianica* (Mill.) Thellung # PROLO; johnsongrass, *Sorghum halepense* (L.) Pers. # SORHA; Palmer amaranth, *Amaranthus palmeri* S. Wats. # AMAPA; pitted morningglory, *Ipomoea lacunosa* L. # IPOLA; silverleaf nightshade, *Solanum elaeagnifolium* Cav. # SOLEL; yellow nutsedge, *Cyperus esculentus* L. # CYPES; cotton, *Gossypium hirsutum* L. 'Paymaster 1220 BG/RR'.

Additional index words: Weed population shifts.

Abbreviations: fb, followed by; gly, glyphosate; pend, pendimethalin; POST-1, first postemergence application timing; POST-2, second postemergence application timing; PPI, preplant incorporated; PRE, preemergence; pro, prometryn; pyri, pyrithiobac; quiz, quizalofop; WAP, weeks after planting.

INTRODUCTION

Glyphosate is a non-selective herbicide that controls many annual and perennial grasses, broadleaf weeds, and sedges commonly found in agronomic crop production. In susceptible plants, glyphosate inhibits 5-enolpyruvylshikimate-3-phosphate synthase and subsequently limits the synthesis and regulation of aromatic amino acids. Cotton's normal intolerance to glyphosate was overcome by selection, insertion, and expression of a gene encoding a glyphosate-tolerant 5-enolpyruvylshikimate-3-phosphate synthase (Kishore et al. 1992; Thompson et al. 1987). Glyphosate can be applied postemergence (POST) over-the-top of glyphosate-tolerant cotton from emergence until the four-leaf growth stage, then it must be directed at the base of the plant to avoid potential fruit abortion (Kalaher et al. 1997). Glyphosate's lack of residual activity often results in the need for multiple applications or application of a residual soil-applied herbicide for season-long weed control.

Increased herbicide use over the last 40 yr along with continuous monoculture has contributed to increased selection pressure for certain weed populations (Holt and LeBaron 1990). Weed population shifts frequently occur in situations where a weed control technique is continually used, thus resulting in high selection pressure on specific weed populations (Buhler et al. 1994; Gressel and Segel 1990; Vencill and Banks 1994). Weed population shifts may include the shift from one species to another or to another biotype of the same species which occurs with herbicide resistance (Maxwell and Mortimer 1994). Practices like crop rotation and application of tank-mixtures with multiple modes-of-action have been encouraged to decrease selection pressure on weed populations particularly for lowering selection of resistant biotypes (Wrubel and Gressel 1994; Manley et al. 2001).

Researchers have documented weed species shifts in systems where herbicides were continually applied over multiple years. Dowler and Hauser (1974) reported that repeated applications of fluometuron over 3 yr decreased the broadleaf weed population and shifted the population to yellow nutsedge and annual grass species like large crabgrass [*Digitaria sanguinalis* (L.) Scop.] and crowfootgrass [*Dactyloctenium aegyptium* (L.) Willd.]. In a similar experiment, populations of large crabgrass and crowfootgrass were decreased, while the yellow nutsedge population increased with continual application of trifluralin over 3 yr (Weber et al. 1974).

Continuous monoculture combined with multiple herbicide applications within a single growing season could result in weed population shifts in a conventional or glyphosate-tolerant cotton system. Knowledge concerning weed population shifts is important to both researchers and producers since weed shifts may increase the numbers of difficult-to-control weeds in a population and require implementation of new weed control practices. The objective of this research is to measure weed population shifts over a 3-yr period in a glyphosate-tolerant cotton system that includes glyphosate and conventional herbicide systems used in Oklahoma.

MATERIALS AND METHODS

Field experiments were conducted in 1998, 1999, and 2000 at the South Central Research Station near Chickasha, OK. The soil type at this location was a Reinach silt loam (a coarse-silty, mixed, superactive, thermic Pachic Haplustoll) with a pH of 6.5 and a 0.5% organic matter content. A weed population was already present at the study location; and it included predominantly johnsongrass, devil's-claw, silverleaf nightshade, and common cocklebur; however, a smaller population of Palmer amaranth, pitted morningglory, yellow nutsedge, and common lambsquarters was also present in the initial yr of the experiment.

In all 3 yr before disking and bedding the study area, 112 kg/ha of 46-0-0 was applied based on soil test determinations and yield goal recommendations for Oklahoma. PPI herbicides were applied to preformed beds and incorporated with a rolling cultivator on April 16, May 6, and April 25 in the three respective years. At the time of herbicide incorporation, beds were reformed. 'Paymaster 1220 BG/RR/' cotton was planted at a rate of 14 seed/m of row with a 1.0-m row spacing each year. Planting and PRE application dates were May 19, May 20, and May 22 in 1998, 1999, and 2000, respectively. Plots were 12 rows wide and 30 m long.

The experimental design was a randomized complete block with 16 herbicide treatments replicated four times. Treatments were applied to the same plots all 3 yr of these experiments. All applications were made with a tractor-mounted, compressed-air sprayer calibrated to deliver 140 L/ha at 260 kPa. Herbicides (and their rates) included: pendimethalin (1.4 kg ai/ha) or no PPI herbicide; prometryn (2.2 kg ai/ha), pyrithiobac (0.05 kg ai/ha), a tank-mixture of prometryn plus pyrithiobac (2.2 + 0.05 kg/ha), or no PRE herbicide; and glyphosate (1.1 kg ai/ha), pyrithiobac (0.07 kg ai/ha), quizalofop (0.09 kg ai/ha applied once or 0.05 kg ai/ha sequential POST), or no POST over-the-top herbicide. A nonionic surfactant[2] at 0.25% (v/v) was included with pyrithiobac POST, while a crop oil concentrate[3] at 1% (v/v) was included with quizalofop POST.

To simulate applications a producer would likely make in-season, several planned POST applications were not required or the order of application was adjusted based on weeds present at the time of POST application; as a result, these adjustments resulted in fewer than the intended 16 treatments, because some of the 16 were duplications. This duplication resulted in nine different treatments in 1998 and seven which were different in 1999 and 2000. In the last 2 yr, duplication of the treatments pendimethalin PPI fb prometryn PRE fb pyrithiobac POST-1 (Treatments 4 and 7) and pendimethalin PPI fb prometryn plus pyrithiobac PRE fb pyrithiobac POST-1 (Treatments 5 and 6) resulted in seven treatments because pyrithiobac was moved to a POST-1 application (replacing quizalofop) to control broadleaf weeds that were present. In 1998, johnsongrass populations warranted a single glyphosate or quizalofop application POST-1 or sequential quizalofop applications POST-1 and POST-2. In 1999 and 2000, broadleaf weeds were predominant; therefore, glyphosate or pyrithiobac was applied POST-1 instead of quizalofop. Only one POST application was required for season-long weed control in 1999 and 2000 due to late-season drought and the resulting

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[2]Latron AG-98 contains 80% alkylaryl polyoxyethylene glycol. Rohm and Haas Co., Philadelphia, PA 19106.

[3]Agridex, a heavy range paraffin base petroleum oil, polyol fatty acid esters, and polyethoxylated derivatives. Helena Chemical Co., 6075 Poplar Ave., Suite 500, Memphis, TN 38119.

lack of weed germination and emergence.

In all 3 yr, the POST-1 application was made at 4 wk after planting (WAP) when cotton was in the two-to-four leaf growth stage and was 8- to 15-cm tall. The POST-2 application in 1998 was made at 6 WAP when cotton was in the six-to-eight leaf growth stage and was 20- to 30-cm tall. In 1998, all weeds were in the three-to-nine leaf stage and were 7- to 25-cm tall at the POST-1 application. At POST-2, all weeds were in the seven-to-sixteen leaf stage and were 19- to 40-cm tall. In 1999, weeds were in the three-to-eight leaf stage and were 3- to 20-cm tall, whereas, in 2000 they were in the three-to-ten leaf stage and 10- to 25-cm tall at the time of application. All plots were cultivated one time each year 6 WAP.

Weed populations were identified, counted, and measured in all plots at 7 WAP each year. Populations were determined in the center four rows (middles within rows 5, 6, 7, and 8) of each plot. This number was then converted to a number of weeds/plot (360 m^2).

As a result of treatment duplication, unequal numbers of observations per mean resulted; therefore, data were subjected to analyses of variance using Proc Mixed, and least squares means were calculated (SAS 1999). Treatment means were separated by Fisher's protected LSD at $P = 0.05$. A significant treatment by year interaction was present; therefore, data from each year are presented separately.

RESULTS AND DISCUSSION

Johnsongrass. In 1998, there was no difference in johnsongrass counts between the untreated check and plots treated with pendimethalin PPI fb prometryn PRE fb quizalofop POST-2 (Treatment 3) at 7 WAP (3 wk after POST-1 and 1 wk after POST-2 application) (Table 1). For example, there were 7,810 johnsongrass plants in the untreated check and 8,010 johnsongrass plants in plots treated with pendimethalin PPI fb prometryn PRE fb quizalofop POST-2. Since POST-2 treatments had only been applied

1 wk, the lack of treatment differences may be attributed to inadequate time for complete herbicide activity. Plots treated with glyphosate alone POST-1 (Treatment 1) or with pendimethalin fb glyphosate POST-1 (Treatment 2) contained < 10 johnsongrass plants per plot in 1998. Although different numerically, johnsongrass counts in plots treated with Treatments 1 and 2 were not statistically different than plots treated with Treatment 6, which contained 390 johnsongrass plants (Table 1).

No differences in johnsongrass counts were observed between any herbicide treatment in 1999 or 2000. All herbicide treatments had ≤ 15 johnsongrass plants per plot while the untreated check had 216 and 232 johnsongrass plants per plot in 1999 and 2000, respectively (Table 1). Johnsongrass numbers increased slightly in plots treated with a single glyphosate application POST-1 from zero to 10 plants per plot over 3 yr, while johnsongrass numbers decreased in all other plots regardless of treatment. The lack of a soil-applied herbicide labeled for seedling johnsongrass control in plots treated with glyphosate alone POST-1 allowed the johnsongrass populations to slowly increase over 3 yr. In plots treated with Treatment 3, johnsongrass numbers decreased from 8,010 in 1998 to five plants per plot in 2000 (Table 1). A similar population shift occurred in the untreated check where johnsongrass counts decreased from 7,810 to 232 plants per plot from 1998 to 2000.

Devil's-claw. Devil's-claw counts were highest in plots treated with pendimethalin PPI fb prometryn plus pyrithiobac PRE fb quizalofop POST-1 (Treatment 5) in 1998 (Table 1). For example, there were 224 devil's-claw plants in plots treated with Treatment 5, while in the untreated check 36 devil's-claw plants were present. Devil's-claw counts were not different in plots treated with Treatment 1 or 2 in 1998.

In 1999 and 2000, treatments containing pyrithiobac POST-1 (Treatments 4, 5, 6, and 7) regardless of PPI and PRE combination reduced devil's-claw to four or fewer plants per plot (Table 1). Glyphosate alone POST-1 decreased devil's-claw numbers from 111 plants in 1998 to one plant in 2000. Previous research has reported greater than 90% control of devil's-claw with either pyrithiobac or glyphosate applied POST (Dotray et al. 1996; Dotray et al. 1999; Prostko and Chandler 1998). Plots treated with pendimethalin PPI fb prometryn PRE (Treatment 3) had 90 devil's-claw plants per plot which was higher than the untreated check that contained 39 plants per plot in 2000 (Table 1). The low devil's-claw numbers in the untreated check indicates that devil's-claw may not be as competitive as other weeds like Palmer amaranth and common cocklebur which were present in the untreated check in 2000. However, in plots where these species were controlled with soil-applied herbicides such as pendimethalin and prometryn devil's-claw numbers increased due to the lack of competition.

Common Cocklebur. Plots treated with pendimethalin PPI fb prometryn PRE fb quizalofop POST-1 (Treatment 3) contained 250 common cocklebur plants per plot in 1998 which was not different than the untreated check that contained 182 common cocklebur (Table 1). Also, there were no differences in common cocklebur counts between plots treated with Treatment 2 or 5. For example, there were 73 common cocklebur in plots treated with Treatment 2, while plots treated with Treatment 5 contained 75 common cocklebur (Table 1). The lowest common cocklebur counts occurred in plots treated with glyphosate alone POST-1 which contained 42 plants per plot less than any other treatment.

Common cocklebur counts decreased in all plots in 1999 while increasing in 2000. For example, in plots treated with Treatment 3 common cocklebur counts dropped from 250 in 1998 to 180 in 1999; however, in 2000 there were 2,710 common cocklebur plants per plot (Table 1). This increase in the common cocklebur population may be partly attributed to variable environmental conditions in 2000 which favored the germination and emergence of common cocklebur.

Silverleaf Nightshade. In 1998, plots treated with pendimethalin PPI fb prometryn plus pyrithiobac PRE fb quizalofop POST-1 (Treatment 5) had 76 silverleaf nightshade plants per plot which was at least 43 plants per plot more than any other treatment (Table 2). Silverleaf nightshade counts were not statistically different in plots treated with glyphosate alone POST-1 (Treatment 1) or pendimethalin PPI fb pyrithiobac PRE fb glyphosate POST-1 fb quizalofop POST-2 (Treatment 8); however, there was nearly a four-fold numerical difference in silverleaf nightshade counts between these two treatments (Table 2).

Silverleaf nightshade counts decreased in all plots, regardless of treatment, from 1998 to 1999. Treatment 3 lowered silverleaf nightshade counts from 76 plants per plot in 1998 to eight plants per plot in 1999; however, in 2000 there were 33 silverleaf nightshade plants per plot with this treatment. The fluctuations in silverleaf nightshade populations in 1999 may be attributed to environmental conditions rather than the herbicide treatment since silverleaf nightshade is not controlled with pendimethalin, prometryn, or pyrithiobac. Treatment with glyphosate alone POST-1 (Treatment 1) or pendimethalin PPI fb glyphosate POST-1 (Treatment 2) reduced silverleaf nightshade counts over 3 yr. For example, in 1998 there were 33 silverleaf nightshade plants in plots treated with Treatment 1 or Treatment 2, while in 2000 there was one silverleaf nightshade in plots treated with Treatment 1 and six silverleaf nightshade in plots treated with Treatment 2 (Table 2). Previous research has also reported silverleaf nightshade control with POST applications of glyphosate in cotton (Westerman and Murray 1994).

Palmer Amaranth. All plots treated with pendimethalin PPI had one or fewer Palmer amaranth plants per plot, regardless of year (Table 2). In the untreated check the Palmer amaranth population increased from 70 plants per plot in 1998 to 17,940 plants per plot in 2000. Palmer amaranth also increased slightly in plots treated with glyphosate alone POST-1 (Treatment 1). For example, in 1998 there were only two Palmer amaranth per plot; however, by 2000 there were 24 Palmer amaranth plants per plot (Table 2). If not controlled, large increases in Palmer amaranth populations can be expected. Earlier research has reported that Palmer amaranth populations can double in only 1 yr (Keeling et al. 1991).

Yellow Nutsedge. In 1998, plots treated with pendimethalin PPI fb prometryn PRE fb quizalofop POST-1 and POST-2 (Treatment 7) had 20 yellow nutsedge plants per plot (Table 2). This population was higher than the yellow nutsedge population in plots treated with pendimethalin PPI fb glyphosate POST-1 which contained one yellow nutsedge plant per plot. No yellow nutsedge plants were found in the untreated check, regardless of year.

Although yellow nutsedge numbers increased in plots treated with Treatment 3 from 15 to 29 plants per plot from 1998 to 1999, by 2000 yellow nutsedge numbers had dropped to 12 per plot which was similar to the number found in 1998 (Table 2). In plots treated with glyphosate POST-1 (Treatment 1) or with pendimethalin PPI fb glyphosate POST-1 (Treatment 2), yellow nutsedge counts increased slightly over 3 yr. For example, in 1998 there was one yellow nutsedge per plot in plots treated with Treatment 2; however, in 2000 the yellow nutsedge population increased to 15 plants per plot (Table 2). This could be expected since yellow nutsedge is not as competitive as other weeds and normally becomes a problem after other grass or broadleaf weeds are eliminated which allows the yellow nutsedge to flourish.

