ECONOMIC ASSESSMENT OF WEED MANAGEMENT FOR TRANSGENIC AND NON-TRANSGENIC COTTON (*GOSSYPIUM HIRSUTUM*) IN CONVENTIONAL AND NO TILLAGE SYSTEMS

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ABSTRACT

Studies were conducted to evaluate weed management programs in non-transgenic, Buctril-resistant, and Roundup-resistant cotton in no-tillage and conventional-tillage environments. Tillage did not affect the level of weed control provided by herbicides evaluated. Early season stunting in no-tillage cotton was 3% regardless of herbicide system and was transient. Conventionally tilled cotton yielded 17% more on average than no-tillage cotton. Excellent (> 90%) velvetleaf, common lambsquarters, jimsonweed, *Ipomoea* morningglory spp., and prickly sida control was achieved with programs containing Staple, Buctril, and Roundup. Residual herbicide inputs were necessary for adequate large crabgrass and goosegrass control. Buctril and Staple postemergence did not control sicklepod unless supplemented with MSMA and followed by a late post-directed treatment of Bladex plus MSMA. Herbicide programs that included Roundup controlled sicklepod regardless of late postemergence-directed treatment. When Cotoran applied preemergence was included in Buctril programs, net returns were at least \$375 A^{-1} and not different from the higher-yielding programs in non-transgenic cotton. Late-season weed control was usually greater than 90% from Roundup programs and net returns from Roundup programs were as high or higher than net returns from programs that utilized mid-season treatments of Buctril, Staple, or Cotoran plus MSMA.

INTRODUCTION

Preplant-incorporated (PPI) herbicides and cultivation, formerly the primary methods of weed control in cotton (*Gossypium hirsutum* L.), have recently been augmented with new postemergence over-the-top (POT) herbicide options. In addition to cultivation, which precludes no-tillage cotton production, formerly available postemergence weed control options usually required high use rates of relatively non-selective herbicides and specialized equipment for postemergence-directed (PD) applications (Wilcut et al. 1996, 1997). Heightened concerns over the environmental impact of pesticides and conventional tillage practices have increased demand for no-tillage crop production (Wauchope et al. 1985).

Poor weed control was previously cited as the greatest limitation to successful cotton production in conservation-tillage (McWhorter and Jordan 1985). Recent developments in POT technology have allowed cotton producers to explore reduced-tillage or no-tillage production options and total postemergence weed management (Culpepper and York 1997, 1999; Wilcut et al. 1996). Herbicides registered for POT broadleaf control in cotton include Buctril, Roundup, MSMA, and Staple (Culpepper and York 1997, 1999; Jordan et al. 1997; Wilcut and Askew 1999). Roundup and MSMA control many broadleaf and grass weeds; however, when applied POT, lower rates of MSMA are required to minimize crop injury (Anonymous 1999). Buctril and Staple control many broadleaf weeds, but do not control most grass weeds (Culpepper and York 1997; Jordan et al. 1993; Paulsgrove and Wilcut 1999). As the weed control spectrums of these herbicides differ, the need for additional inputs of preemergence (PRE) and/or PD herbicides also varies.

Low commodity prices and a competitive market place requires cotton producers to reduce inputs and increase efficiency of cotton production. No-tillage cotton production may reduce inputs and save time by eliminating tillage requirements. Previous studies have evaluated herbicide systems in non-transgenic, Buctril-resistant, and Roundup-resistant cotton in conventionally tilled seedbeds and cultivation early and late in the season (Culpepper and York 1999). Since many producers are adopting conservation tillage systems with the advent of herbicides registered for POT application in cotton, an economic evaluation of cotton cultivars in programs employing POT herbicides in no-tillage and conventional-tillage production is needed. Studies were conducted to compare weed control, cotton response and yield, and net economic returns in no-tillage and conventional-tillage cotton using Buctril, Roundup, MSMA, and Staple herbicide programs.

MATERIALS AND METHODS

Site Preparation

Field studies were established in 1997 and 1998 at the Central Crops Research Station located near Clayton, NC and at the Cherry Farm Unit near Goldsboro, NC. Soils were a Norfolk loamy sand (fine-loamy, siliceous, thermic Typic Paleudults) with 1.8% organic matter and pH 5.8 at Clayton and a Wickham loamy sand (fine-loamy, mixed, thermic Typic Hapludults) with 2.1% organic matter and pH 5.2 at Goldsboro.

