The *Journal of Cotton Science 7:194–204 (2003)*
http://journal.cotton.org, © The Cotton Foundation 2003

ECONOMICS AND MARKETING

Transgenic Cotton Cultivars: An Economic Comparison in Arkansas

Kelly J. Bryant, Robert L. Nichols, Charles T. Allen, N. Ray Benson, Fred M. Bourland, Larry D. Earnest, Marwan S. Kharboutli, Kenneth L. Smith, and Eric P. Webster

ABSTRACT

The development of transgenic cotton cultivars gives cotton producers more options for controlling pests. The value of these cultivars to producers depends not only on the cost-savings that they may contribute to the pest management systems employed, but also on the gross revenues from the sale of the crop produced. This study examines the cost and returns associated with alternative pest control systems using transgenic and non-transgenic cultivars in an effort to identify the most economical alternatives. The experiments were done as holistic comparisons of production systems. The treatment variable was a specific combination of a cultivar and a pest management system that was consistent with the genetic potential of the cultivars. Over 5 site-years in Arkansas, yield was the factor most closely associated with profitability at each site in each year. In 3 of the 5 site-years, yields were not statistically different for most or all of the cultivars tested, so the least expensive treatment would also be the most profitable treatment. Comparisons among the cultivars tested in this research, indicate that the currently available cultivars offer ample opportunities to identify high-yielding cultivars and profitable systems within non-transgenic, insect-resistant, herbicide-resistant, or combined insect- and herbicide-resistance (so-called "stack gene") category of transgenic cottons.

K.J. Bryant and K. L. Smith, Southeast Research and Extension Center, University of Arkansas, Box 3508, Monticello, AR 71655-3508, R. L. Nichols, Cotton Incorporated, 6399 Weston Parkway, Cary, NC 27513; C. T. Allen and M. S. Kharboutli, Texas Boll Weevil Eradication Foundation, Inc., P.O. Box 5089, Abilene, TX 79608; N. R. Benson, 731 W. Fleeman, Manila, AR 72442; F. M. Bourland, Northeast Research and Extension Center, University of Arkansas, Box 48, Keiser, AR 72351, L. D. Earnest, Southeast Branch Experiment Station, University of Arkansas, P.O. Box 155, Rohwer, AR 71666, E. P. Webster, Department of Agronomy, Louisiana State University, Baton Rouge, 70803
*corresponding author: bryantk@uamont.edu

The development of transgenic cotton cultivars gives cotton producers more options for controlling pests, but their value to producers depends not only on the cost-savings that they may contribute to the pest management systems employed, but also on the gross revenues from the sale of the crop produced. Thus, the overall value of transgenic cultivars depends on their yield and quality, as expressed in the context of the pest management system whose use is possible because of their genetic modification (May et al., 2000). Comprehensive economic evaluation of cotton cultivars with pest-managing traits may require evaluation in systems trials in which the different types of cultivars are evaluated against one another in terms of net returns with each cultivar employing the pest management system consistent with its pesticide tolerances and pest resistances (May et al., 2003).

All the commercial transgenic insect-resistant cultivars express one or more endotoxins produced by soil bacterium *Bacillus thuringiensis* (Bt). Expression of the toxins suppresses feeding by armyworm species (*Spodoptera spp*.) and is highly and moderately effective for control of tobacco budworm [*Heliothis virescens* (F.)] and cotton bollworm [*Helicoverpa zea* (Boddie)], respectively. The Bt endotoxins do not control other major insect pests of cotton, such as the boll weevil (*Anthonomus grandis* Boheman), thrips (*Frankliniella spp*.), cotton aphids (*Aphis gossyphi* Glover), and plant and stink bugs [several genera, including *Lygus spp*.and *Acrosternum hilare* (Say), *Euchistus spp*., and *Nezara viridula* (L.)]. Before introduction of the Bt cotton cultivars, tobacco budworm was the most economically damaging pest of cotton (Head, 1991; 1992; 1993; Williams 1994; 1995). From 1996 to 2001, transgenic Bt cultivars appeared to have increased profits in most cases for the southern regions of Arkansas but have not been profitable for the northern regions of the state (Bryant et al., 2002). Over a 4-yr period, yields and costs were similar when comparing transgenic Bt cultivars to non-transgenic cultivars on farms in Mississippi (Cooke et al., 2001).