Pitted Morningglory. All plots except those treated with Treatment 1 or 2 contained four or fewer pitted morningglory plants per plot, regardless of year (Table 3). Plots treated with Treatment 5 had four pitted morningglory plants per plot in 1998; however, in 2000 there was only one pitted morningglory plant per plot. In plots treated with glyphosate alone POST-1, the pitted morningglory population increased from eight to 11 plants per plot, while plots treated with pendimethalin PPI fb glyphosate POST-1 also had a small increase in pitted morningglory from two to eight plants per plot over 3 yr (Table 3).

Common Lambsquarters. Regardless of year, there were no common lambsquarters counted in any plots except the untreated check (Table 3). In 1998, there were zero common lambsquarters plants in the untreated check; however, in 1999 there were 176 common lambsquarters plants per plot. This number then decreased to three plants per plot in 2000 in the untreated check. Common lambsquarters seed favor cool, moist conditions for optimum germination (Minotti and Sweet 1981). In 1999, a cool, moist April and May favored common lambsquarters germination and resulted in the increased population in the untreated checks in 1999.

These data are similar to previous research evaluating the effect of continual herbicide application on weed population shifts where researchers observed an increase in yellow nutsedge populations when other weeds were controlled (Dowler and Hauser 1974; Weber et al. 1974). Variable environmental conditions had a pronounced effect on the populations of common lambsquarters and Palmer amaranth that were predominant in the untreated checks in 1999 and 2000, respectively. In plots treated with glyphosate POST-1 or with pendimethalin PPI fb glyphosate POST-1, there was a small increase in the pitted morningglory and yellow nutsedge population. Although pitted morningglory and yellow nutsedge populations increased in plots treated with Treatment 1 or 2 over 3 yr, resulting populations were insignificant when compared to the populations of predominant species at this location. Thus, the increase in pitted morningglory and yellow nutsedge populations should be viewed only as a possible indicator of future weed problems that could emerge in a continuous glyphosate-tolerant system. Plots treated with conventional herbicides like those in Treatment 6 reduced all predominant weed populations evaluated in this experiment except silverleaf nightshade. Thus, indicating that 3 yr of repeated herbicide application can select for weed populations that are not controlled or only marginally controlled by their activity and result in population shifts.

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Table 1. Johnsongrass, devil's-claw, and common cocklebur counts taken 7 wk after planting following herbicide applications made 4 wk after planting (POST-1) and 6 wk after planting (POST-2) in a 3-yr glyphosate-tolerant cotton system.

Trt. No.	Trt.[a,b]	Obs.	Rate	Timing	SORHA[a]	PROLO	XANST
					1998		
			kg ai/ha		no./plot[c]		
1	Gly	(16)	1.1	POST-1	0b[d]	111b	31c
2	Pend fb		1.4	PPI			
	gly	(16)	1.1	POST-1	8b	109b	73c
3	Pend fb		1.4	PPI			
	pro fb		2.2	PRE			
	quiz	(4)	0.09	POST-2	8,010a	76b	250a
4	Pend fb		1.4	PPI			
	pro fb		2.2	PRE			
	quiz	(4)	0.09	POST-1	0b	86b	94bc
5	Pend fb		1.4	PPI			
	pro +		2.2				
	pyri fb		0.05	PRE			
	quiz	(4)	0.09	POST-1	60b	224a	75bc
6	Pend fb		1.4	PPI			
	pro +		2.2				
	pyri fb		0.05	PRE			
	quiz fb		0.05	POST-1			
	quiz	(4)	0.05	POST-2	390b	35bc	133bc

Trt. No.	Trt.	Obs.	Rate	Timing	SORHA '99	SORHA '00	PROLO '99	PROLO '00	XANST '99	XANST '00
			kg ai/ha		no./plot					
1	Same as 1998				4b	10b	14b	1c	4e	17b
2	Same as 1998									
					1b	0b	11b	3c	9de	21b
3	Pend fb		1.4	PPI						
	pro	(4)	2.2	PRE	15b	5b	39a	90a	180a	2,710a
4	Pend fb		1.4	PPI						
	pro fb		2.2	PRE						
	pyri	(8)	0.07	POST-1	4b	2b	2c	4c	40c	109b
5	Pend fb		1.4	PPI						
	pro +		2.2							
	pyri fb		0.05	PRE						
	pyri	(8)	0.07	POST-1	1b	0b	2c	4c	31cd	90b
6	Same as Trt. No. 5 in 1999 and 2000.									

Table 1. Continued.

Trt. No.	Trt.[a,b]	Obs.	Rate	Timing	SORHA[a] 1998	PROLO 1998	XANST 1998
			kg ai/ha		no./plot[c]		
7	Pend fb		1.4	PPI			
	pro fb		2.2	PRE			
	quiz fb		0.05	POST-1			
	quiz	(4)	0.05	POST-2	450b[d]	63bc	90bc
8	Pend fb		1.4	PPI			
	pyri fb		0.05	PRE			
	gly fb		1.1	POST-1			
	quiz	(8)	0.09	POST-2	0b	24c	98bc
9	Untrt Chk	(4)			7,810a	36bc	182ab

Trt. No.	Trt.	Obs.	Rate	Timing	SORHA '99	SORHA '00	PROLO '99	PROLO '00	XANST '99	XANST '00
			kg ai/ha		no./plot					
7	Same as Trt. No. 4 in 1999 and 2000.									
8	Pend fb		1.4	PPI						
	pyri fb		0.05	PRE						
	gly	(8)	1.1	POST-1	0b	0b	6b	1c	15c-e	16b
9	Untrt Chk	(4)			216a	232a	35a	39b	83b	152b

[a]Abbreviations: Gly, glyphosate; pend, pendimethalin; pro, prometryn; pyri, pyrithiobac; quiz, quizalofop; fb, followed by; Obs., observations per mean; PPI, preplant incorporated; PRE, preemergence; POST-1, first postemergence timing; POST-2, second postemergence timing; Trt No., treatment number; Trt., treatment; Untrt Chk, untreated check; SORHA, johnsongrass; PROLO, devil's-claw; XANST, common cocklebur.

[b]Crop oil concentrate at 1% v/v was included with quizalofop POST, while nonionic surfactant at 0.25% v/v was included with pyrithiobac POST.

[c]Number/plot is the number of weeds/360m^2.

[d]Means within the same column followed by the same letter were not significantly different as determined by Fisher's protected LSD test at P = 0.05. LSD's vary from treatment pair to treatment pair because of the different number of observations per mean.

Table 2. Silverleaf nightshade, Palmer amaranth, and yellow nutsedge counts taken 7 wk after planting following herbicide applications made 4 wk after planting (POST-1) and 6 wk after planting (POST-2) in a 3-yr glyphosate-tolerant cotton system.

Trt. No.	Trt.[a,b]	Obs.	Rate	Timing	SOLEL[a] 1998	AMAPA 1998	CYPES 1998
			kg ai/ha		no./plot[c]		
1	Gly	(16)	1.1	POST-1	33b[d]	2b	4bc
2	Pend fb		1.4	PPI			
	gly	(16)	1.1	POST-1	33b	0b	1c
3	Pend fb		1.4	PPI			
	pro fb		2.2	PRE			
	quiz	(4)	0.09	POST-2	15b	0b	15bc
4	Pend fb		1.4	PPI			
	pro fb		2.2	PRE			
	quiz	(4)	0.09	POST-1	9b	0b	0bc
5	Pend fb		1.4	PPI			
	pro +		2.2				
	pyri fb		0.05	PRE			
	quiz	(4)	0.09	POST-1	76a	0b	11bc
6	Pend fb		1.4	PPI			
	pro +		2.2				
	pyri fb		0.05	PRE			
	quiz fb		0.05	POST-1			
	quiz	(4)	0.05	POST-2	3b	0b	19ab

Trt. No.	Trt.	Obs.	Rate	Timing	SOLEL '99	SOLEL '00	AMAPA '99	AMAPA '00	CYPES '99	CYPES '00
			kg ai/ha		no./plot					
1	Same as 1998				1b	1b	12a	24b	4b	13a
2	Same as 1998									
					3ab	6b	1b	0b	3b	15a
3	Pend fb		1.4	PPI						
	pro	(4)	2.2	PRE	0b	17a	0b	0b	29a	12a
4	Pend fb		1.4	PPI						
	pro fb		2.2	PRE						
	pyri	(8)	0.07	POST-1	1b	17a	0b	0b	5b	0a
5	Pend fb		1.4	PPI						
	pro +		2.2							
	pyri fb		0.05	PRE						
	pyri	(8)	0.07	POST-1	8a	33a	0b	0b	10b	9a
6	Same as Trt. No. 5 in 1999 and 2000.									

Table 2. Continued.

Trt. No.	Trt.[a,b]	Obs.	Rate	Timing	SOLEL[a]	AMAPA	CYPES	Trt. No.	Trt.	Obs.	Rate	Timing	SOLEL '99	SOLEL '00	AMAPA '99	AMAPA '00	CYPES '99	CYPES '00
					1998													
			kg ai/ha		no./plot[c]						kg ai/ha		no./plot					
7	Pend fb		1.4	PPI				7	Same as Trt. No. 4 in 1999 and 2000.									
	pro fb		2.2	PRE														
	quiz fb		0.05	POST-1														
	quiz	(4)	0.05	POST-2	13b[d]	0b	20ab											
8	Pend fb		1.4	PPI				8	Pend fb		1.4	PPI						
	pyri fb		0.05	PRE					pyri fb		0.05	PRE						
	gly fb		1.1	POST-1					gly	(8)	1.1	POST-1	1b	4b	0b	0b	0b	1a
	quiz	(8)	0.09	POST-2	9b	0b	1c											
9	Untrt Chk	(4)			2b	70a	0bc	9	Untrt Chk	(4)			0b	0b	0b	17,940a	0b	0a

[a]Abbreviations: Gly, glyphosate; pend, pendimethalin; pro, prometryn; pyri, pyrithiobac; quiz, quizalofop; fb, followed by; Obs., observations per mean; PPI, preplant incorporated; PRE, preemergence; POST-1, first postemergence timing; POST-2, second postemergence timing; Trt No., treatment number; Trt., treatment; Untrt Chk, untreated check; SOLEL, silverleaf nightshade; AMAPA, Palmer amaranth; CYPES, yellow nutsedge.

[b]Crop oil concentrate at 1% v/v was included with quizalofop POST, while nonionic surfactant at 0.25% v/v was included with pyrithiobac POST.

[c]Number/plot is the number of weeds/360m^2.

[d]Means within the same column followed by the same letter were not significantly different as determined by Fisher's protected LSD test at P = 0.05. LSD's vary from treatment pair to treatment pair because of the different number of observations per mean. *Table 2.*

Table 3. Pitted morningglory and common lambsquarters counts taken 7 wk after planting following herbicide applications made 4 wk after planting (POST-1) and 6 wk after planting (POST-2) in a 3-yr glyphosate-tolerant cotton system.

Trt. No.	Trt.[a,b]	Obs.	Rate	Timing	IPOLA[a]	CHEAL
					1998	
			kg ai/ha		no./plot[c]	
1	Gly	(16)	1.1	POST-1	8a[d]	0a
2	Pend fb		1.4	PPI		
	gly	(16)	1.1	POST-1	2b	0a
3	Pend fb		1.4	PPI		
	pro fb		2.2	PRE		
	quiz	(4)	0.09	POST-2	0b	0a
4	Pend fb		1.4	PPI		
	pro fb		2.2	PRE		
	quiz	(4)	0.09	POST-1	0b	0a
5	Pend fb		1.4	PPI		
	pro +		2.2			
	pyri fb		0.05	PRE		
	quiz	(4)	0.09	POST-1	4ab	0a
6	Pend fb		1.4	PPI		
	pro +		2.2			
	pyri fb		0.05	PRE		
	quiz fb		0.05	POST-1		
	quiz	(4)	0.05	POST-2	1b	0a

Trt. No.	Trt.	Obs.	Rate	Timing	IPOLA '99	IPOLA '00	CHEAL '99	CHEAL '00
			kg ai/ha		no./plot			
1	Same as 1998				9a	11a	0b	0a
2	Same as 1998							
					4bc	8a	0b	0a
3	Pend fb		1.4	PPI				
	pro	(4)	2.2	PRE	2c	0ab	1b	0a
4	Pend fb		1.4	PPI				
	pro fb		2.2	PRE				
	pyri	(8)	0.07	POST-1	2c	1bc	0b	0a
5	Pend fb		1.4	PPI				
	pro +		2.2					
	pyri fb		0.05	PRE				
	pyri	(8)	0.07	POST-1	2c	1bc	0b	0a
6	Same as Trt. No. 5 in 1999 and 2000.							

Table 3. Continued.

Trt. No.	Trt.[a,b]	Obs.	Rate	Timing	IPOLA[a] 1998	CHEAL 1998	Trt. No.	Trt.	Obs.	Rate	Timing	IPOLA '99	IPOLA '00	CHEAL '99	CHEAL '00
			kg ai/ha		no./plot[c]					kg ai/ha		no./plot			
7	Pend fb		1.4	PPI			7	Same as Trt. No. 4 in 1999 and 2000.							
	pro fb		2.2	PRE											
	quiz fb		0.05	POST-1											
	quiz	(4)	0.05	POST-2	0b[d]	0a									
8	Pend fb		1.4	PPI			8	Pend fb		1.4	PPI				
	pyri fb		0.05	PRE				pyri fb		0.05	PRE				
	gly fb		1.1	POST-1				gly	(8)	1.1	POST-1	0c	1a-c	0b	0b
	quiz	(8)	0.09	POST-2	1ab	0a									
9	Untrt Chk	(4)			0b	0a	9	Untrt Chk	(4)			0c	0ab	176a	3a

[a]Abbreviations: Gly, glyphosate; pend, pendimethalin; pro, prometryn; pyri, pyrithiobac; quiz, quizalofop; fb, followed by; Obs., observations per mean; PPI, preplant incorporated; PRE, preemergence; POST-1, first postemergence timing; POST-2, second postemergence timing; Trt No., treatment number; Trt., treatment; Untrt Chk, untreated check; IPOLA, pitted morningglory; CHEAL, common lambsquarters.

[b]Crop oil concentrate at 1% v/v was included with quizalofop POST, while nonionic surfactant at 0.25% v/v was included with pyrithiobac POST.

[c]Number/plot is the number of weeds/360m^2.

[d]Means within the same column followed by the same letter were not significantly different as determined by Fisher's protected LSD test at P = 0.05. LSD's vary from treatment pair to treatment pair because of the different number of observations per mean.

Chapter III

Pitted Morningglory (*Ipomoea lacunosa*) Control Systems in Irrigated Glyphosate-Tolerant Cotton (*Gossypium hirsutum*)

Pitted Morningglory (*Ipomoea lacunosa*) Control Systems in Irrigated Glyphosate-Tolerant Cotton (*Gossypium hirsutum*)

INTERPRETIVE SUMMARY

The introduction of glyphosate (Roundup)-tolerant cotton cultivars has given producers an option for total postemergence weed control with the added benefit of no rotational crop restrictions. Prior to the introduction of glyphosate-tolerant cotton, producers relied heavily on preemergence herbicides for weed control because herbicides like MSMA applied over-the-top of cotton caused injury and subsequently reduced yield. Glyphosate effectively controls many grasses, broadleaf weeds, and certain sedge species found in cotton; however, it can only be applied over-the-top of cotton until the four-leaf stage, while applications made to larger cotton must be post-directed. Low cotton prices coupled with high production costs have made weed control decisions increasingly important. These decisions are often based factors such as crop yield potential, crop rotations, weed species encountered, herbicide cost, and net profits.

Today, approximately one-third of Oklahoma cotton and 40% of the cotton grown in the United States is produced under irrigated conditions. These conditions often favor multiple weed populations that emerge throughout the growing season due to extended periods with high soil moisture. Cotton producers usually strive for season-long weed control not only to increase yields, but to increase harvest efficiency and to avoid poor lint grades. Early-season herbicide application is important when trying to achieve season-long weed control in cotton, since cotton is less competitive than other crops during the first few weeks following emergence.

In a Southern Weed Science Society survey conducted in 1998, morningglories ranked in the top ten most common and most troublesome weeds in cotton for 11 of 12 states from North Carolina to Texas.

Pitted morningglory is a problem weed found in cotton producing areas throughout the United States. Previous research has documented that pitted morningglory is a very competitive weed and that it can reduce cotton yield if not controlled. Currently, there is little information evaluating pitted morningglory control systems or the economics of pitted morningglory control systems in irrigated transgenic cotton systems. Research was conducted in Oklahoma to evaluate the efficacy and economics of pitted morningglory control systems utilizing glyphosate and standard herbicides in glyphosate-tolerant cotton grown under irrigated conditions.