Land preparation began with desiccation of a wheat (*Triticum aestivum* L.) cover crop with Roundup at 1 lb ai A^{-1} 2 wk prior to planting. For conventionally tilled plots, soil was disked and smoothed, and PPI herbicides were applied and incorporated 1.5 to 3 in deep. Soil was then bedded at Clayton only. In no-tillage plots, crop seed was planted directly into cotton residue on existing beds from the previous season. Cotton cultivars, 'Paymaster 1220RR' (Roundup-resistant), 'Stoneville BXN47' (Buctril-resistant), and 'Stoneville 474' (non-transgenic), were planted on May 21, 1997 and May 5, 1998 at Clayton and May 28, 1997 and June 2, 1998 at Goldsboro. Cotton was seeded at 4.5 seed ft^{-1} of row. Plots were 25 ft long and four 38-in rows wide.

Experimental Design and Herbicide Programs

The experimental design was a randomized complete block with each block replicated three times. A split-plot treatment arrangement with main plot tillage and subplot herbicide program was utilized to facilitate tillage and planting. Fourteen herbicide programs were evaluated in each main plot and differ between the tillage regimes only with respect to Prowl application method. Prowl was applied PPI in conventional-tillage plots and PRE in no-tillage plots.

Three cotton cultivars were required to evaluate the fourteen herbicide programs in each tillage regime. Six herbicide programs in non-transgenic cotton included: no herbicide treatment, Prowl at 1 lb ai A^{-1} (PPI in tilled plots or PRE in non-tilled plots) plus Cotoran at 1 lb ai A^{-1} PRE, Prowl and Cotoran PRE followed by (fb) Cotoran at 1 lb ai A^{-1} plus MSMA at 2 lb ai A^{-1} PD, Prowl and Cotoran PRE fb Cotoran and MSMA PD fb Bladex at .8 lb ai A^{-1} plus MSMA at 2 lb ai A^{-1} late PD, Prowl and Cotoran PRE fb Staple POT at .06 lb ai A^{-1} fb Bladex plus MSMA late PD, and the aforementioned program with MSMA at .75 lb A^{-1} mixed with Staple POT. Herbicide programs for Buctril-resistant cotton included: Prowl PRE or PPI fb Buctril at .5 lb ai A^{-1} POT as needed spray (ANS) for weed control fb Bladex plus MSMA late PD, the aforementioned program with MSMA at 840 g ha^{-1} mixed with the first Buctril application, Prowl and Cotoran PRE fb Buctril POT fb Bladex plus MSMA late PD, and the aforementioned program with MSMA at .75 lb A^{-1} mixed with Buctril POT. Herbicide programs for Roundup-resistant cotton included: Prowl and Cotoran PRE fb Roundup at .75 lb ai A^{-1} ANS (applied POT if cotton had less than five leaves and PD if cotton had more than four leaves), Prowl and Cotoran PRE fb Roundup POT fb Bladex plus MSMA late PD, Roundup ANS, and Roundup ANS fb Bladex plus MSMA late PD.

Buctril and Roundup ANS treatments were applied when visually estimated weed control dropped below 80% (Askew and Wilcut 1999). The number of ANS applications necessary varied from two to four depending on weed management program and location. In all instances, the first Roundup ANS treatment was applied POT of two- to four-leaf cotton. Subsequent ANS treatments were applied PD to minimize Roundup contact with cotton foliage as specified by the Roundup label (Anonymous 1999).

Application Information
Nonionic surfactant[1] at 0.25% (v/v) was included with PD, POT, and late PD herbicides except Buctril and Roundup. Herbicides were applied with a compressed-CO^2 sprayer calibrated to 15 gal A^{-1} at 21 PSI. Application dates were May 25 to June 2 (PPI and PRE), June 15 to June 20 (POT, PD, and first ANS), and June 29 to July 16 (late PD) depending on location and year.