Herbicide-resistant transgenic cultivars permit use of certain broad-spectrum herbicides at low rates and costs. BXN cultivars express an enzyme that metabolizes the herbicide bromoxynil, and renders the transformed cultivars virtually immune to its effects. Bromoxynil is highly effective for management of certain troublesome weeds in cotton, including cocklebur (*Xanthium strumarium* L.) and morningglories (*Ipomea spp*.) (Wilcut et al., 2003). Roundup Ready cultivars express an alternative 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), the enzyme inhibited by the herbicide, glyphosate. Glyphosate is an exceptionally broad-spectrum herbicide, and may be used as the primary means of cottonweed management (Culpepper and York, 1999). Glyphosate is virtually non-toxic to vertebrates, strongly adsorbed to soil colloids, and typically biodegrades with a half-life of about 45 d (Vencil et al., 2002).

The actual or potential net returns to various pest control systems with and without transgenic crops have been addressed in the agricultural economics literature in various ways. Hubbell et al. (2000) combined revealed preference data with stated preference data to estimate the demand for Bt cotton. Marra et al. (2002) reviewed numerous studies in an effort to "…compile and characterize the farm-level evidence of the impacts of transgenic field crops…", and concluded that "…compared to their conventional counterparts, transgenic crops have consistently higher average profit and, for the most part, lower pesticide use…".

Other studies (Culpepper and York, 1999; Wilcut et al., 2003) have used methodology similar to that employed in this article. In a 2-yr study comparing weed control, cotton yield and net returns with various weed management systems using one bromoxynil-resistant cultivar, one glyphosate-resistant cultivar, and one non-transgenic cultivar, net returns closely followed trends in yield (Culpepper and York, 1999). Wilcut et al. (2003) conducted a regional evaluation to assess weed management, cotton response, and the economic effect of weed management options in cotton across a number of states. One bromoxynil-resistant cultivar, one glyphosate-resistant cultivar, and one non-transgenic cultivar were grown at each of 22 locations in eight states in 1998, 1999 and 2000. Yield among treatments within locations were different in certain years, but not among types of cultivars. They also concluded that, "overall, the Roundup Ready system with reduced soil-applied and or lay-by herbicide use cost less than the other systems" (Wilcut et al., 2003).

The number of transgenic cotton cultivars available for commercial production has increased in recent years. Cotton producers now have multiple choices when choosing transgenic cotton cultivars. The choice of cultivar is now linked to the insect and weed control programs that will or can be used. This study examines the cost and returns associated with alternative pest control systems using transgenic and non-transgenic cultivars in an effort to identify the most economical alternatives.

MATERIALS AND METHODS

The experiments were done as holistic comparisons of production systems. The treatment variable was a specific combination of a cultivar and a pest management system that was consistent with the genetic potential of the cultivar. Transgenic and non-transgenic cotton cultivars were chosen for experiments at the Northeast Research and Extension Center (NEREC) at Keiser, Arkansas, and the Southeast Branch Experiment Station (SEBES) at Rohwer, Arkansas. There were 9 and 10 cultivars at each location in 1998 and 1999, and 14 cultivars at the NEREC in 2000 (Table 1). Each cultivar was replicated four times. Plots were 12.2 m long by four 1-m rows wide, arranged in a randomized complete block design. Yields were taken from the center two rows of each plot. The plots at NEREC were planted on 9 May 1998, 12 May 1999, and 12 May 2000. The plots at SEBES were planted on 5 May 1998 and 19 May 1999.

Each cultivar was farmed with the goal of maximizing profit, and managed according to standard recommendations of the University of Arkansas, as administered by the authors. Fertilization and irrigation programs were held constant across all plots at a given location in a given year. Plots were machine harvested. To determine the percentage of lint, seed cotton samples were ginned using laboratory-scale equipment. In our experience, laboratory-scale ginning frequently leaves relatively high levels of trash in the lint, and the classing of these samples may not give fiber length or length uniformity data that are equivalent to those from commercially-ginned samples of the same cotton, so the samples were not classed.

For each cultivar, the pest management program was a specific set of choices determined by genetic

Table 1. Cotton cultivars and gene technology evaluated each year

Technology	Cultivars		
	1998	1999	2000
Insect- and glyphosate-resistant	DP 5415BGRR	DP 458BR	DP 458BR
	PM 1220BGRR	PM 1218BR	PM 1218BR
			SG 215BR
Glyphosate-resistant	DP-5415RR	DP 5415RR	DP 5415RR
	PM 1220RR	PM 1220RR	DP 436RR
			ST 9903RR
Insect-resistant	DP NuCotn 33B	DP NuCotn 33B	DP NuCotn 33B
	PM 1220BG	PM 1560BG	PM 1560BG
			ST 4691B
Non-transgenic	DP-5415	DP 5415	DP 5415
	PM-H1220	DP 5111	Phytogen 355
	ST-474	ST 474	ST 474
			SG 747
Bromoxynil-tolerant		ST BXN47	ST BXN47