At 10 WAP, fluometuron applied preemergence followed by a single glyphosate application controlled morningglory better than a single application of glyphosate alone in 1 of 2 yr. The addition of soil-applied herbicides did not improve late-season weed control or yield when three glyphosate applications were made. Pitted morningglory control, cotton yield, and adjusted net returns were not different when comparing three glyphosate applications and two pyrithiobac (Staple) applications. Two pyrithiobac applications resulted in less return per dollar spent on weed control than glyphosate applied either two or three times.

When considering weed control costs and adjusted net returns associated with weed control, this research demonstrates that glyphosate-tolerant cotton can be an economical and effective option for pitted morningglory control.

ABSTRACT

Pitted morningglory (*Ipomoea lacunosa* L.) is one of the most troublesome weeds found throughout the southern United States. Cotton (*Gossypium hirsutum* L.) grown under irrigated conditions will often encounter multiple weed populations that emerge throughout the growing season. Glyphosate [*N*-(phosphonomethyl)glycine]-tolerant cotton has potential for total postemergence (POST) weed control; however, glyphosate's lack of residual activity may reduce its effectiveness under irrigated conditions. Since little information is available comparing glyphosate systems to traditional herbicides under irrigated conditions, field experiments were conducted near Altus, OK in 1999 and 2000. These experiments evaluated the effectiveness and economics of pitted morningglory control under irrigated conditions with glyphosate and traditional herbicides in a glyphosate-tolerant cotton system. One postemergence (POST) glyphosate application did not control pitted morningglory > 55% 10 wk after planting (WAP), regardless of year. Fluometuron {*N,N*-dimethyl-*N'*-[3-(trifluoromethyl)phenyl]urea} preemergence (PRE) followed by (fb) one POST glyphosate application improved pitted morningglory control 8 and 13% over a single glyphosate application in 1999 and 2000, respectively. Pitted morningglory control, cotton lint yield, and adjusted net returns for three POST glyphosate applications and two POST pyrithiobac {2-chloro-6-[(4,6-dimethoxy-2-pyrimidinyl)thio]benzoic acid, sodium salt} applications were not different in 1999 or 2000; however, systems with three glyphosate POST applications had a higher return ratio (amount of increased return for each dollar spent on weed control) than pyrithiobac systems with two POST applications. Economical pitted morningglory control can be achieved POST with two or three applications of glyphosate in a glyphosate-tolerant cotton system.

INTRODUCTION

Annual morningglories (*Ipomoea* spp.) are the fourth most common and second most troublesome weeds to Oklahoma cotton production and are found in agricultural areas throughout the southern United States (Dowler 1998). Morningglories infest about 25,000 ha of cotton in Oklahoma and account for an estimated 14% yield reduction (Byrd 2000). Pitted morningglory is one of several species in the genus found in

Oklahoma cotton producing areas. Due to its competitive ability, season-long infestations can reduce cotton yield and affect harvestability. In earlier research, ivyleaf morningglory [Ipomoea hederacea (L.) Jacq.] reduced cotton lint yield 4 to 7% for each weed per 10 m of row, while pitted morningglory densities of 8 and 32 plants per 15 m of row reduced cotton yield 3 and 44%, respectively (Wood et al. 1999; Rogers et al. 1996; Crowley and Buchanan 1978). In California, cotton yield was zero when morningglories were allowed to interfere with cotton during the first 12 wk of growth (Keeley et al. 1986).

Glyphosate-tolerant cotton gives producers an option for total postemergence (POST) weed control. Cotton's normal intolerance to glyphosate was overcome by insertion of a gene coding for expression of a glyphosate-tolerant 5-enolpyruvylshikimate-3-phosphate synthase (Kishore et al. 1992; Thompson et al. 1987). Glyphosate can be safely applied POST over-the-top from the time cotton emerges until the fourth true-leaf stage of development, then it must be directed toward the base of the plant to avoid potential crop injury (Vencill 1998; Jones and Snipes 1999). Although several herbicides are labeled for post-directed application in cotton, producers prefer to apply herbicides over-the-top rather than post-directing due to the slow application speed, the required height difference between the crop and weeds, and the added expense of specialized application equipment.

Herbicide application decisions are often based on factors such as crop yield potential, crop rotations, weed spectrum present, and cost of treatment. Pyrithiobac controls many broadleaf weeds and can be applied over-the-top of cotton throughout the growing season without restriction; however, pyrithiobac does not control grass weeds and would require a separate graminicide application for grass weed control (Ferreira and Coble 1994; Tredaway et al. 1998). Glyphosate controls many annual and perennial grass and broadleaf weeds found in cotton, but only suppresses yellow nutsedge (*Cyperus esculentus* L.) at rates labeled for glyphosate-tolerant cotton (Roundup Ultra label from Monsanto Co., St. Louis, MO). In addition, glyphosate's lack of residual activity often necessitates multiple applications or the application of a residual soil-applied herbicide for season-long weed control of weeds like pitted morningglory and common cocklebur (*Xanthium strumarium* L.) that may germinate and emerge throughout a single growing season (Askew et al. 1998; Flint et al. 1999; Harris and Vencill 1999). In a glyphosate-tolerant cotton system, soil-applied herbicides can lower the number of glyphosate applications needed in a growing season by reducing the growth and competitive ability of weeds (Wilcut et al. 1998; Holloway and Shaw 1995).

Since irrigated conditions often favor germination and emergence of multiple weed populations in a single growing season, herbicide selection, cost, and application timing are critical decisions when trying to achieve economical, season-long pitted morningglory control in cotton. The objectives of this research are to evaluate the effectiveness and economics of pitted morningglory control in an irrigated glyphosate-tolerant cotton system by comparing glyphosate systems to traditional herbicides used in Oklahoma cotton production.

MATERIALS AND METHODS

Field experiments were conducted in 1999 and 2000 at the Southwest Research and Extension Center near Altus, OK. The soil type at this location was a Tillman-Hollister clay loam (a fine, smectitic, thermic Typic Haplustert) with a pH of 8.1 and a 1.1% organic matter content.

A population of pitted morningglory was already present at the study location. On March 1 in each year, trifluralin [2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl)benzenamine] was applied at 1.1 kg ai ha^{-1} to preformed beds and incorporated with a rolling cultivator set to conform to the beds. In 1999, 'Paymaster 1220 BG/RR' cotton was planted. In 2000, Paymaster 1218 BG/RR cotton was planted because Paymaster 1220 BG/RR was no longer available. A rate of 14 seed m^{-1} of row was utilized with a 1.0-m row spacing. An organophosphate insecticide, phorate {0,0-diethyl S-[(ethylthio) methyl] phosphorodithioate} was applied both yr at a rate of 3.9 kg product ha^{-1} in-furrow as a crop safener for clomazone treatments. In 2000, the experiment was relocated within the same field to an area not treated the previous year. Planting and PRE application dates were June 2 and May 10 in 1999 and 2000, respectively. Plots were four rows wide and 30 m long with 0.5 m removed from each end shortly before harvest to reduce the end-row effect; thus, harvested row length was 29 m. Cotton was furrow-irrigated on July 14 and 27, August 10 and 23, and September 7, 1999. In 2000, furrow irrigations took place on June 2, July 22 and 27, August 8 and 22, and September 6. Approximately 10 cm of water was applied per irrigation event, regardless of year. Insecticide applications were made as judged necessary by sampling of fields.

The experimental design was a randomized complete block with 21 herbicide treatments replicated four times. PPI and PRE treatments were applied at the labeled rates appropriate for that location's soil type (Table 1). Herbicides (and their rates) included: clomazone {2-[(2-chlorophenyl)methyl]-4,4-dimethyl-3-isoxazolidinone} (1.1 kg ai ha^{-1}), fluometuron (1.9 kg ai ha^{-1}), prometryn [*N,N'*-bis(1-methylethyl)-6-(methylthio)-1,3,5-triazine-2,4-diamine] (2.2 kg ai ha^{-1}), pyrithiobac (0.05 kg ai ha^{-1}), prometryn plus pyrithiobac (2.2 + 0.04 kg ai ha^{-1}), fomesafen {5-[2- chloro-4-(trifluoromethyl)phenoxy]-*N*-(methylsulfonyl)-2-nitrobenzamide} (0.4 kg ai ha^{-1}), or no PRE herbicide; glyphosate (0.8 and 1.1 kg ai ha^{-1}), pyrithiobac (0.07 and 0.1 kg ai ha^{-1}), or no herbicide at the first postemergence date (POST-1); glyphosate (1.1 kg ai ha^{-1}), pyrithiobac (0.07 kg ai ha^{-1}), pyrithiobac plus MSMA (monosodium salt of methylarsonic acid) (0.04 + 1.1 kg ai ha^{-1}), prometryn plus MSMA (0.8 + 1.1 kg ai ha^{-1}), or no herbicide at the second postemergence date (POST-2); glyphosate (1.7 kg ai ha^{-1} as a late-season over-the-top salvage treatment) or no herbicide at the third postemergence date (POST-3); glyphosate (1.1 kg ai ha^{-1}), lactofen {(±)-2-ethoxy-1-methyl-2-oxoethyl 5-[2-chloro-4- (trifluoromethyl)phenoxy]-2-nitrobenzoate} (0.2 kg ai ha^{-1}), oxyfluorfen [2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene] (0.6 kg ai ha^{-1}), or no herbicide postemergence directed (POST-D). A nonionic surfactant (Latron AG-98, containing 80% alkylaryl polyoxyethylene glycol from Rohm and Haas Co., Philadelphia, PA) at 0.25% (v v^{-1}) was included with all POST herbicides except glyphosate and lactofen. Crop oil concentrate (Agridex, a heavy range paraffin base petroleum oil, polyol fatty acid esters, and polyethoxylated derivatives from Helena Chemical Co., Memphis, TN) at 1.17 L ha^{-1} was included with lactofen POST-D. All PPI, PRE, and POST over-the-top applications were made with a tractor-mounted, compressed-air sprayer calibrated to deliver 140 L/ha at 260 kPa. POST-D applications were made with a tractor-mounted, post-direct sprayer calibrated to deliver 140 L/ha at 105 kPa. Twenty-one treatment combinations were developed from the abovementioned list and applied at the appropriate times for pitted morningglory control.

Clethodim {(*E,E*)-(±)-2-[1-[[(3-chloro-2-propenyl)oxy]imino]propyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one} (0.28 kg ai ha^{-1}) was applied at 4 WAP for johnsongrass [Sorghum halepense (L.) Pers.] control in 1999; however, populations of that weed did not warrant treatment in 2000.

In 1999, one over-the-top glyphosate application was made (POST-1) prior to cotton reaching the four-leaf stage; thus, the POST-2 application was POST-D. However, two (POST-1 and POST-2) over-the-top glyphosate applications were made in 2000 before cotton reached the four-leaf stage.

In 1999 and 2000, POST-1 applications were made 2 WAP when cotton was in the one-to-three leaf growth stage and was 3- to 10-cm tall. POST-2 applications were made at 4 WAP when cotton was in the three-to-ten leaf growth stage and was 13- to 30-cm tall. POST-3 and POST-D applications were made at 6 WAP in 1999 and at 8 WAP in 2000. At POST-3 and POST-D, cotton was in the 10-to-14 leaf growth stage and was 40- to 45-cm tall in 1999. In 2000, cotton was in the 18-to-20 leaf growth stage and was 45- to 50-cm tall POST-3 and POST-D. At the time of POST-1 application, pitted morningglory was in the one-to-three leaf growth stage and 3- to 5-cm tall, while at POST-2 they were in the three-to-ten leaf stage and 5- to 25-cm tall in 1999 and 2000. At POST-3 and POST-D, pitted morningglory was in the 18-to-20 leaf stage and 25- to 40-cm tall in 1999 and in the 12-to-16 leaf stage and 15- to 25-cm tall in 2000. Both years at 2 WAP, pitted morningglory density in the untreated check was 25 to 40 plants m^{-2}.

Weed control and cotton injury were determined visually at 4, 6, and 10 WAP based on a scale of 0 (no effect) to 100% (death of weed or crop). Cotton was harvested on November 11, 1998 and January 25, 2001. The center two rows of each plot were harvested with a spindle picker followed by weighing, collection of a "grab" sample, and ginning to determine lint percentage and lint yield.

Five-year moving average cotton lint prices of \$1.43 kg^{-1} in 1999 and \$1.26 kg^{-1} in 2000, along with current herbicide prices from a local chemical supplier (Estes Inc. Oklahoma City, OK) were used to calculate variable costs for weed control and adjusted net returns for comparison of glyphosate and standard herbicide treatments (Oklahoma Agricultural Statistics Service 2000). Application cost was \$8.10 ha^{-1} per application based on estimates published in Oklahoma (Kletke 1996). Adjusted net return was calculated for each treatment as the difference between total return (price times yield) minus variable cost minus total return for the untreated check. Variable costs included herbicide, adjuvant, application, and a seed technology fee of \$16.00 ha^{-1} for glyphosate-tolerant cotton. Seed technology fees were not applied to treatments that did not use glyphosate. A return ratio was calculated for each treatment by dividing the net return by the variable cost. This ratio represents the increased return for each dollar spent on weed control.

Data were subjected to ANOVA and treatment means were separated by Fisher's protected LSD at $P = 0.05$. A year by treatment interaction was not observed for weed control at 4 and 6 WAP; therefore, these data were combined over years. However, a significant year by treatment interaction was observed for all other variables. Consequently, these data are presented separately.

RESULTS AND DISCUSSION

Pitted Morningglory Control

No crop injury was observed with any treatment in 1999 or 2000 (data not shown). Since trifluralin was applied to all plots, it will not be mentioned with all treatments in the discussion; however, trifluralin and the PRE herbicides alone did not control pitted morningglory > 72% 4 WAP (2 wk after POST-1 and prior to POST-2 application) (Table 1). In treatments that did not contain a POST-1 application, only the PRE herbicides were being evaluated at 4 WAP as a result of the POST-2 or POST-D applications not being applied yet. At 4 WAP, Prometryn PRE (Treatment 15) and prometryn plus pyrithiobac PRE (Treatment 13) controlled pitted morningglory equally. For example, Treatment 15 controlled pitted morningglory 64%, while Treatment 13 controlled pitted morningglory 72% (Table 1). Fomesafen PRE (Treatment 14) controlled pitted morningglory only 26% at 4 WAP. Previous research reported 86% pitted morningglory control with fomesafen PRE at the same rate up to 24 days after treatment (Bond et al. 1998). Favorable conditions for germination and emergence of pitted morningglory and the extremely high pitted morningglory population (25 to 40 m^{-2}) may have contributed to the poor pitted morningglory control with all of the PRE herbicides 4 WAP.

Glyphosate alone POST-1 (Treatment 3) controlled pitted morningglory 73% 4 WAP (Table 1). Clomazone or prometryn PRE fb glyphosate POST-1 improved pitted morningglory control from 73% with a single glyphosate application to 89% with clomazone fb glyphosate (Treatment 1) and 90% with prometryn fb glyphosate (Treatment 6), regardless of glyphosate rate (Table 1). Pyrithiobac alone POST-1 (Treatment 17) controlled pitted morningglory 81% at 4 WAP, which was not different than control with glyphosate alone POST-1 (Treatment 3).

At 6 WAP (2 wk after POST-2 application and prior to POST-3 or POST-D application), Treatment 3 controlled pitted morningglory 69% (Table 1). A single glyphosate application POST-1 (Treatment 3) and glyphosate applied POST-1 and POST-2 (Treatment 4) controlled pitted morningglory equally 6 WAP. Although no statistical difference in control was observed between Treatments 1 or 5 and Treatment 3 at 6 WAP, the addition of the soil-applied herbicides in Treatments 1 and 5 improved control numerically from 69% with glyphosate alone POST-1 (Treatment 3) to at least 81% with clomazone PRE fb glyphosate POST-1 (Treatment 1) (Table 1). Pyrithiobac POST-1 (Treatment 17) or pyrithiobac POST-1 fb pyrithiobac POST-2 (Treatment 18) improved pitted morningglory over glyphosate POST-1 from 69 to 89% with Treatment 17 and 93% with Treatment 18.