Data Collection
Late-season weed control, based on leaf discoloration and biomass reduction, was estimated visually on a scale of 0 to 100 where 0 = no control and 100 = death of all plants (Frans et al. 1986). Three separate injury parameters (stunting, discoloration, and stand reduction) were visually estimated for cotton 1 to 2 wk after POT treatment and late in the season. Overall injury was also estimated as a combination of the three injury parameters. The two center rows of each plot were harvested once with a spindle picker modified for small-plot harvesting. Lint and seed yield were adjusted based on the 2-year statewide average percent lint composition of each cultivar (Bowman 1998).

Economic Analysis
An enterprise budget developed by the North Carolina Cooperative Extension Service (Brown and Cole 1997) that included operating inputs, fixed costs, and cotton yield value was modified to represent the various weed management programs. Cost of seed, technology fee, herbicides, and adjuvants were based on averages of quoted prices from two local agricultural suppliers. Planting costs including costs of seed and technology fees were \$11.80 A^{-1}, \$18.00 A^{-1}, and \$22.00 A^{-1} for non-transgenic, Buctril-resistant, and Roundup-resistant programs, respectively. Estimated costs of POT, PD, and PPI applications were \$1.20, \$2.20, and \$3.20 A^{-1}, respectively, (Anonymous 1998b; Askew and Wilcut 1999). Chemical costs per A were as follows: Buctril, \$12.80; Bladex, \$5.40; Cotoran, \$8.90; Roundup, \$7.60; MSMA POT, \$1.90; MSMA PD, \$5.20; Prowl, \$7.70; Staple, \$21.50; and nonionic surfactant, \$0.60. Crop value was adjusted in the budget by multiplying the lint yield from each herbicide program by an estimated market price of \$0.60 lb^{-1}.

Statistical Analysis
Nontreated control plots could not be harvested due to weed interference with machinery. Therefore, the nontreated control was removed prior to analysis to improve homogeneity of variance. Percent data were arcsine square-root transformed to stabilize variance. Data were subjected to ANOVA and treatment sums of squares were partitioned to reflect the split-plot treatment design and year-location effects (McIntosh 1983). Where year and location effects were not significant, data were pooled. Data were analyzed separately if significant year by location effects resulted. Appropriate transformed means were separated using Fisher's Protected LSD at $P = 0.05$, however, non-transformed means are presented for clarity.

RESULTS AND DISCUSSION

Cotton Response

Early season injury was minimal. Averaged over years, locations, and tillage options, Prowl and Cotoran PRE fb Cotoran plus MSMA PD discolored cotton 2% (data not shown). No other herbicide program significantly discolored cotton (data not shown) and the slight discoloration, chlorosis on the lower cotton leaves, was transient and indicative of a urea herbicide (Ahrens 1994; Anonymous 1998a).

A tillage main effect existed for early season cotton stunting (data not shown). Averaged over years, locations, and treatments, non-tilled cotton was stunted 3% while no stunting occurred in conventionally tilled cotton (data not shown). This stunting may be due to cooler soil temperature in non-tilled cotton. Soil-temperatures were 3 C lower in non-tilled compared to conventionally tilled cotton at planting (data not shown). Soil warming is often slower in non-tilled environments, and cool temperatures may delay cotton development (McWhorter and Jordan 1985). The stunting observed in non-tilled cotton could explain a yield reduction observed between non-tilled and conventionally tilled cotton to be discussed later. No significant stand reduction or overall injury was observed early season and no differences were noted in cotton response late in the season (data not shown).

Weed Control

A herbicide-program main effect was observed on all weed control data, and tillage did not affect weed control by the herbicides evaluated (Table 1).

Prowl and Cotoran PRE controlled common lambsquarters 87% while control was > 98% with programs that contained POT or PD herbicides (data not shown). Buctril and Roundup control common lambsquarters (Askew and Wilcut 1999; Culpepper and York 1997; Paulsgrove and Wilcut 1999). In Staple programs, Prowl, Cotoran, and Bladex controlled common lambsquarters.