Treatment 8 controlled pitted morningglory 94% in 1999 10 WAP (4 wk after POST-3 and POST-D application in 1999) (Table 1). Pitted morningglory control with glyphosate POST-1, POST-2, and POST-D (Treatment 2) or glyphosate POST-1 and POST-2 (Treatment 4) was not different than control with Treatment 8 at 10 WAP, regardless of year. Pyrithiobac alone POST-1 (Treatment 17) controlled pitted morningglory 71% 10 WAP. Pyrithiobac POST-1 and POST-2 (Treatment 18) and Treatment 17 controlled pitted morningglory equally in 1999 10 WAP. However, a single pyrithiobac application POST-1 controlled pitted morningglory at least 26% more than a single glyphosate application POST-1 in 1999.

In 1999 and 2000, pyrithiobac PRE fb prometryn plus MSMA POST-2 (Treatment 19) controlled pitted morningglory < 20% 10 WAP (Table 1). Overall late-season pitted morningglory control was less in 2000 than in 1999 10 WAP with treatments containing soil applied herbicides fb glyphosate. For example, in 1999, fluometuron fb glyphosate POST-1 and POST-D (Treatment 8) controlled pitted morningglory 94%, while in 2000 the same treatment controlled pitted morningglory only 68% (Table 1). The lower weed control in systems containing soil-applied herbicides and glyphosate may have resulted from drier conditions at the time of PRE application and subsequent lack of PRE herbicide activation prior to weed germination and emergence. Also, the POST-3 and POST-D applications had only been applied 2 wk before the 10 wk rating versus 4 wk in 1999 allowing time for complete herbicide activity. The lack of PRE herbicide activation may have resulted in larger early-season populations than encountered in 1999. These larger early-season pitted morningglory populations contributed to poor late-season control following emergence of multiple populations throughout the growing season. Other research has demonstrated that environmental conditions at the time of herbicide application and early-season control are crucial factors in an effort to achieve season-long pitted morningglory control (Shaw et al. 1990).

In 2000 10 WAP (2 wk after POST-3 and POST-D application), pyrithiobac alone POST-1 (Treatment 17) controlled pitted morningglory 84% (Table 1). Treatment 17 and Treatment 18 controlled pitted morningglory equally in 2000. Pitted morningglory control with glyphosate or pyrithiobac POST-1 was not different in 2000; however, pyrithiobac POST-1 and POST-2 (Treatment 18) controlled pitted morningglory at least 37% more than glyphosate POST-1 and POST-2 (Treatment 4). Pitted morningglory control was not different with Treatment 4 or glyphosate POST-1 fb pyrithiobac plus MSMA POST-2 (Treatment 12), regardless of year.

Lint Yield

In 1999, plots treated with glyphosate POST-1 fb pyrithiobac plus MSMA (Treatment 12) cotton yielded 1,050 kg ha^{-1} which was not statistically different than yield in plots treated with Treatments 4, 5, 7, 8, 10, 11, 17, or 18 (Table 2). Glyphosate alone POST-1 or prometryn plus pyrithiobac PRE did not control pitted morningglory season-long which resulted < 500 kg ha^{-1} yield from those plots. The application of fluometuron PRE fb glyphosate POST-1 improved pitted morningglory control in 1999 and subsequently improved cotton yield compared to glyphosate alone POST-1. For example, cotton yield in plots treated with glyphosate POST-1 was 490 kg ha^{-1}, while yield in plots treated with fluometuron PRE fb glyphosate POST-1 was 950 kg ha^{-1} (Table 2). Cotton yield in plots treated with Treatments 14, 19, or 20 was not different than the untreated check. Waiting until POST-2 for a POST application resulted in early-season competition that reduced cotton yield. Treatment at the POST-1 timing reduced early season pitted morningglory competition and subsequent yield loss. Researchers have reported yield losses up to 30% in glyphosate-tolerant cotton resulting from weed competition during the first three wk of cotton growth and up to 100% yield loss from 12 wk of morningglory competition (Askew and Wilcut 1999; Keeley et al. 1986).

In 2000, plots treated with Treatment 2 yielded 700 kg ha^{-1}, which was not different than yield from plots treated with Treatment 17 or 18

(Table 2). Plots treated with glyphosate alone POST-1 yielded 180 kg ha^{-1}, which was not different than yield from the untreated check (Table 2). In addition, plots treated with Treatments 13, 14, 19, or 20 did not yield greater than the untreated check. As mentioned earlier, the lack of a POST-1 application or a residual soil-applied herbicide allowed early-season competition resulting in yield loss.

Cotton yield in 2000 was less than 1999 cotton yield in part due to rainfall that hindered cotton harvest until mid-January 2001. Another factor that may have contributed to higher yield in 1999 was the early June planting date that may have resulted in less morningglory competition than encountered with the May planted cotton in 2000. Earlier research has reported that morningglory competition and biomass in June planted cotton was lower than in cotton planted in May (Klingaman and Oliver 1994; Keeley et al. 1986). Elimination of multiple flushes of pitted morningglory with tillage and the reduction of in-season competition associated with planting in June could be beneficial in areas with longer growing seasons.

Adjusted Net Return and Return Ratio

In 1999, Treatment 12 resulted in an adjusted net return of \$1,342 ha^{-1} and a return ratio of 9.60 which indicates for every dollar spent on weed control with Treatment 12 there was a 960% increase in returns over no treatment at all (Table 3). Adjusted net returns and return ratios from Treatments 4 and 5 were not different from glyphosate POST-1 fb pyrithiobac plus MSMA POST-2 (Treatment 12). For example, adjusted net returns were at least \$1,100 ha^{-1} and return ratios were at least 9.29 with Treatments 4 or 5 (Table 3). Glyphosate alone POST-1 (Treatment 3) resulted in a \$597 ha^{-1} adjusted net return, which was less than adjusted net returns with Treatments 4 or 10.

Adjusted net returns and return ratios from plots treated with pyrithiobac alone POST-1 (Treatment 17) were not different from plots treated with glyphosate POST-1 and POST-2 (Treatment 4) in 1999 (Table 3). However, the return ratio from Treatment 18 was less than the return ratio from Treatment 4 even though adjusted net returns were similar. This indicates less return per dollar spent with the pyrithiobac treatment in 1999. The difference in return ratios can be attributed to the high cost of the pyrithiobac POST-1 and POST-2 treatment that cost \$89 ha^{-1} more than glyphosate POST-1 and POST-2 (Table 3).

In 2000, treatment with glyphosate alone POST-1 resulted in a negative adjusted net return and return ratio (Table 3). This demonstrates the lack of season-long weed control and yield loss associated with a single glyphosate application in a situation with a high pitted morningglory population and conditions favorable for season-long emergence. Adjusted net return from Treatment 2 was \$537 ha^{-1} which was greater than adjusted net return associated with Treatment 4. However, adjusted net returns from Treatment 2 were not different from adjusted net returns from pyrithiobac alone POST-1 (Treatment 17) or applied POST-1 and POST-2 (Treatment 18) in 2000 (Table 3). Treatment 18 had a return ratio less than Treatment 2; however, a single POST pyrithiobac application (Treatment 17) had a return ratio that was not different than Treatment 2.

These data indicate that pitted morningglory control can be obtained in a total POST program utilizing multiple glyphosate applications in a glyphosate-tolerant cotton system. Under irrigated conditions, these data also demonstrate the importance of early-season weed control to yield and net returns. The application of fluometuron PRE fb glyphosate POST-1 improved late-season weed control, cotton yield, and adjusted net returns when compared to a single glyphosate application. Timing of POST application was very important in systems with no soil-applied herbicide. For example, in systems with no soil-applied herbicide when the POST application was delayed until POST-2 (6 WAP) cotton yield was reduced due to early-season weed competition. Previous research has also demonstrated the importance of early-season weed control in relation to cotton yield (Askew and Wilcut 1999; Culpepper and York 1998).

Late-season pitted morningglory control, cotton lint yield, and adjusted net return was not different between systems with glyphosate applied POST-1, POST-2, and POST-D or pyrithiobac applied POST-1 and POST-2. However, return ratios were greater for glyphosate systems with multiple applications when compared with two POST pyrithiobac applications. This difference in the return ratios can be attributed to the higher cost of pyrithiobac when compared to glyphosate (Table 3). Use of a glyphosate weed control system also gives producers the added benefit of no rotational crop restrictions if a crop failure is encountered. It must be noted that this experiment was conducted with unusually high pitted morningglory populations and that in situations with smaller pitted morningglory populations similar results may be achieved with fewer herbicide applications.

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Table 1. Pitted morningglory control 4, 6, and 10 wk after planting in irrigated glyphosate-tolerant cotton.

				Pitted morningglory control[a]			
				4 WAP	6 WAP	10 WAP	
Trt. No.[b]	Trt.[b,c]	Rate	Timing			1999	2000
		kg ai/ha		%			
1	Clomazone fb	1.1	PRE				
	glyphosate	1.1	POST-1	89	81	63	58
2	Glyphosate fb	1.1	POST-1				
	glyphosate fb	1.1	POST-2				
	glyphosate	1.1	POST-D	77	71	81	78
3	Glyphosate	1.1	POST-1	73	69	45	55
4	Glyphosate fb	1.1	POST-1				
	glyphosate	1.1	POST-2	71	79	78	55
5	Fluometuron fb	1.9	PRE				
	glyphosate	1.1	POST-1	79	84	86	68
6	Prometryn fb	2.2	PRE				
	glyphosate	1.1	POST-1	90	80	61	58
7	Prometryn fb	2.2	PRE				
	glyphosate fb	0.8	POST-1				
	glyphosate	1.1	POST-D	91	86	84	80
8	Fluometuron fb	1.9	PRE				
	glyphosate fb	1.1	POST-1				
	glyphosate	1.1	POST-D	83	84	94	68
9	Pyrithiobac fb	0.05	PRE				
	glyphosate	1.1	POST-D	43	26	33	40
10	Glyphosate fb	1.1	POST-1				
	pyrithiobac	0.07	POST-2	69	83	81	58
11	Glyphosate +	1.1 +					
	pyrithiobac fb	0.04	POST-1				
	glyphosate	1.1	POST-D	81	68	74	63
12	Glyphosate fb	1.1	POST-1				
	pyrithiobac +	0.04 +					
	MSMA	1.1	POST-2	75	83	88	53
13	Prometryn +	2.2 +					
	pyrithiobac	0.04	PRE	72	51	26	45

Table 1. (Continued).

Trt. No.[b]	Trt.[b,c]	Rate	Timing	Pitted morningglory control[a] 4 WAP	6 WAP	10 WAP 1999	2000
		kg ai/ha		%			
14	Fomesafen fb	0.4	PRE				
	lactofen	0.2	POST-D	26	31	28	25
15	Prometryn fb	2.2	PRE				
	oxyfluorfen	0.6	POST-D	64	54	46	48
16	Fluometuron fb	1.9	PRE				
	pyrithiobac	0.07	POST-2	41	80	45	86
17	Pyrithiobac	0.1	POST-1	81	89	71	84
18	Pyrithiobac fb	0.07	POST-1				
	pyrithiobac	0.07	POST-2	81	93	86	92
19	Pyrithiobac fb	0.05	PRE				
	prometryn +	0.8 +					
	MSMA	1.1	POST-2	34	24	10	19
20	Clomazone fb	1.1	PRE				
	glyphosate	1.7	POST-3	31	21	66	34
21	Check			0	0	0	0
	LSD (0.05)			13	15	22	32

[a]Data for 4 and 6 WAP ratings are pooled over years.

[b]Abbreviations: fb, followed by; PPI, preplant incorporated; PRE, preemergence; POST-1, first postemergence timing; POST-2, second postemergence timing; POST-3, third postemergence timing; POST-D, directed postemergence application; Trt. No., treatment number; Trt., treatment; WAP, weeks after planting.

[c]Trifluralin was applied PPI to the entire study area at a rate of 1.1 kg ai/ha. Nonionic surfactant at 0.25% v/v was included in all pyrithiobac POST applications and to all POST-D applications except lactofen which contained 1.17 L/ha crop oil concentrate.

Table 2. Cotton lint yield resulting from various herbicide treatments in an irrigated glyphosate-tolerant production system in 1999 and 2000.

Trt. No.	Trt.[a,b]	Rate	Timing	Lint yield 1999	Lint yield 2000
		kg ai/ha		kg/ha	
1	Clomazone fb	1.1	PRE		
	glyphosate	1.1	POST-1	700	400
2	Glyphosate fb	1.1	POST-1		
	glyphosate fb	1.1	POST-2		
	glyphosate	1.1	POST-D	720	700
3	Glyphosate	1.1	POST-1	490	180
4	Glyphosate fb	1.1	POST-1		
	glyphosate	1.1	POST-2	870	500
5	Fluometuron fb	1.9	PRE		
	glyphosate	1.1	POST-1	950	540
6	Prometryn fb	2.2	PRE		
	glyphosate	1.1	POST-1	670	400
7	Prometryn fb	2.2	PRE		
	glyphosate fb	0.8	POST-1		
	glyphosate	1.1	POST-D	940	630
8	Fluometuron fb	1.9	PRE		
	glyphosate fb	1.1	POST-1		
	glyphosate	1.1	POST-D	840	560
9	Pyrithiobac fb	0.05	PRE		
	glyphosate	1.1	POST-D	350	340
10	Glyphosate fb	1.1	POST-1		
	pyrithiobac	0.07	POST-2	810	550
11	Glyphosate +	1.1 +			
	pyrithiobac fb	0.04	POST-1		
	glyphosate	1.1	POST-D	850	440
12	Glyphosate fb	1.1	POST-1		
	pyrithiobac +	0.04 +			
	MSMA	1.1	POST-2	1,050	550
13	Prometryn +	2.2 +			
	pyrithiobac	0.04	PRE	470	310

Table 2. (Continued).

Trt. No.	Trt.[a,b]	Rate	Timing	Lint yield 1999	2000
		kg ai/ha		kg/ha	
14	Fomesafen fb	0.4	PRE		
	lactofen	0.2	POST-D	230	230
15	Prometryn fb	2.2	PRE		
	oxyfluorfen	0.6	POST-D	400	440
16	Fluometuron fb	1.9	PRE		
	pyrithiobac	0.07	POST-2	480	630
17	Pyrithiobac	0.1	POST-1	860	570
18	Pyrithiobac fb	0.07	POST-1		
	pyrithiobac	0.07	POST-2	860	650
19	Pyrithiobac fb	0.05	PRE		
	prometryn +	0.8 +			
	MSMA	1.1	POST-2	140	270
20	Clomazone fb	1.1	PRE		
	glyphosate	1.7	POST-3	300	250
21	Check			41	170
	LSD (0.05)			280	150

[a]Trifluralin was applied PPI to the entire study area at a rate of 1.1 kg ai/ha. Nonionic surfactant at 0.25% v/v was included in all pyrithiobac POST applications and to all POST-D applications except lactofen which contained 1.17 L/ha crop oil concentrate.

[b]Abbreviations: fb, followed by; PPI, preplant incorporated; PRE, preemergence; POST-1, first postemergence timing; POST-2, second postemergence timing; POST-3, third postemergence timing; POST-D, directed postemergence application; Trt. No., treatment number; Trt., treatment.

Table 3. Adjusted net return, herbicide cost, and return ratio from selected herbicide treatments in an irrigated glyphosate-tolerant production system in 1999 and 2000.

Trt. No.	Trt.[b,c]	Rate	Timing	Adjusted net return (Cost)[a] 1999	Adjusted net return (Cost)[a] 2000	Return Ratio[a] 1999	Return Ratio[a] 2000
		kg ai/ha		$/ha	$/ha		
1	Clomazone fb	1.1	PRE				
	glyphosate	1.1	POST-1	842 (139)	165 (134)	6.06	1.23
2	Glyphosate fb	1.1	POST-1				
	glyphosate fb	1.1	POST-2				
	glyphosate	1.1	POST-D	852 (156)	537 (130)	5.46	4.13
3	Glyphosate	1.1	POST-1	597 (82)	-55 (71)	7.28	-0.77
4	Glyphosate fb	1.1	POST-1				
	glyphosate	1.1	POST-2	1,102 (119)	312 (101)	9.26	3.09
5	Fluometuron fb	1.9	PRE				
	glyphosate	1.1	POST-1	1,208 (128)	345 (124)	9.44	2.78
6	Prometryn fb	2.2	PRE				
	glyphosate	1.1	POST-1	808 (134)	175 (118)	6.03	1.48
7	Prometryn fb	2.2	PRE				
	glyphosate fb	0.8	POST-1				
	glyphosate	1.1	POST-D	1,144 (171)	435 (142)	6.69	3.06
8	Fluometuron fb	1.9	PRE				
	glyphosate fb	1.1	POST-1				
	glyphosate	1.1	POST-D	1,012 (165)	333 (154)	6.13	2.16
9	Pyrithiobac fb	0.05	PRE				
	glyphosate	1.1	POST-D	323 (149)	89 (125)	2.17	0.71
10	Glyphosate fb	1.1	POST-1				
	pyrithiobac	0.07	POST-2	968 (171)	342 (142)	5.66	2.41
11	Glyphosate +	1.1 +					
	pyrithiobac fb	0.04	POST-1				
	glyphosate	1.1	POST-D	1,034 (160)	203 (141)	6.46	1.44
12	Glyphosate fb	1.1	POST-1				
	pyrithiobac +	0.04 +					
	MSMA	1.1	POST-2	1,342 (140)	349 (126)	9.59	2.77
13	Prometryn +	2.2 +					
	pyrithiobac	0.04	PRE	521 (121)	69 (104)	4.31	0.66

Table 3. (Continued).

Trt. No.	Trt.[b,c]	Rate	Timing	Adjusted net return (Cost)[a] 1999	Adjusted net return (Cost)[a] 2000	Return Ratio[a] 1999	Return Ratio[a] 2000
		kg ai/ha		$/ha			
14	Fomesafen fb	0.4	PRE				
	lactofen	0.2	POST-D	181 (124)	-37 (116)	1.46	-0.32
15	Prometryn fb	2.2	PRE				
	oxyfluorfen	0.6	POST-D	406 (147)	189 (151)	2.76	1.25
16	Fluometuron fb	1.9	PRE				
	pyrithiobac	0.07	POST-2	499 (164)	434 (149)	3.04	2.91
17	Pyrithiobac	0.1	POST-1	1,050 (156)	384 (125)	6.73	3.07
18	Pyrithiobac fb	0.07	POST-1				
	pyrithiobac	0.07	POST-2	999 (208)	436 (167)	4.80	2.61
19	Pyrithiobac fb	0.05	PRE				
	prometryn +	0.8 +					
	MSMA	1.1	POST-2	46 (131)	15 (111)	0.35	0.14
20	Clomazone fb	1.1	PRE				
	glyphosate	1.7	POST-3	266 (139)	-41 (145)	1.91	-0.28
21	Check			0 (28)	0 (25)	0.00	0.00
	LSD (0.05)			400 (0)	190 (0)	3.00	1.50

[a]Adjusted net return is the difference between total return (price times yield) minus variable cost, minus total return for the untreated check. Values in parentheses represent herbicide, adjuvant, application, and technology costs for each program. Return ratio equals increased return per dollar of weed control cost.

[b]Trifluralin was applied PPI to the entire study area at a rate of 1.1 kg ai/ha. Nonionic surfactant at 0.25% v/v was included in all pyrithiobac POST applications and to all POST-D applications except lactofen which contained 1.17 L/ha crop oil concentrate.

[c]Abbreviations: fb, followed by; PPI, preplant incorporated; PRE, preemergence; POST-1, first postemergence timing; POST-2, second postemergence timing; POST-3, third postemergence application timing; POST-D, directed postemergence application; Trt. No., treatment number; Trt., treatment.

APPENDIX

Appendix Table 4. Herbicide treatments[a] for Chickasha Long-term Experiment 1998 to 2000.

Trt.[a]	PPI	PRE	POST-1[b]	POST-2	POST-3	Replications I	II	III	IV
1	None	None	Gly (1.1)	None	None	208	401	601	703
2	Pend (1.4)[c]	None	Gly (1.1)	None	None	106	402	508	707
3	None	None	Gly (1.1)	Gly (1.1)	None	202	307	602	806
4	Pend (1.4)	None	Gly (1.1)	Gly (1.1)	None	204	304	607	802
5	None	None	Gly (1.1)	Gly (1.1)	None	203	305	606	801
6	Pend (1.4)	None	Gly (1.1)	Gly (1.1)	None	108	405	507	708
7	None	None	Gly (1.1)	Gly (1.1) + pyri (0.07)	None	104	403	501	807
8	Pend (1.4)	None	Gly (1.1)	Gly (1.1) + pyri (0.07)	None	105	303	502	803
9	Pend (1.4)	Pro (2.2)	None	Quiz (0.09)	None	101	308	504	804
10	Pend (1.4)	Pro (2.2)	Quiz (0.09)	Pyri (0.07)	None	206	306	604	705
11	Pend (1.4)	Pro (2.2) + pyri (0.05)	Quiz (0.09)	Pyri (0.07)	None	207	408	503	702
12	Pend (1.4)	Pro (2.2) + pyri (0.05)	Quiz (0.05)	Quiz (0.05)	Pyri (0.07)	107	302	603	808
13	Pend (1.4)	Pro (2.2)	Quiz (0.05)	Quiz (0.05)	Pyri (0.07)	201	301	608	805
14	Pend (1.4)	Pyri (0.05)	Gly (1.1)	Quiz (0.09)	None	205	407	506	704
15	Pend (1.4)	Pyri (0.05)	Gly (1.1)	Quiz (0.09)	Pyri (0.07)	102	404	505	701
16	None	None	None	None	None	103	406	605	706

[a]All plots were cultivated one time each year. Abbreviations: Trt, treatment; PPI, preplant incorporated PRE, preemergence; POST-1, first postemergence timing; POST-2, second postemergence timing; pend, pendimethalin; pro, prometryn; pyri, pyrithiobac; gly, glyphosate; quiz, quizalofop. Nonionic surfactant at 0.25% v/v was applied with pyri POST-1 or POST-2, while crop oil concentrate was applied at 1% v/v with quiz POST-1 or POST-2.

[b]In 1998, POST-3 treatments were not applied while POST-1 and POST-2 treatments were applied as listed; however, in 1999 and 2000, POST-2 and POST-3 Pyri treatments were applied POST-1 in place of Quiz and no POST-2 or POST-3 applications were made.

[c]Values in parentheses represent herbicide rate in kg ai/ha.

Appendix Table 5. Weed Control ratings 10 WAP for Chickasha Long-term experiment in 1998[a].

Treatment	Replication	SORHA	PROLO	SOLEL	XANST	AMAPA
		%				
1	I	100	0	100	100	100
	II	100	0	100	95	100
	III	100	95	100	100	100
	IV	100	0	100	100	100
	Mean	100	24	100	99	100
2	I	100	0	20	90	100
	II	100	20	70	100	100
	III	100	0	100	90	100
	IV	100	0	0	90	100
	Mean	100	5	48	93	100
3	I	100	0	95	80	100
	II	100	20	100	100	100
	III	100	70	100	100	100
	IV	100	100	100	90	100
	Mean	100	48	99	93	100
4	I	100	80	100	95	100
	II	100	0	100	100	100
	III	100	90	100	100	100
	IV	100	0	100	100	100
	Mean	100	43	100	99	100
5	I	100	0	80	100	100
	II	100	0	100	95	100
	III	90	0	100	100	100
	IV	100	0	95	100	100
	Mean	98	0	94	99	100
6	I	100	75	100	90	100
	II	100	100	100	90	100
	III	100	90	100	100	100
	IV	100	50	100	60	100
	Mean	100	79	100	85	100
7	I	100	20	80	100	100
	II	100	0	100	100	100
	III	100	90	100	100	100
	IV	100	0	75	95	100
	Mean	100	28	89	99	100
8	I	100	0	100	100	100
	II	100	0	100	100	100
	III	85	0	70	90	100
	IV	100	100	0	100	100
	Mean	96	25	68	98	100

Appendix Table 5. (Continued).

Treatment	Replication	SORHA	PROLO	SOLEL	XANST	AMAPA
		%				
9	I	90	0	0	20	100
	II	90	0	95	70	100
	III	90	0	100	90	100
	IV	80	0	100	40	100
	Mean	88	0	74	55	100
10	I	85	0	95	90	100
	II	100	0	100	80	100
	III	100	0	100	70	100
	IV	90	0	100	0	100
	Mean	94	0	99	60	100
11	I	95	0	90	70	100
	II	90	0	0	80	100
	III	80	0	100	100	100
	IV	100	0	70	80	100
	Mean	91	0	65	83	100
12	I	90	100	95	60	100
	II	90	0	100	90	100
	III	100	95	95	90	100
	IV	100	80	95	60	100
	Mean	95	69	96	75	100
13	I	90	0	100	0	100
	II	85	0	100	70	100
	III	90	0	40	0	100
	IV	70	0	95	50	100
	Mean	84	0	84	30	100
14	I	100	90	100	90	100
	II	100	90	100	100	100
	III	100	100	80	95	100
	IV	100	100	100	95	100
	Mean	100	95	95	95	100
15	I	100	90	100	95	100
	II	90	100	100	100	100
	III	100	100	50	70	100
	IV	100	100	100	100	100
	Mean	98	98	88	91	100
16	I	0	0	0	0	0
	II	0	0	0	0	0
	III	0	0	0	0	0
	IV	0	0	0	0	0
	Mean	0	0	0	0	0

[a]Abbreviations: WAP, weeks after planting; SORHA, johnsongrass; PROLO, devil's-claw; SOLEL, silverleaf nightshade; XANST, common cocklebur; AMAPA, Palmer amaranth.

Appendix Table 6. Weed Control ratings 17 WAP for Chickasha Long-term experiment in 1998[a].

Treatment	Replication	SORHA	PROLO	SOLEL	XANST	AMAPA
		%				
1	I	100	20	100	100	100
	II	100	20	100	100	100
	III	95	100	100	100	100
	IV	100	90	60	100	100
	Mean	99	58	90	100	100
2	I	100	70	0	90	100
	II	100	20	80	90	100
	III	100	0	100	100	100
	IV	100	70	0	100	100
	Mean	100	40	45	95	100
3	I	100	40	100	100	100
	II	90	30	100	100	100
	III	100	80	100	100	100
	IV	90	70	95	95	100
	Mean	95	55	99	99	100
4	I	100	95	100	95	100
	II	100	75	100	100	100
	III	95	100	0	30	100
	IV	95	100	100	100	100
	Mean	98	93	75	81	100
5	I	100	0	60	100	100
	II	100	0	100	100	100
	III	95	20	0	90	100
	IV	95	40	100	100	100
	Mean	98	15	65	98	100
6	I	90	20	100	40	100
	II	100	70	100	90	100
	III	90	100	20	60	100
	IV	100	100	100	80	100
	Mean	95	73	80	68	100
7	I	100	95	100	100	100
	II	90	60	100	100	100
	III	100	70	95	100	100
	IV	100	70	100	90	100
	Mean	98	74	99	98	100
8	I	100	0	80	100	100
	II	95	20	100	100	100
	III	90	20	0	100	100
	IV	100	100	0	95	100
	Mean	96	35	45	99	100

Appendix Table 6. (Continued).

Treatment	Replication	SORHA	PROLO	SOLEL	XANST	AMAPA
		%				
9	I	95	0	30	0	100
	II	70	40	100	30	100
	III	70	0	95	0	100
	IV	95	30	40	0	100
	Mean	83	18	66	8	100
10	I	100	30	100	80	100
	II	100	0	100	0	100
	III	100	95	100	0	100
	IV	90	0	95	20	100
	Mean	98	31	99	25	100
11	I	90	0	60	0	100
	II	90	20	0	100	100
	III	90	30	95	70	100
	IV	100	30	0	80	100
	Mean	93	20	39	63	100
12	I	75	80	100	0	100
	II	70	70	95	90	100
	III	100	30	0	60	100
	IV	90	100	95	0	100
	Mean	84	70	73	38	100
13	I	90	0	100	60	100
	II	95	60	90	40	100
	III	90	0	0	30	100
	IV	90	30	90	40	100
	Mean	91	23	70	43	100
14	I	95	95	100	90	100
	II	100	20	100	80	100
	III	100	85	95	95	100
	IV	100	100	100	100	100
	Mean	99	75	99	91	100
15	I	100	100	100	100	100
	II	100	100	100	100	100
	III	100	75	0	90	100
	IV	95	100	100	100	100
	Mean	99	94	75	98	100
16	I	0	0	0	0	0
	II	0	0	0	0	0
	III	0	0	0	0	0
	IV	0	0	0	0	0
	Mean	0	0	0	0	0

[a]Abbreviations: WAP, weeks after planting; SORHA, johnsongrass; PROLO, devil's-claw; SOLEL, silverleaf nightshade; XANST, common cocklebur; AMAPA, Palmer amaranth.

Appendix Table 7. Weed Control ratings 2 WAP for Chickasha Long-term experiment in 1999[a].

Treatment	Replication	SORHA	PROLO	SOLEL	XANST	AMAPA
		%				
1	I	95	30	90	85	0
	II	70	0	85	50	25
	III	70	40	55	65	0
	IV	60	0	30	20	0
	Mean	74	18	65	55	6
2	I	100	70	0	90	100
	II	95	80	85	60	100
	III	95	60	85	80	100
	IV	95	60	20	30	100
	Mean	96	68	48	65	100
3	I	50	0	90	75	100
	II	0	0	30	0	0
	III	95	50	60	80	100
	IV	50	65	30	20	0
	Mean	49	29	53	44	50
4	I	100	80	90	90	95
	II	95	60	90	65	100
	III	100	95	20	70	100
	IV	100	70	75	90	100
	Mean	99	76	69	79	99
5	I	70	0	80	85	40
	II	20	0	0	30	0
	III	90	0	0	90	0
	IV	40	0	60	80	20
	Mean	55	0	35	71	15
6	I	100	50	95	70	100
	II	95	90	80	0	100
	III	100	60	0	0	100
	IV	100	90	90	30	100
	Mean	99	73	66	25	100
7	I	95	40	90	20	0
	II	90	0	60	80	0
	III	70	60	70	80	0
	IV	20	0	25	15	0
	Mean	69	25	61	49	0
8	I	95	60	40	0	100
	II	100	70	90	80	100
	III	100	40	0	95	100
	IV	95	50	40	60	100
	Mean	98	55	43	59	100

Appendix Table 7. (Continued).

Treatment	Replication	SORHA	PROLO	SOLEL	XANST	AMAPA
		%				
9	I	100	95	100	0	100
	II	95	95	70	30	100
	III	90	70	90	30	100
	IV	95	90	50	70	100
	Mean	95	88	78	33	100
10	I	100	80	90	80	100
	II	95	85	80	0	100
	III	95	90	80	50	95
	IV	90	95	70	40	100
	Mean	95	88	80	43	99
11	I	100	95	0	90	100
	II	100	100	50	95	100
	III	100	95	90	75	100
	IV	100	90	95	95	100
	Mean	100	95	59	89	100
12	I	95	90	95	20	100
	II	100	100	100	100	100
	III	100	95	90	90	100
	IV	100	95	95	85	100
	Mean	99	95	95	74	100
13	I	90	90	90	70	100
	II	70	75	85	0	100
	III	100	60	0	60	95
	IV	95	80	75	70	90
	Mean	89	76	63	50	96
14	I	100	95	90	70	100
	II	95	90	85	0	100
	III	100	95	90	65	100
	IV	100	95	90	85	100
	Mean	99	94	89	55	100
15	I	100	90	85	90	100
	II	100	95	90	95	100
	III	100	90	80	20	100
	IV	100	90	80	85	100
	Mean	100	91	84	73	100
16	I	0	0	0	0	0
	II	0	0	0	0	0
	III	0	0	0	0	0
	IV	0	0	0	0	0
	Mean	0	0	0	0	0

[a]Abbreviations: WAP, weeks after planting; SORHA, johnsongrass; PROLO, devil's-claw; SOLEL, silverleaf nightshade; XANST, common cocklebur; AMAPA, Palmer amaranth.

Appendix Table 8. Weed Control ratings 10 WAP for Chickasha Long-term experiment in 1999[a].