The soil-applied only program controlled goosegrass 79% late in the season (Table 1). Subsequent application of Cotoran plus MSMA PD or Staple POT improved control to at least 88%. The program containing a single POT application of Buctril plus MSMA with soil-applied and late PD herbicides improved control (95%) compared to a similar program that excluded Cotoran and contained ANS Buctril applications (87%). Goosegrass was controlled at least 94% when soil-applied or late PD herbicides were included with either Roundup POT or ANS while Roundup ANS alone controlled goosegrass 86% late in the season.

Postemergence herbicide-containing programs controlled jimsonweed at least 98% (data not shown). Prowl and Cotoran PRE controlled large crabgrass 91% late in the season (data not shown). Programs containing Cotoran and MSMA PD, Staple plus MSMA POT, or Buctril plus MSMA POT improved control compared to soil-applied herbicides alone.

Soil-applied herbicides alone controlled prickly sida 55% late-season (Table 1). Programs using Cotoran plus MSMA PD controlled prickly sida 86% without late PD herbicides and 98% with Bladex plus MSMA late PD. Staple, Buctril, and Roundup programs controlled prickly sida at least 96%. Prowl and Cotoran do not provide acceptable control of prickly sida (Paulsgrove and Wilcut 1999). Herbicide systems that included Buctril, Roundup, and Staple in conjunction with cultivation controlled prickly sida at least 97% in other studies (Culpepper and York 1999).

Prowl and Cotoran PRE controlled morningglory species no more than 52% (Table 1). Programs using Cotoran plus MSMA PD controlled these species 86 to 92% without late PD herbicides and 94 to 99% when Bladex plus MSMA was applied late PD. Buctril, Staple, and Roundup programs controlled morningglory at least 93%. Although Staple controls tall morningglory less than other *Ipomoea* spp. (Sunderland et al. 1995), plants were suppressed such that control was improved following Bladex plus MSMA late PD (data not shown).

Soil-applied herbicides controlled velvetleaf only 56% and control increased to 80 and 91% with the addition of Cotoran plus MSMA PD and Cotoran plus MSMA PD fb Bladex plus MSMA late PD, respectively (Table 1). Staple, Buctril, and Roundup programs controlled velvetleaf at least 98%.

Prowl plus Cotoran alone controlled smooth pigweed 81% and control was increased with all other herbicide programs (Table 1). Staple and Roundup programs controlled smooth pigweed more than Buctril programs that did not contain Cotoran PRE. Buctril does not provide complete control of smooth pigweed (Culpepper and York 1997).

Soil-applied herbicides alone controlled sicklepod 34% (Table 1). Cotoran plus MSMA PD following soil-applied herbicides controlled sicklepod 64% and the addition of Bladex plus MSMA late PD improved control (80%). In programs where Staple POT was applied alone, sicklepod control was 59% and the addition of MSMA to Staple improved control (80%). Likewise, Buctril programs controlled more sicklepod when MSMA was included with early POT Buctril application. When MSMA was included with either Staple or Buctril, sicklepod was stunted such that a height differential was obtained between cotton and sicklepod. This height differential allowed for more effective control by subsequent application of Cotoran or Bladex PD. Sicklepod control by late PD herbicidal applications was increased when MSMA was added to Buctril (Paulsgrove et al. 1998) and Staple (Wilcut and Hinton 1997) EPOST. Roundup programs controlled sicklepod at least 97%.

Cotton Yield

In non-transgenic cotton, the soil-applied-only program of Prowl fb Cotoran yielded less (110 lb A^{-1} lint) than all other programs (data not shown). When Cotoran plus MSMA PD was applied following soil-applied herbicides, lint yield increased 70 lb A^{-1}. The addition of Bladex plus MSMA late PD following the early PD herbicides did not further improve yield.

In Buctril-resistant cotton in 1997, programs using Buctril ANS without Cotoran PRE resulted in yield equivalent to programs using single applications of Buctril with Cotoran PRE (data not shown). Early season weed interference reduces more cotton yield than late-season interference (Buchanan and Burns 1970) and may have reduced yield value from multiple Buctril applications when Cotoran PRE was not used. Yields from Buctril programs were not different from the higher yielding programs in non-transgenic cotton in 1997. In 1998, exclusion of Cotoran from Buctril ANS systems decreased yield compared to Buctril programs that contained Cotoran PRE (data not shown).