Treatment	Replication	SORHA	PROLO	SOLEL	XANST	AMAPA
		%				
1	I	100	60	95	100	85
	II	100	80	95	100	90
	III	100	100	100	100	90
	IV	100	95	100	95	95
	Mean	100	84	98	99	90
2	I	100	100	85	100	100
	II	100	90	100	100	100
	III	100	80	95	100	100
	IV	100	100	85	95	100
	Mean	100	93	91	99	100
3	I	100	100	100	100	100
	II	95	90	100	95	100
	III	100	95	100	100	100
	IV	100	100	100	100	100
	Mean	99	96	100	99	100
4	I	100	90	100	100	100
	II	100	90	100	100	100
	III	100	100	85	100	100
	IV	95	100	100	100	100
	Mean	99	95	96	100	100
5	I	100	60	100	100	100
	II	100	80	100	100	95
	III	100	85	100	100	90
	IV	100	80	95	100	100
	Mean	100	76	99	100	96
6	I	100	100	100	100	100
	II	100	100	100	100	100
	III	100	100	100	90	100
	IV	100	100	100	95	100
	Mean	100	100	100	96	100
7	I	100	100	100	100	90
	II	100	100	100	100	100
	III	100	90	100	100	95
	IV	90	80	95	95	100
	Mean	98	93	99	99	96
8	I	100	95	100	100	100
	II	100	95	100	100	100
	III	95	100	90	100	100
	IV	100	70	95	95	100
	Mean	99	90	96	99	100

Appendix Table 8. (Continued).

Treatment	Replication	SORHA	PROLO	SOLEL	XANST	AMAPA
		%				
9	I	70	20	80	0	95
	II	80	20	95	20	100
	III	85	10	95	0	100
	IV	100	60	85	85	100
	Mean	84	28	89	26	98
10	I	100	100	100	90	100
	II	100	100	100	85	100
	III	90	100	100	100	100
	IV	80	100	100	100	100
	Mean	93	100	100	94	100
11	I	100	80	95	70	100
	II	100	100	15	100	100
	III	100	90	95	100	100
	IV	100	95	100	100	100
	Mean	100	91	76	93	100
12	I	100	100	100	75	100
	II	100	100	100	100	100
	III	95	100	100	100	100
	IV	100	100	100	90	100
	Mean	99	100	100	91	100
13	I	90	95	100	100	100
	II	100	100	100	100	100
	III	100	100	100	100	100
	IV	100	100	100	80	100
	Mean	98	99	100	95	100
14	I	100	95	100	100	100
	II	100	90	100	100	100
	III	100	100	100	100	100
	IV	100	95	100	100	100
	Mean	100	95	100	100	100
15	I	100	100	100	100	100
	II	100	100	100	100	100
	III	100	100	100	80	100
	IV	100	100	100	100	100
	Mean	100	100	100	95	100
16	I	0	0	0	0	0
	II	0	0	0	0	0
	III	0	0	0	0	0
	IV	0	0	0	0	0
	Mean	0	0	0	0	0

[a]Abbreviations: WAP, weeks after planting; SORHA, johnsongrass; PROLO, devil's-claw; SOLEL, silverleaf nightshade; XANST, common cocklebur; AMAPA, Palmer amaranth.

Appendix Table 9. Weed Control ratings 17 WAP for Chickasha Long-term experiment in 1999[a].

Treatment	Replication	SORHA	PROLO	SOLEL	XANST	AMAPA
		%				
1	I	100	95	95	95	70
	II	90	85	95	95	80
	III	95	95	95	95	85
	IV	100	95	95	95	90
	Mean	96	93	95	95	81
2	I	100	100	100	100	100
	II	100	95	70	90	100
	III	95	90	95	80	100
	IV	100	60	20	95	100
	Mean	99	86	71	91	100
3	I	95	95	95	85	95
	II	90	95	95	95	100
	III	100	95	95	90	85
	IV	95	95	95	90	100
	Mean	95	95	95	90	95
4	I	100	100	100	100	100
	II	100	100	100	100	100
	III	95	85	90	90	80
	IV	95	90	95	75	100
	Mean	98	94	96	91	95
5	I	100	80	95	85	85
	II	90	70	95	95	75
	III	95	90	95	90	80
	IV	95	85	95	85	75
	Mean	95	81	95	89	79
6	I	100	95	90	90	100
	II	95	90	95	90	90
	III	100	100	100	90	100
	IV	100	90	95	75	100
	Mean	99	94	95	86	98
7	I	100	95	100	95	85
	II	95	95	95	95	85
	III	95	95	95	90	70
	IV	95	95	90	90	85
	Mean	96	95	95	93	81
8	I	100	95	95	80	95
	II	100	90	95	85	100
	III	95	95	95	95	95
	IV	100	100	100	85	100
	Mean	99	95	96	86	98

Appendix Table 9. (Continued).

Treatment	Replication	SORHA	PROLO	SOLEL	XANST	AMAPA
				%		
9	I	85	0	70	0	95
	II	85	95	95	30	100
	III	100	100	95	0	100
	IV	95	75	95	70	100
	Mean	91	68	89	25	99
10	I	100	95	95	70	95
	II	100	95	95	75	95
	III	95	95	95	85	100
	IV	100	100	100	100	100
	Mean	99	96	96	83	98
11	I	100	80	60	65	100
	II	100	100	100	100	100
	III	100	95	95	80	100
	IV	100	95	95	100	100
	Mean	100	93	88	86	100
12	I	100	95	90	70	100
	II	100	100	100	100	100
	III	100	100	100	100	100
	IV	100	100	100	95	100
	Mean	100	99	98	91	100
13	I	90	95	100	70	100
	II	100	95	100	75	100
	III	100	95	95	85	100
	IV	100	95	95	80	100
	Mean	98	95	98	78	100
14	I	100	90	100	100	100
	II	100	95	100	80	100
	III	100	95	95	85	100
	IV	100	85	90	95	100
	Mean	100	91	96	90	100
15	I	100	95	95	80	100
	II	100	95	95	85	100
	III	100	95	95	80	100
	IV	100	100	100	100	100
	Mean	100	96	96	86	100
16	I	0	0	0	0	0
	II	0	0	0	0	0
	III	0	0	0	0	0
	IV	0	0	0	0	0
	Mean	0	0	0	0	0

[a]Abbreviations: WAP, weeks after planting; SORHA, johnsongrass; PROLO, devil's-claw; SOLEL, silverleaf nightshade; XANST, common cocklebur; AMAPA, Palmer amaranth.

Appendix Table 10. Weed Control ratings 2 WAP for Chickasha Long-term experiment in 2000[a].

Treatment	Replication	SORHA	PROLO	SOLEL	XANST	AMAPA
				%		
1	I	100	20	90	95	40
	II	60	40	20	40	0
	III	80	40	30	60	0
	IV	95	70	30	80	20
	Mean	84	43	43	69	15
2	I	100	70	0	80	100
	II	100	80	75	60	100
	III	95	40	20	70	100
	IV	70	70	20	80	100
	Mean	91	65	29	73	100
3	I	95	75	70	90	30
	II	90	60	50	65	50
	III	95	60	30	80	20
	IV	75	70	40	80	0
	Mean	89	66	48	79	25
4	I	100	100	100	100	100
	II	100	90	95	90	100
	III	95	90	0	95	100
	IV	95	70	40	70	100
	Mean	98	88	59	89	100
5	I	90	60	60	80	20
	II	85	0	40	80	20
	III	90	20	20	50	0
	IV	80	40	20	70	30
	Mean	86	30	35	70	18
6	I	95	0	90	75	100
	II	100	90	80	90	100
	III	100	85	60	70	100
	IV	95	70	100	55	100
	Mean	98	61	83	73	100
7	I	95	0	80	60	0
	II	95	60	80	90	20
	III	90	0	20	0	0
	IV	80	40	30	75	0
	Mean	90	25	53	56	5
8	I	100	70	75	90	100
	II	95	85	80	95	100
	III	100	90	95	90	100
	IV	95	70	10	65	90
	Mean	98	79	65	85	98

Appendix Table 10. (Continued).

Treatment	Replication	SORHA	PROLO	SOLEL	XANST	AMAPA
		%				
9	I	70	0	0	0	95
	II	60	85	70	40	90
	III	90	0	0	0	90
	IV	95	60	20	80	100
	Mean	79	36	23	30	94
10	I	100	80	70	90	100
	II	95	80	80	60	100
	III	95	70	0	80	100
	IV	95	80	30	70	95
	Mean	96	78	45	75	99
11	I	95	80	60	75	95
	II	95	90	0	80	100
	III	95	70	65	80	100
	IV	100	95	90	95	100
	Mean	96	84	54	83	99
12	I	100	95	90	20	100
	II	100	100	100	100	100
	III	100	80	40	20	100
	IV	100	95	20	90	100
	Mean	100	93	63	58	100
13	I	95	90	85	80	100
	II	85	70	70	80	100
	III	95	70	20	65	100
	IV	95	85	10	70	100
	Mean	93	79	46	74	100
14	I	100	95	95	100	100
	II	100	95	80	95	100
	III	75	80	80	75	100
	IV	100	95	70	100	100
	Mean	94	91	81	93	100
15	I	100	90	95	90	100
	II	95	95	90	80	100
	III	95	80	70	60	90
	IV	100	95	95	95	100
	Mean	98	90	88	81	98
16	I	0	0	0	0	0
	II	0	0	0	0	0
	III	0	0	0	0	0
	IV	0	0	0	0	0
	Mean	0	0	0	0	0

[a]Abbreviations: WAP, weeks after planting; SORHA, johnsongrass; PROLO, devil's-claw; SOLEL, silverleaf nightshade; XANST, common cocklebur; AMAPA, Palmer amaranth.

Appendix Table 11. Weed Control ratings 10 WAP for Chickasha Long-term experiment in 2000[a].

Treatment	Replication	SORHA	PROLO	SOLEL	XANST	AMAPA
		%				
1	I	100	100	100	100	95
	II	100	100	100	100	95
	III	100	100	100	100	95
	IV	90	100	100	100	70
	Mean	98	100	100	100	89
2	I	100	95	90	75	100
	II	100	100	100	100	100
	III	100	95	95	80	100
	IV	100	100	100	100	100
	Mean	100	98	96	89	100
3	I	100	100	100	100	90
	II	100	100	100	95	75
	III	95	100	100	100	100
	IV	100	100	100	100	95
	Mean	99	100	100	99	90
4	I	100	100	100	100	100
	II	100	100	100	100	100
	III	100	100	100	100	100
	IV	100	100	100	100	100
	Mean	100	100	100	100	100
5	I	100	100	100	90	90
	II	100	100	100	100	100
	III	100	100	95	100	70
	IV	90	100	100	100	90
	Mean	98	100	99	98	88
6	I	100	95	100	90	95
	II	100	85	90	100	100
	III	100	100	100	100	100
	IV	100	100	100	90	100
	Mean	100	95	98	95	99
7	I	100	100	95	100	70
	II	90	95	95	100	70
	III	100	100	100	100	90
	IV	85	100	100	90	70
	Mean	94	99	98	98	75
8	I	100	100	100	100	100
	II	100	95	100	95	90
	III	100	100	90	100	100
	IV	100	100	100	100	100
	Mean	100	99	98	99	98

Appendix Table 11. (Continued).

Treatment	Replication	SORHA	PROLO	SOLEL	XANST	AMAPA
		%				
9	I	80	0	95	90	100
	II	70	0	10	0	95
	III	90	0	80	0	100
	IV	100	100	100	95	100
	Mean	85	25	71	46	99
10	I	95	100	75	95	100
	II	90	95	100	85	100
	III	90	100	95	90	100
	IV	100	100	0	50	100
	Mean	94	99	68	80	100
11	I	100	100	85	95	100
	II	100	80	10	95	100
	III	100	100	100	100	100
	IV	100	95	90	80	100
	Mean	100	94	71	93	100
12	I	100	98	95	90	100
	II	100	100	100	100	100
	III	100	100	100	100	100
	IV	100	100	100	95	100
	Mean	100	100	99	96	100
13	I	100	100	100	95	100
	II	100	100	95	100	100
	III	100	100	90	30	100
	IV	100	90	90	80	100
	Mean	100	98	94	76	100
14	I	100	100	100	100	100
	II	100	100	100	100	100
	III	100	100	90	80	100
	IV	100	100	100	100	100
	Mean	100	100	98	95	100
15	I	100	100	100	100	100
	II	100	100	100	100	100
	III	100	100	100	100	100
	IV	100	100	100	100	100
	Mean	100	100	100	100	100
16	I	0	0	0	0	0
	II	0	0	0	0	0
	III	0	0	0	0	0
	IV	0	0	0	0	0
	Mean	0	0	0	0	0

[a]Abbreviations: WAP, weeks after planting; SORHA, johnsongrass; PROLO, devil's-claw; SOLEL, silverleaf nightshade; XANST, common cocklebur; AMAPA, Palmer amaranth.

Appendix Table 12. Weed Control ratings 17 WAP for Chickasha Long-term experiment in 2000[a].

Treatment	Replication	SORHA	PROLO	SOLEL	XANST	AMAPA
		%				
1	I	95	100	90	90	85
	II	95	90	95	95	100
	III	90	95	95	95	85
	IV	80	100	100	95	70
	Mean	90	96	95	94	85
2	I	95	95	90	70	95
	II	100	95	80	95	100
	III	95	100	90	70	95
	IV	95	100	100	90	100
	Mean	96	98	90	81	98
3	I	95	90	95	95	95
	II	100	100	95	90	80
	III	90	100	100	95	100
	IV	95	95	90	95	100
	Mean	95	96	95	94	94
4	I	100	100	95	100	95
	II	95	100	100	100	100
	III	100	95	90	90	100
	IV	100	100	100	90	95
	Mean	99	99	96	95	98
5	I	95	100	90	95	95
	II	100	95	95	95	100
	III	90	95	95	90	85
	IV	85	95	85	90	90
	Mean	93	96	91	93	93
6	I	100	95	100	85	95
	II	100	80	95	95	95
	III	100	100	95	95	95
	IV	95	100	100	80	90
	Mean	99	94	98	89	94
7	I	95	100	95	100	90
	II	85	90	90	95	80
	III	95	95	90	80	95
	IV	80	95	95	80	75
	Mean	89	95	93	89	85
8	I	100	90	90	85	95
	II	100	85	95	90	100
	III	100	100	80	95	95
	IV	100	100	100	80	95
	Mean	100	94	91	88	96

Appendix Table 12. (Continued).

Treatment	Replication	SORHA	PROLO	SOLEL	XANST	AMAPA
		%				
9	I	90	0	85	80	100
	II	75	10	0	10	90
	III	80	10	70	10	90
	IV	95	100	100	85	100
	Mean	85	30	64	46	95
10	I	90	95	60	90	95
	II	100	90	95	80	90
	III	80	95	90	95	95
	IV	100	95	10	30	100
	Mean	93	94	64	74	95
11	I	95	90	80	90	100
	II	100	80	0	90	90
	III	95	100	95	95	100
	IV	95	90	80	60	95
	Mean	96	90	64	84	96
12	I	100	90	95	90	95
	II	95	100	100	95	95
	III	100	100	95	90	100
	IV	100	100	100	95	100
	Mean	99	98	98	93	98
13	I	95	95	90	80	100
	II	100	95	90	95	100
	III	100	95	90	20	90
	IV	95	80	85	75	100
	Mean	98	91	89	68	98
14	I	100	90	90	95	95
	II	95	100	100	100	95
	III	95	95	90	70	85
	IV	100	95	95	95	95
	Mean	98	95	94	90	93
15	I	100	90	95	85	90
	II	90	95	95	95	100
	III	100	90	85	90	100
	IV	95	100	95	90	100
	Mean	96	94	93	90	98
16	I	0	0	0	0	0
	II	0	0	0	0	0
	III	0	0	0	0	0
	IV	0	0	0	0	0
	Mean	0	0	0	0	0

[a]Abbreviations: WAP, weeks after planting; SORHA, johnsongrass; PROLO, devil's-claw; SOLEL, silverleaf nightshade; XANST, common cocklebur; AMAPA, Palmer amaranth.

Appendix Table 13. Weed counts for Chickasha Long-term experiment in 1998[a].

Trt.	Rep.	SORHA	PROLO	SOLEL	XANST	AMAPA	CYPES	IPOLA	CHEAL
		no./plot							
1	I	0	68	4	28	0	0	4	0
	II	0	88	0	12	0	4	0	0
	III	0	44	0	20	0	0	12	0
	IV	0	64	64	8	0	0	0	0
	Mean	0	66	17	17	0	1	4	0
2	I	0	140	40	16	0	0	0	0
	II	0	132	12	20	0	20	0	0
	III	0	248	0	112	0	0	0	0
	IV	0	92	36	24	0	0	4	0
	Mean	0	153	22	43	0	5	1	0
3	I	0	84	0	12	0	0	0	0
	II	0	36	0	124	4	0	0	0
	III	0	28	0	20	0	48	12	0
	IV	0	40	12	24	0	0	4	0
	Mean	0	47	3	45	1	12	4	0
4	I	0	36	0	20	0	0	0	0
	II	0	44	0	20	0	0	0	0
	III	0	12	104	4	0	0	0	0
	IV	120	52	0	20	0	0	8	0
	Mean	30	36	26	16	0	0	2	0
5	I	0	220	156	4	0	0	4	0
	II	0	420	8	24	4	0	4	0
	III	0	248	88	52	4	0	4	0
	IV	0	148	16	44	0	0	36	0
	Mean	0	259	67	31	2	0	12	0
6	I	0	40	0	340	0	0	0	0
	II	0	20	0	56	0	0	0	0
	III	0	32	40	208	0	0	0	0
	IV	0	4	4	80	0	0	0	0
	Mean	0	24	11	171	0	0	0	0
7	I	0	88	76	28	0	0	12	0
	II	0	52	68	16	0	0	0	0
	III	0	104	8	32	12	4	4	0
	IV	0	48	20	52	0	0	32	0
	Mean	0	73	43	32	3	1	12	0
8	I	0	248	40	56	0	0	0	0
	II	0	180	0	8	0	0	4	0
	III	0	252	200	36	0	0	8	0
	IV	0	216	52	140	0	0	8	0
	Mean	0	224	73	60	0	0	5	0

Appendix Table 13. (Continued).

Trt.	Rep.	SORHA	PROLO	SOLEL	XANST	AMAPA	CYPES	IPOLA	CHEAL
		no./plot							
9	I	13,081	72	48	168	0	0	0	0
	II	9,120	56	0	300	0	0	0	0
	III	8,280	120	0	376	0	60	0	0
	IV	1,560	56	12	156	0	0	0	0
	Mean	8,010	76	15	250	0	15	0	0
10	I	0	100	36	72	0	0	0	0
	II	0	48	0	108	0	0	0	0
	III	0	88	0	152	0	0	0	0
	IV	0	108	0	44	0	0	0	0
	Mean	0	86	9	94	0	0	0	0
11	I	0	188	100	84	0	0	0	0
	II	240	220	152	12	0	0	0	0
	III	0	344	12	152	0	44	16	0
	IV	0	144	40	52	0	0	0	0
	Mean	60	224	76	75	0	11	4	0
12	I	120	64	0	240	0	0	0	0
	II	0	32	4	24	0	16	0	0
	III	360	32	0	124	0	60	4	0
	IV	1,080	12	8	144	0	0	0	0
	Mean	390	35	3	133	0	19	1	0
13	I	960	96	0	72	0	0	0	0
	II	0	40	0	48	0	80	0	0
	III	240	48	8	92	0	0	0	0
	IV	600	68	44	148	0	0	0	0
	Mean	450	63	13	90	0	20	0	0
14	I	0	60	8	100	0	0	0	0
	II	0	20	0	76	0	0	4	0
	III	0	32	0	204	0	0	0	0
	IV	0	24	0	44	0	0	0	0
	Mean	0	34	2	106	0	0	1	0
15	I	0	20	4	84	0	0	0	0
	II	0	8	4	44	0	0	0	0
	III	0	20	52	188	0	0	0	0
	IV	0	4	4	44	0	4	4	0
	Mean	0	13	16	90	0	1	1	0
16	I	10,921	44	8	88	168	0	0	0
	II	11,761	36	0	300	32	0	0	0
	III	1,352	28	0	272	16	0	0	0
	IV	7,200	36	0	68	64	0	0	0
	Mean	7,809	36	2	182	70	0	0	0

[a]Weed counts were made at 7 weeks after planting. Number/plot is the number of weeds/360m^2 or 12m x 30m. Abbreviations: SORHA, johnsongrass; PROLO, devil's-claw; SOLEL, silverleaf nightshade; XANST, common cocklebur; AMAPA, Palmer amaranth; CYPES, yellow nutsedge; IPOLA, pitted morningglory; CHEAL, common lambsquarters.

Appendix Table 14. Weed counts for Chickasha Long-term experiment in 1999[a].

Trt.	Rep.	SORHA	PROLO	SOLEL	XANST	AMAPA	CYPES	IPOLA	CHEAL
		no./plot							
1	I	4	12	0	0	28	0	8	0
	II	0	20	0	0	20	0	4	0
	III	0	4	0	4	12	0	12	0
	IV	4	20	0	4	8	0	0	0
	Mean	2	14	0	2	17	0	6	0
2	I	0	16	16	0	0	0	0	0
	II	0	8	0	0	0	32	4	0
	III	4	20	0	20	0	0	20	0
	IV	0	28	8	0	0	0	0	0
	Mean	1	18	6	5	0	8	6	0
3	I	0	4	0	4	4	4	0	0
	II	4	0	0	16	16	0	0	0
	III	4	8	0	4	4	40	8	0
	IV	0	8	0	0	0	0	8	0
	Mean	2	5	0	6	6	11	4	0
4	I	0	4	0	0	0	0	4	0
	II	0	36	0	0	0	0	0	0
	III	4	16	8	4	0	0	0	0
	IV	0	4	0	8	4	0	4	0
	Mean	1	15	2	3	1	0	2	0
5	I	4	16	4	0	0	0	16	0
	II	8	44	0	0	12	0	0	0
	III	4	20	4	4	8	0	0	0
	IV	0	24	0	16	28	0	40	0
	Mean	4	27	2	5	12	0	14	0
6	I	0	0	0	8	4	0	0	0
	II	8	0	0	12	0	0	4	0
	III	0	4	4	24	0	0	0	0
	IV	0	0	0	4	0	0	0	0
	Mean	2	1	1	12	1	0	1	0
7	I	8	4	0	0	16	0	0	0
	II	4	16	0	4	0	16	0	0
	III	0	4	0	0	28	4	12	0
	IV	24	8	0	8	12	0	28	0
	Mean	9	8	0	3	14	5	10	0
8	I	0	20	0	32	0	0	4	0
	II	0	0	0	4	0	0	0	0
	III	4	4	8	8	0	16	8	0
	IV	0	12	4	20	4	4	12	0
	Mean	1	9	3	16	1	5	6	0

Appendix Table 14. (Continued).

Trt.	Rep.	SORHA	PROLO	SOLEL	XANST	AMAPA	CYPES	IPOLA	CHEAL
		no./plot							
9	I	4	28	0	160	0	0	0	0
	II	20	32	0	152	0	0	0	0
	III	36	72	0	284	0	64	4	4
	IV	0	24	0	124	0	52	4	0
	Mean	15	39	0	180	0	29	2	1
10	I	4	0	0	8	0	0	0	0
	II	4	0	0	60	0	0	0	0
	III	8	4	0	48	0	4	12	0
	IV	0	0	0	24	0	0	4	0
	Mean	4	1	0	35	0	1	4	0
11	I	0	0	44	52	0	0	4	0
	II	0	8	8	0	0	0	4	0
	III	0	8	4	32	0	24	4	0
	IV	0	0	4	28	0	0	0	0
	Mean	0	4	15	28	0	6	3	0
12	I	8	0	0	80	0	0	0	0
	II	0	0	0	16	0	36	0	0
	III	0	0	0	12	0	20	0	0
	IV	0	0	0	28	0	0	0	0
	Mean	2	0	0	34	0	14	0	0
13	I	16	12	0	32	0	0	0	0
	II	0	0	0	48	0	36	0	0
	III	0	0	0	16	0	0	0	0
	IV	0	0	8	84	0	0	0	0
	Mean	4	3	2	45	0	9	0	0
14	I	0	8	0	4	0	0	0	0
	II	0	4	0	60	0	0	0	0
	III	0	4	0	8	0	0	0	0
	IV	0	8	0	0	0	0	0	0
	Mean	0	6	0	18	0	0	0	0
15	I	0	0	0	0	0	0	0	0
	II	0	4	0	28	0	0	0	0
	III	0	4	4	12	0	0	0	0
	IV	0	12	0	8	0	0	0	0
	Mean	0	5	1	12	0	0	0	0
16	I	140	32	0	8	2,520	0	0	0
	II	296	24	0	112	1,800	0	0	352
	III	212	28	0	168	3,960	0	0	2,280
	IV	2,760	56	0	44	3,120	0	0	2,040
	Mean	852	35	0	83	2,850	0	0	1,168

[a]Weed counts were made at 7 weeks after planting. Number/plot is the number of weeds/360m^2 or 12m x 30m. Abbreviations: SORHA, johnsongrass; PROLO, devil's-claw; SOLEL, silverleaf nightshade; XANST, common cocklebur; AMAPA, Palmer amaranth; CYPES, yellow nutsedge; IPOLA, pitted morningglory; CHEAL, common lambsquarters.

Appendix Table 15. Weed counts for Chickasha Long-term experiment in 2000[a].

Trt.	Rep.	SORHA	PROLO	SOLEL	XANST	AMAPA	CYPES	IPOLA	CHEAL
		no./plot							
1	I	16	0	0	0	16	0	8	0
	II	0	4	0	0	44	0	0	0
	III	0	0	0	0	12	0	8	0
	IV	0	8	0	4	16	0	16	0
	Mean	4	3	0	1	22	0	8	0
2	I	0	0	56	0	0	0	0	0
	II	0	12	0	0	0	152	8	0
	III	0	0	0	60	0	0	8	0
	IV	0	12	4	12	0	0	4	0
	Mean	0	6	15	18	0	38	5	0
3	I	4	0	0	4	8	16	0	0
	II	8	0	0	116	28	0	0	0
	III	20	0	0	12	8	124	0	0
	IV	4	0	0	32	8	0	0	0
	Mean	9	0	0	41	13	35	0	0
4	I	0	0	0	0	0	0	0	0
	II	0	0	0	12	0	0	8	0
	III	0	0	24	0	0	0	4	0
	IV	0	0	0	0	0	12	8	0
	Mean	0	0	6	3	0	3	5	0
5	I	32	4	16	32	20	0	32	0
	II	0	0	0	0	8	0	4	0
	III	0	0	0	0	56	0	4	0
	IV	12	0	0	16	4	8	8	0
	Mean	11	1	4	12	22	2	12	0
6	I	0	0	0	16	0	0	0	0
	II	0	4	0	4	0	0	0	0
	III	0	0	8	60	0	0	0	0
	IV	0	4	0	12	0	0	0	0
	Mean	0	2	2	23	0	0	0	0
7	I	4	0	0	0	100	0	0	0
	II	12	0	0	0	8	52	20	0
	III	8	0	0	0	20	4	0	0
	IV	32	4	0	56	32	0	72	0
	Mean	14	1	0	14	40	14	23	0
8	I	0	0	0	20	0	0	28	0
	II	0	12	0	12	0	0	0	0
	III	4	0	4	4	0	56	36	0
	IV	0	4	0	116	0	12	24	0
	Mean	1	4	1	38	0	17	22	0

Appendix Table 15. (Continued).

Trt.	Rep.	SORHA	PROLO	SOLEL	XANST	AMAPA	CYPES	IPOLA	CHEAL
		no./plot							
9	I	0	136	40	1,060	0	0	0	0
	II	20	160	0	4,080	0	0	0	0
	III	0	64	24	5,520	0	44	0	0
	IV	0	0	4	188	0	4	0	0
	Mean	5	90	17	2,712	0	12	0	0
10	I	0	0	8	156	0	0	0	0
	II	0	4	0	68	0	0	4	0
	III	8	8	80	40	0	0	0	0
	IV	0	12	20	52	0	0	0	0
	Mean	2	6	27	79	0	0	1	0
11	I	0	0	124	16	0	0	0	0
	II	0	0	20	40	0	0	0	0
	III	0	16	64	36	0	16	0	0
	IV	0	0	32	16	0	12	0	0
	Mean	0	4	60	27	0	7	0	0
12	I	0	8	4	440	0	0	0	0
	II	0	4	0	20	0	36	0	0
	III	0	0	0	76	0	8	4	0
	IV	0	0	20	72	0	0	0	0
	Mean	0	3	6	152	0	11	1	0
13	I	4	0	0	32	0	0	0	0
	II	0	0	0	148	0	0	0	0
	III	0	8	0	76	0	0	0	0
	IV	0	0	28	300	0	0	0	0
	Mean	1	2	7	139	0	0	0	0
14	I	0	0	0	8	0	0	0	0
	II	0	0	4	12	0	0	0	0
	III	0	0	0	28	0	0	0	0
	IV	0	0	4	0	0	0	0	0
	Mean	0	0	2	12	0	0	0	0
15	I	0	4	0	8	0	4	0	0
	II	0	4	0	0	0	0	0	0
	III	0	0	12	72	0	0	4	0
	IV	0	0	12	0	0	4	4	0
	Mean	0	2	6	20	0	2	2	0
16	I	112	24	0	16	18,000	0	0	0
	II	352	104	0	264	18,480	0	0	12
	III	80	8	0	172	20,280	0	0	0
	IV	384	20	0	156	15,000	0	0	0
	Mean	232	39	0	152	17,940	0	0	3

[a]Weed counts were made at 7 weeks after planting. Number/plot is the number of weeds/360m^2 or 12m x 30m. Abbreviations: SORHA, johnsongrass; PROLO, devil's-claw; SOLEL, silverleaf nightshade; XANST, common cocklebur; AMAPA, Palmer amaranth; CYPES, yellow nutsedge; IPOLA, pitted morningglory; CHEAL, common lambsquarters.

Appendix Table 16. Cotton lint yield for Chickasha Long-term experiment in 1998, 1999, and 2000[a].

		Cotton lint yield		
Treatment	Replication	1998	1999	2000
		kg/ha		
1	I	419	749	183
	II	428	733	222
	III	401	822	343
	IV	404	606	151
	Mean	413	727	225
2	I	429	628	186
	II	328	738	248
	III	441	461	106
	IV	330	600	177
	Mean	382	607	179
3	I	234	860	362
	II	371	635	293
	III	400	727	317
	IV	329	597	181
	Mean	334	705	288
4	I	496	768	311
	II	392	786	334
	III	333	551	124
	IV	511	525	75
	Mean	433	658	211
5	I	325	790	335
	II	334	721	348
	III	463	516	150
	IV	386	597	110
	Mean	377	656	236
6	I	571	598	115
	II	422	607	313
	III	412	541	248
	IV	325	407	171
	Mean	433	538	212
7	I	504	782	204
	II	425	687	285
	III	428	825	333
	IV	397	606	221
	Mean	438	725	260
8	I	531	762	180
	II	333	752	295
	III	267	781	189
	IV	526	512	124
	Mean	414	701	197

Appendix Table 16. (Continued).

Treatment	Replication	Cotton lint yield		
		1998	1999	2000
		kg/ha		
9	I	149	325	50
	II	202	300	82
	III	290	221	109
	IV	466	194	121
	Mean	277	260	90
10	I	408	625	295
	II	366	647	389
	III	357	549	234
	IV	389	512	237
	Mean	380	583	289
11	I	221	636	230
	II	420	562	180
	III	374	636	101
	IV	279	587	232
	Mean	323	605	186
12	I	390	466	179
	II	323	673	300
	III	467	663	449
	IV	320	467	190
	Mean	375	567	280
13	I	206	709	305
	II	208	685	302
	III	420	542	105
	IV	342	385	181
	Mean	294	580	223
14	I	520	711	360
	II	454	654	241
	III	501	607	213
	IV	421	442	179
	Mean	474	604	248
15	I	422	664	269
	II	557	617	278
	III	548	559	213
	IV	433	659	255
	Mean	490	625	254
16	I	25	332	0
	II	117	168	0
	III	202	40	0
	IV	69	90	0
	Mean	103	157	0

[a]Rows 5, 6, 7, and 8 were stripper harvested.

Appendix Table 17. Mean control of five weed species 2 weeks after planting with herbicide programs in glyphosate-tolerant cotton.