In 1997, Roundup programs had equivalent yield and averaged 230 lb lint A^{-1} regardless if soil-applied or late PD residual herbicides were used (data not shown). These yields were not different from the higher yielding Buctril or Staple programs. In 1998, weed densities were higher and the Roundup ANS program that contained soil-applied Prowl and Cotoran yielded more than Roundup-only or Roundup fb Bladex plus MSMA late PD programs. Roundup programs that did not contain soil-applied herbicides resulted in decreased yield that may be attributed to early season interference from weeds prior to the first Roundup applications (Buchanan and Burns 1970).

The interaction of tillage by year averaged over herbicide programs was significant for cotton yield (Table 2). In both years, average yield from conventionally tilled cotton was higher than yield from no-tillage cotton. Conventionally tilled cotton yielded 20 lb lint A^{-1} more in 1997 and 40 lb lint A^{-1} more in 1998 than no-tillage cotton. Differences in soil temperature were noted at planting time and likely stunted growth of non-tilled cotton as mentioned earlier. Since weed control did not differ by tillage regime, decreased early season vigor of no-tillage cotton (McWhorter and Jordan 1985) may have caused the reduction in yield.

Economic Returns

Trends in net returns were similar to yield trends, however no year effect existed for net returns. Programs that had lower weed control and yield resulted in lower net returns and a higher coefficient of variation (CV). In non-transgenic cotton, the soil-applied only program resulted in a net loss of \$140 A^{-1} while addition of Cotoran plus MSMA PD to this program resulted in a net return of \$180 A^{-1}. Addition of Bladex plus MSMA late PD to the program of Prowl and Cotoran PRE fb Cotoran plus MSMA PD increased net returns 93% and decreased the CV by 107%. The preceding program resulted in net returns equal to programs where Staple or Staple plus MSMA were used instead of Cotoran plus MSMA PD.

In Buctril-resistant cotton, exclusion of Cotoran PRE resulted in lower net returns. When Cotoran PRE was included in Buctril programs, net return was at least \$380 A^{-1} and did not differ from the higher-yielding programs in non-transgenic cotton. Soil-applied herbicides and MSMA POST did not affect net returns from Buctril systems in other studies where cultivation was utilized (Culpepper and York 1999).

When Roundup ANS followed Prowl and Cotoran PRE, net returns were \$460 A^{-1} and 31% higher than Roundup ANS alone. The program of Prowl and Cotoran PRE fb Roundup POT fb Bladex plus MSMA late PD increased net returns 24% compared to Roundup ANS alone.

As with yield, a tillage by year interaction averaged over herbicides existed for net returns (Table 2). Average net returns in conventional-tillage cotton increased \$70 A^{-1} in 1997 and \$180 A^{-1} in 1998 compared to the average net return from no-tillage cotton. These increases reflect the differences in yield observed between the two tillage regimes. In addition to decreased net returns, no-tillage programs increased CV values 12% in 1997 and 85% in 1998. Less productive programs often result in higher CV values (Johnson et al. 1997).

Herbicide-resistant cultivars are an important tool to improve weed control and reduce herbicide inputs while increasing flexibility for producers. For instance, the addition of soil-applied Prowl and Cotoran decreased the number of sequential ANS treatments, subsequently increasing net profits for Buctril- and Roundup-tolerant cotton. Furthermore, efficacious systems often resulted in lower coefficients of variation, which suggest improved consistency in profits for the producer. Although poor weed control has been indicated as the primary limitation to no-tillage cotton production (McWhorter and Jordan 1985), weed control did not differ in this study due to highly efficacious weed management systems.

REFERENCES

Ahrens, W. H., ed. 1994. Page 136 *in* Herbicide Handbook 7th ed., Weed Sci. Soc. Am., Champaign, IL.

Anonymous. 1998a. Pages 49-50 *in* Guide to herbicide injury symptoms in cotton 2nd Ed. Agri-Growth, Inc. Hollandale, MN.

Anonymous. 1998b. Pages 1-3 *in* Summary of annual ownership costs, performance rates, and hourly operation costs by machines, 1998 field crop budgets. Department of Agriculture and Resource Economics, North Carolina State University, Raleigh, NC 27695.