				SORHA[a]		PROLO		SOLEL		XANST		AMAPA	
Trt.[a,b]	Herbicide	Rate	Timing[b]	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
		kg ai/ha		%									
1,3,5,7	Glyphosate	1.1	POST	62b[c]	67b	18c	41b	53b	44bc	55a-c	68b	18b	16b
2,4,6,8	Pend fb	1.4	PPI										
	glyphosate	1.1	POST	98a	96a	68b	73a	56b	59b	57a-c	80ab	100a	99a
9	Pend fb	1.4	PPI										
	prometryn	2.2	PRE	95a	79b	88a	36b	78ab	23c	33c	30c	100a	94a
10,13	Pend fb	1.4	PPI										
	prometryn fb	2.2	PRE										
	pyrithiobac	0.07	POST	92a	94a	82a	78a	71ab	46b	46c	74a	98a	99a
11,12	Pend fb	1.4	PPI										
	prometryn +	2.2											
	pyrithiobac fb	0.05	PRE										
	pyrithiobac	0.07	POST	99a	98a	95a	88a	77ab	58b	81ab	70a	100a	99a
14,15	Pend fb	1.4	PPI										
	pyrithiobac fb	0.05	PRE										
	glyphosate	1.1	POST	99a	96a	93a	91a	86a	84a	64a-c	87a	100a	99a
16	Untreated Check			0c	0c	0c	0c	0c	0d	0d	0d	0b	0c

[a]Abbreviations: Trt, treatment; pend, pendimethalin; fb, followed by; PPI, preplant incorporated; PRE, preemergence; POST, postemergence; SORHA, johnsongrass; PROLO, devil's-claw; SOLEL, silverleaf nightshade; XANST, common cocklebur; AMAPA, Palmer amaranth.

[b]Nonionic surfactant at 0.25% v/v was included with pyrithiobac POST. POST treatments were applied 4 weeks after planting.

[c]Means within the same column followed by the same letter were not significantly different as determined by Fisher's protected LSD test at P = 0.05. No 2 WAP data was collected in 1998.

Appendix Table 18. Mean control of five weed species 17 weeks after planting with herbicide programs in glyphosate-tolerant cotton.

				SORHA[a]			PROLO			SOLEL			XANST			AMAPA[a]	
Trt.[a,b]	Herbicide	Rate	Timing[b]	1998	1999	2000	1998	1999	2000	1998	1999	2000	1998	1999	2000	1999	2000
		kg ai/ha		%													
1,3,5,7 **1,3,5,7**	Gly	1.1	POST-1	97a[c]	96b	92b	50bc	91a	96a	88a	95a	93a	98a	92a	92a	84b	89b
2,4,6,8 **2,4,6,8**	Pend fb	1.4	PPI														
	gly	1.1	POST-1	97a	98a	98a	60ab	92a	96a	61b	90a	94a	86ab	89a	88a	98a	96a
9 **9**	Pend fb	1.4	PPI														
	pro fb	2.2	PRE														
	quiz/none	0.09	POST-2	83c	91c	85c	18c	68b	30b	66ab	89a	64c	8d	25c	46c	99a	95ab
10 **10,13**	Pend fb	1.4	PPI														
	pro fb	2.2	PRE														
	quiz/	0.09/															
	pyri	0.07	POST-1	98a	98ab	95a	31b	96a	93a	99ab	97a	76bc	25de	80b	71b	99a	96a
11 **11,12**	Pend fb	1.4	PPI														
	pro +	2.2															
	pyri fb	0.05	PRE														
	quiz/	0.09/															
	pyri	0.07	POST-1	93a	100a	98a	20b	96a	94a	39c	93a	80a-c	63bc	89b	88a	100a	97a
12	Pend fb	1.4	PPI														
	pro +	2.2															
	pyri fb	0.05	PRE														
	quiz fb	0.05	POST-1														
	quiz	0.05	POST-2														
	pyri	0.07	POST-3	84c	100a	98a	70ab	96a	94a	73ab	93a	80a-c	38cd	89b	88a	100a	97a

Appendix Table 18. (Continued).

				SORHA[a]			PROLO			SOLEL			XANST			AMAPA[a]	
Trt.[a,b]	Herbicide	Rate	Timing[b]	1998	1999	2000	1998	1999	2000	1998	1999	2000	1998	1999	2000	1999	2000
		kg ai/ha									%						
13	Pend fb	1.4	PPI														
	pro fb	2.2	PRE														
	quiz fb	0.05	POST-1														
	quiz	0.05	POST-2														
	pyri	0.07	POST-3	91b	98ab	95a	23bc	96a	93a	70ab	97a	76bc	43c	80b	71b	99a	96a
14,15 **14,15**	Pend fb	1.4	PPI														
	pyri fb	0.05	PRE														
	gly fb	1.1	POST-1														
	quiz/none	0.09	POST-2	99a	100a	97a	84a	94a	94a	87ab	96a	93ab	94a	88b	90 a	100 a	95 a
16,**16**	Untreated Check			0d	0d	0d	0c	0c	0c	0d	0b	0d	0d	0d	0 d	0 c	0 c

[a]Abbreviations: Pend, pendimethalin; pro, prometryn; gly, glyphosate; pyri, pyrithiobac; quiz, quizalofop; fb, followed by; PPI, preplant incorporated; PRE, preemergence; POST-1 first postemergence timing; POST-2, second postemergence timing; POST-3, third postemergence timing; SORHA, johnsongrass; PROLO, devil's-claw; SOLEL, silverleaf nightshade; XANST, common cocklebur; AMAPA, Palmer amaranth. POST-1 treatments were applied 4 weeks after planting, while POST-2 were applied 6 weeks after planting. AMAPA was not rated in 1998 due to a sparse population.

[b]Crop oil concentrate at 1% v/v was included with quizalofop POST, while nonionic surfactant was included with pyrithiobac POST. Quiz and gly was applied POST in 1998 due to high johnsongrass populations. Pyrithiobac and gly was applied POST in 1999 and 2000 due to high broadleaf weed populations and absence of johnsongrass. 1998 treatments are regular text, 1999 and 2000 treatments are bold text.

[c]Means within the same column followed by the same letter were not significantly different as determined by Fisher's protected LSD test at P = 0.05.

Appendix Table 19. Herbicide treatments for Altus morningglory experiment 1999 and 2000.

Trt.[a]	PPI[b]	PRE	POST-1	POST-2	POST-3	POST-DIRECT
1	Trif (1.1)[b]	Clom (1.1)	Gly (1.1)	None	None	None
2	Trif (1.1)	None	Gly (1.1)	Gly (1.1)	None	Gly (1.1)
3	Trif (1.1)	None	Gly (1.1)	None	None	None
4	Trif (1.1)	None	Gly (1.1)	Gly (1.1)	None	None
5	Trif (1.1)	Fluo (1.9)	Gly (1.1)	None	None	None
6	Trif (1.1)	Pro (2.2)	Gly (1.1)	None	None	None
7	Trif (1.1)	Pro (2.2)	Gly (0.8)	None	None	Gly (1.1)
8	Trif (1.1)	Fluo (1.9)	Gly (1.1)	None	None	Gly (1.1)
9	Trif (1.1)	Pyri (0.05)	None	None	None	Gly (1.1)
10	Trif (1.1)	None	Gly (1.1)	Pyri (0.07)	None	None
11	Trif (1.1)	None	Gly (1.1) + pyri (0.04)	None	None	Gly (1.1)
12	Trif (1.1)	None	Gly (1.1)	Pyri (0.04) + MSMA (1.1)	None	None
13	Trif (1.1)	Pro (2.2) + pyri (0.04)	None	None	None	None
14	Trif (1.1)	Fome (0.4)	None	None	None	Lac (0.2)
15	Trif (1.1)	Pro (2.2)	None	None	None	Oxy (0.6)
16	Trif (1.1)	Fluo (1.9)	None	Pyri (0.07)	None	None
17	Trif (1.1)	None	Pyri (0.1)	None	None	None
18	Trif (1.1)	None	Pyri (0.07)	Pyri (0.07)	None	None
19	Trif (1.1)	Pyri (0.05)	None	None	None	Pro (0.8) + MSMA (1.1)
20	Trif (1.1)	Clom (1.1)	None	None	Gly (1.7)	None
21	Trif (1.1)	None	None	None	None	None

[a]NIS at 0.25% v/v was applied with pyrithiobac POST treatments and with all POST-DIRECT treatments except lactofen. Crop oil concentrate at 1.17 L/ha was applied with lactofen POST-DIRECT. Clethodim was applied at 0.28 kg ai/ha POST for johnsongrass control if needed.

[b]Abbreviations: Trt, treatment; PPI, preplant incorporated; PRE, preemergence; POST-1, first postemergence timing; POST-2, second postemergence timing; POST-3, third postemergence timing; POST-DIRECT, postemergence directed; Clom, clomazone; Fome, fomesafen; Fluo, fluometuron; Gly, glyphosate; Lac, lactofen; Oxy, oxyfluorfen; Pro, prometryn; Pyri, pyrithiobac; Trif, trifluralin. Values in parentheses represent herbicide rate in kg ai/ha.

Appendix Table 20. Pitted morningglory control 2, 4, 6, and 10 WAP in the Altus irrigated cotton experiment in 1999 and 2000.[a]

		2 WAP	4 WAP		6 WAP		10 WAP	
Trt.	Rep.	1999	1999	2000	1999	2000	1999	2000
		%						
1	I	80	90	90	85	90	80	85
	II	90	90	95	98	40	75	50
	III	60	80	75	80	90	30	65
	IV	90	98	90	98	70	65	30
	Mean	80	90	88	90	73	63	58
2	I	0	90	65	90	70	90	50
	II	0	75	95	85	70	90	90
	III	0	70	60	85	25	85	80
	IV	0	85	75	65	75	60	90
	Mean	0	80	74	81	60	81	78
3	I	0	50	70	65	75	30	65
	II	0	70	90	80	65	70	50
	III	0	70	70	70	50	60	85
	IV	0	85	80	75	75	20	20
	Mean	0	69	78	73	66	45	55
4	I	0	70	80	85	90	90	70
	II	0	40	80	80	70	75	60
	III	0	65	75	85	75	75	10
	IV	0	75	85	75	75	70	80
	Mean	0	63	80	81	78	78	55
5	I	40	65	80	95	95	95	95
	II	30	85	90	75	90	90	80
	III	35	75	90	95	85	90	75
	IV	55	90	60	95	40	70	20
	Mean	40	79	80	90	78	86	68
6	I	70	90	90	70	90	65	90
	II	85	90	95	65	85	70	70
	III	90	98	80	85	85	60	40
	IV	90	98	80	90	70	50	30
	Mean	84	94	86	78	83	61	58
7	I	90	95	80	95	80	90	95
	II	90	98	95	95	80	95	85
	III	90	95	90	85	85	80	90
	IV	85	95	80	90	75	70	50
	Mean	89	96	86	91	80	84	80
8	I	70	90	70	80	75	95	95
	II	60	95	90	95	90	95	95
	III	20	85	70	75	80	95	10
	IV	20	70	95	95	80	90	70
	Mean	43	85	81	86	81	94	68

Appendix Table 20. (Continued).

		2 WAP	4 WAP		6 WAP		10 WAP	
Trt.	Rep.	1999	1999	2000	1999	2000	1999	2000
					%			
9	I	45	25	70	30	30	50	75
	II	60	60	80	30	40	10	55
	III	40	25	40	30	10	20	20
	IV	30	40	0	30	10	50	10
	Mean	44	38	48	30	23	33	40
10	I	0	85	30	98	80	90	35
	II	0	75	95	95	80	80	60
	III	0	70	50	85	80	90	70
	IV	0	55	90	75	70	65	65
	Mean	0	71	66	88	78	81	58
11	I	0	45	75	10	70	50	60
	II	0	80	95	80	80	85	70
	III	0	80	80	70	70	70	95
	IV	0	95	95	95	70	90	25
	Mean	0	75	86	64	73	74	63
12	I	0	70	60	95	65	95	40
	II	0	75	70	85	85	80	50
	III	0	75	90	85	80	90	45
	IV	0	80	80	90	80	85	75
	Mean	0	75	75	89	78	88	53
13	I	85	80	70	40	85	70	70
	II	80	75	60	35	70	15	30
	III	85	75	60	60	20	10	30
	IV	80	85	70	40	60	10	50
	Mean	83	79	65	44	59	26	45
14	I	75	20	65	30	90	60	40
	II	60	35	30	20	40	10	40
	III	65	20	0	30	0	30	0
	IV	30	20	20	20	20	10	20
	Mean	58	24	29	25	38	28	25
15	I	60	25	60	40	60	20	20
	II	90	70	85	60	20	60	40
	III	70	30	80	20	70	20	80
	IV	90	90	70	95	70	85	50
	Mean	78	54	74	54	55	46	48
16	I	55	30	50	70	90	70	90
	II	60	15	75	70	90	30	90
	III	30	25	40	65	98	40	90
	IV	60	60	30	80	80	40	75
71	Mean	51	33	49		90	45	86

Appendix Table 20. (Continued).

		2 WAP	4 WAP		6 WAP		10 WAP	
Trt.	Rep.	1999	1999	2000	1999	2000	1999	2000
		%						
17	I	0	60	95	95	85	75	90
	II	0	85	70	90	90	60	80
	III	0	85	85	95	80	85	85
	IV	0	75	90	90	90	65	80
	Mean	0	76	85	93	86	71	84
18	I	0	50	80	90	95	90	85
	II	0	85	95	95	95	90	90
	III	0	90	85	98	95	90	95
	IV	0	70	95	80	98	75	98
	Mean	0	74	89	91	96	86	92
19	I	40	20	40	25	20	20	40
	II	20	15	80	10	10	0	20
	III	30	10	50	25	60	10	10
	IV	40	30	30	30	10	10	5
	Mean	33	19	50	23	25	10	19
20	I	50	10	70	20	80	70	85
	II	40	20	40	20	10	65	10
	III	30	0	25	10	0	60	20
	IV	60	20	60	10	20	70	20
	Mean	45	13	49	15	28	66	34
21	I	0	0	0	0	0	0	0
	II	0	0	0	0	0	0	0
	III	0	0	0	0	0	0	0
	IV	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0	0

[a]Abbreviations: Trt, treatment; rep, replication; WAP, weeks after planting. In 2000, no 2 WAP data were collected due to the lack of an activating rainfall for the preemergence treatments.

Appendix Table 21. Cotton lint yield for Altus irrigated experiment in 1999 and 2000.

Treatment	Replication	Cotton lint yield	
		1999	2000
		kg/ha	
1	I	668	418
	II	941	608
	III	876	374
	IV	319	224
	Mean	701	406
2	I	647	661
	II	846	654
	III	803	740
	IV	585	740
	Mean	720	699
3	I	522	245
	II	549	332
	III	756	46
	IV	134	101
	Mean	490	181
4	I	944	457
	II	990	569
	III	1,065	483
	IV	474	476
	Mean	868	496
5	I	1,255	638
	II	828	651
	III	1,099	522
	IV	613	353
	Mean	949	541
6	I	687	319
	II	652	571
	III	904	430
	IV	454	286
	Mean	674	402
7	I	761	661
	II	828	610
	III	1,053	755
	IV	1,098	484
	Mean	935	628
8	I	884	569
	II	688	647
	III	772	600
	IV	1,009	405
	Mean	838	556

Appendix Table 21. (Continued).

Treatment	Replication	Cotton lint yield 1999	2000
		kg/ha	
9	I	681	358
	II	236	405
	III	218	402
	IV	249	188
	Mean	346	339
10	I	621	624
	II	1,029	710
	III	886	533
	IV	711	345
	Mean	812	553
11	I	547	399
	II	1,238	587
	III	936	550
	IV	679	231
	Mean	850	442
12	I	1,209	513
	II	1,170	554
	III	740	540
	IV	1,083	576
	Mean	1,051	546
13	I	628	280
	II	377	386
	III	393	67
	IV	463	488
	Mean	465	306
14	I	624	305
	II	227	373
	III	47	147
	IV	18	100
	Mean	229	231
15	I	399	326
	II	479	277
	III	209	670
	IV	522	482
	Mean	402	439
16	I	805	632
	II	552	755
	III	405	743
	IV	156	399
	Mean	480	632

Appendix Table 21. (Continued).

Treatment	Replication	Cotton lint yield 1999	2000
		kg/ha	
17	I	1,185	638
	II	876	589
	III	585	682
	IV	789	384
	Mean	859	573
18	I	1,058	679
	II	1,080	538
	III	644	814
	IV	651	562
	Mean	858	648
19	I	209	252
	II	93	254
	III	93	307
	IV	165	261
	Mean	140	269
20	I	394	299
	II	175	302
	III	327	225
	IV	301	177
	Mean	299	251
21	I	0	261
	II	0	166
	III	59	95
	IV	108	150
	Mean	42	168

VITA

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