Anonymous. 1999. Pages 1504 and 2269 *in* Crop Protection Reference. 15th ed. C & P Press, New York, NY.

Askew, S. D. and J. W. Wilcut. 1999. Cost and weed management with herbicide programs in Roundup-resistant cotton (*Gossypium hirsutum*). Weed Technol. 13:308-313

Bowman, D. T. 1998. Variety selection. Pages 24-42 *in* 1998 Cotton Information. North Carolina Cooperative Extension Service, North Carolina State University, Raleigh, NC.

Brown, A. B. and T. Cole. 1997. Cotton: estimated revenue, operating expenses, annual ownership costs, and net revenue per acre. Raleigh, NC: North Carolina State University, Department of Agriculture and Resource Economics Budget 76-1. 3p.

Buchanan, G. A. and E. R. Burns. 1970. Influence of weed competition on cotton. Weed Sci. 18:149-154.

Culpepper, A. S. and A. C. York. 1997. Weed Management in no-tillage Buctril-tolerant cotton (*Gossypium. hirsutum*). Weed Technol. 11:335-345.

Culpepper, A. S. and A. C. York. 1999. Weed management and net returns with transgenic, herbicide-resistant, and nontransgenic cotton (*Gossypium hirsutum*). Weed Technol. 13:411-420.

Frans, R., R. Talbert, D. Marx, and H. Crowley. 1986. Experimental design and techniques for measuring and analyzing plant responses to weed control practices. Page 37 *in* N. D. Camper, Ed. Research Methods in Weed Science 3rd Ed., South. Weed Sci. Soc., Champaign, IL.

Johnson, W. G., J. A. Kendig, R. E. Massey, M. S. Defelice, and C. D. Becker. 1997. Weed control and economic returns with postemergence herbicides in narrow-row soybeans (*Glycine max*). Weed Technol. 11:453-459.

Jordan, D. L., R. E. Frans, and M. R. McClelland. 1993. Total postemergence herbicide programs in cotton (*G. hirsutum*) with sethoxydim and DPX-PE350. Weed Technol. 7:196-201.

Jordan, D. L., A. C. York, J. L. Griffin, P. A. Clay, P. R. Vidrine, and D. B. Reynolds. 1997. Influence of application variables on efficacy of Roundup. Weed Technol. 11:354-362.

McIntosh, M. S. 1983. Analysis of combined experiments. Agron. J. 75:153-155.

McWhorter, C. G. and T. N. Jordan. 1985. Limited tillage in cotton production. Pages 61-75 *in* A. F. Wiese ed., Weed Control in Limited-Tillage Systems. Champaign, IL, Weed Sci. Soc. Am.

Paulsgrove, M. D. and J. W. Wilcut. 1999. Weed management in Buctril-resistant *Gossypium hirsutum*. Weed Sci. 47:596-601.

Paulsgrove, M. D., J. W. Wilcut, S. D. Askew, J. R. Collins, and J. D. Hinton. 1998. Weed management with Buctril and Staple mixtures in BXN cotton. Proc. South. Weed Sci. Soc. 51:264-265.

Sunderland, S. L., J. D. Burton, H. D. Coble, and E. P. Maness. 1995. Physiological mechanism for tall morningglory resistance to DPX-PE350. Weed Sci. 43:21-27.

Wauchope, R. D., L. L. McDowell, and L. J. Hagen. 1985. Environmental effects of limited tillage. Pages 266-281 *in* Weed Control in Limited Tillage Systems. Champaign, IL, Weed Sci. Soc. Am.

Wilcut, J. W., A. C. York, and D. L. Jordan. 1995. Weed management programs for oil seed crops. Pages 343-400 *in* A. E. Smith, ed. Handbook of Weed Management Programs. Marcel-Dekker, New York, NY.

Wilcut, J. W. and J. D. Hinton. 1997. Weed management in no-till and conventional-tillage Roundup Ready cotton. Proc. Beltwide Cotton Conf. 21:780.

Wilcut, J. W., H. D. Coble, A. C. York, and D. W. Monks. 1996. The niche for herbicide-resistant crops in U. S. agriculture. Pages 213-230 *in* S. O. Duke, ed. Herbicide-Resistant Crops. Agricultural, Environmental, Economic, Regulatory, and Technical Aspects. CRC Press, Inc. Boca Raton, FL.

Wilcut, J. W., D. L. Jordan, and J. S. Richburg, III. 1997. Weed management in cotton (*Gossypium hirsutum*) with soil-applied and post-directed herbicides. Weed Technol. 11:221-226.

Wilcut, J. W. and S. D. Askew. 1999. Chemical approaches to weed management. Pages 627-661 in J. R. Ruberson ed., Handbook of Pest Management. Marcel Dekker, New York, NY.

Table 1. Effect of herbicide programs on late-season goosegrass, prickly sida, morningglory, velvetleaf, smooth pigweed, and sicklepod control averaged over location, years, and tillage[a].

	Herbicide program[b]									
Cultivar	Prowl[b]	Cotoran[b]	POST[b]	Late PD[b]	ELEIN	SIDSP	IPOSS	ABUTH	AMACH	CASOB
					%					
ST474	yes	yes	none	no	79 e	55 d	49 d	56 d	81 d	34 f
	yes	yes	early PD	no	88 bcd	86 c	86 c	80 c	99 a	64 de
	yes	yes	early PD	yes	95 ab	98 ab	94 a	91 b	99 a	83 b
	yes	yes	Staple	yes	91 bcd	100 a	94 a	100 a	100 a	59 de
	yes	yes	Staple + MSMA	yes	96 ab	100 a	94 a	100 a	100 a	80 b
BXN47	yes	no	Buctril*	yes	87 cde	97 b	100 a	100 a	91 c	51 e
	yes	no	Buctril* + MSMA	yes	93 abc	99 a	99 a	100 a	93 bc	77 bc
	yes	yes	Buctril	yes	91 bcd	100 a	98 a	100 a	97 ab	65 cd
	yes	yes	Buctril + MSMA	yes	95 ab	100 a	97 a	98 a	97 ab	84 b
PM1330RR	yes	yes	Roundup*	no	94 ab	100 a	96 ab	100 a	100 a	97 a
	yes	yes	Roundup	yes	98 a	100 a	98 a	100 a	100 a	98 a
	no	no	Roundup*	no	86 d	96 b	95 a	100 a	99 a	98 a
	no	no	Roundup*	yes	94 ab	100 a	97 a	100 a	100 a	99 a

[a]The analysis of variance and the LSD comparison were performed on data that were arcsine square-root transformed. Means within a column followed by the same letter are not different based on a Fisher's Protected LSD test ($P < 0.05$).
[b]Herbicide options were: Prowl, "yes" denotes Prowl applied PRE in no-tillage cotton or PPI in conventional-tillage cotton; Cotoran, "yes" denotes Cotoran applied PRE; POST, "none" indicates no postemergence herbicides, "early PD" denotes Cotoran plus applied early PD; "Buctril", "MSMA", "Staple", and "Roundup" denote these herbicides were applied POT; late PD, "yes" denotes Bladex at plus MSMA was applied late post-directed. A (*) indicates applied ANS for weed control until the time of late PD applications.
[c]Abbreviations: ELEIN = *Eleusine indica*, SIDSP = *Sida spinosa,* IPOSS = *Ipomoea* species, ABUTH = *Abutilon theophrasti*, AMACH = *Amaranthus hybridus*, CASOB = *Senna obtusifolia*.

Table 2. Effect of tillage on cotton lint yield and economic returns averaged over locations and herbicide programs.

	Lint yield[a]		Economic returns[ab]			
Tillage regime	1997	1998	1997		1998	
	lb A^{-1}		\$ A^{-1}	CV (%)[c]	\$ A^{-1}	CV (%)
Conventional tillage	220 a	230 a	310 a	91	340 a	87
No tillage	200 b	190 b	240 b	103	160 b	172

[a]Means within a column followed by the same letter are not different based on a Fisher's Protected LSD test ($P < 0.05$).
[b]Economic returns are based on an enterprise budget that included costs for seed and technology, herbicidal application, herbicides, and adjuvants in addition to fixed farm costs unrelated to weed management.
[c]Abbreviations: CV, coefficient of variation.