capability of each cultivar. Thus, the insect and weed management programs were specific to the type of cultivar and developed to take advantage of the transgenic characters, or lack there of, associated with each cultivar. At each location and in each year, the specific insect and weed pressures dictated the choices within the overall programs, as permitted or excluded by the genetic make-up of the cultivars. Herbicides were prescribed based on weed pressure and the genetic characteristics of the cultivar. Plots were scouted for insects weekly. When insect pest economic thresholds were reached, cultivars were treated based on the species of insects involved and the presence or absence of the Bt gene in that cultivar. Once a treatment level was reached, all cultivars within a genetic constitution were treated the same. In all cases, field managers used the permissible pest management practices to achieve insect and weed management that would produce optimum economic results.

The herbicide programs necessary to control weeds at the Northeast Arkansas location are detailed in Table 2. A bromoxynil-tolerant cultivar was not included as a treatment in 1998. In 1998 and 1999, the number of herbicide applications did not differ across cultivars regardless of the transgenic capabilities. The herbicide programs differed only in chemistry applied and slightly in timing. In 2000, the mid- and late-season applications differed by chemistry, timing and number. The conventional cultivars received five herbicide applications, while the glyphosate-tolerant and bromoxynil-tolerant cultivars received only four applications. In 1998, all cultivars received a pre-plant incorporated (PPI) treatment. In 2000, all cultivars received a pre-emergence (PRE) treatment. In 1999, none of the cultivars received a PPI or a PRE treatment.

The applications used to control weeds at the Southeast Arkansas location are detailed in Table 3. Again, a bromoxynil-tolerant cultivar was not included as a treatment in 1998. In both years, all cultivars received a PPI treatment of pendimethalin. In 1999, the PPI treatment also included norflurazon. The conventional cultivars received a PRE application of fluometuron each year. The in-season applications differed by chemistry and timing. Weed control was deemed adequate across all cultivars in both years at both locations.

The insecticide applications necessary at the Northeast Arkansas location are detailed in Table 4. In 1999 and 2000, the insecticide programs were exactly the same for the Bt and non-Bt cultivars. In 1998, the Bt cultivars were able to forego one application of cyhalothrin. Boll weevil pressure was heavy in Northeast Arkansas in 2000. All of the plots received one early season application for thrips and four in-season applications for boll weevil. Insect populations and the numbers of insecticide treatments were the same on the Bt and the non-Bt cultivars.

Table 2. Herbicide programs for three classes of cotton cultivars at the Northeast Research and Extension Center in Keiser, Arkansas, in 1998, 1999, and 2000

Timing (days after planting)[y]	Herbicide	Broadcast rate (kg ai/ha)[z]	Herbicide	Broadcast rate (kg ai/ha)[z]	Herbicide	Broadcast rate (kg ai/ha)[z]
	Conventional		Roundup Ready		Bromoxynil tolerant	
1998						
PPI	trifluralin fluometuron	0.84 0.90	trifluralin fluometuron	0.84 0.90	not planted	
4			glyphosate	1.12		
12	pyrithiobac	0.05*				
30	pryithiobac	0.05*	pyrithiobac	0.05*		
1999						
30	pyrithiobac	0.07*	glyphosate	1.26	bromoxynil	0.42
52	MSMA cyanazine	1.68** 0.84**	glyphosate cyanazine	0.84** 0.84**	bromoxynil cyanazine	0.56** 0.84**
2000						
Burndown	2,4-DLV ester glyphosate	1.12 1.12	2,4-DLV ester glyphosate	1.12 1.12	2,4-DLV ester glyphosate	1.12 1.12
PRE	fluometuron metolachlor glyphosate	1.34 1.28 0.84	fluometuron metolachlor glyphosate	1.34 1.28 0.84	fluometuron metolachlor glyphosate	1.34 1.28 0.84
47	MSMA lactofen	1.68† 0.20†	glyphosate	1.12*	bromoxynil	0.56*
56	MSMA lactofen glyphosate diuron	1.26† 0.18† 1.12‡ 1.12**	glyphosate diuron	1.12** 1.12**		
68	cyanazine MSMA	0.56† 1.68†				
75					bromoxynil clethodim	0.56 0.21

[y] PPI=preplant incorporated; DAP=days after planting.

[z] Herbicides were broadcast unless noted otherwise. * = applied in a band over-the-top; ** = applied post-direct; ‡ = applied in a band over the middle of the row; † = applied post direct on a band.

The applications used to control insects at the Southeast Arkansas location are detailed in Table 5. In 1999, the insecticide programs were exactly the same for the Bt and non-Bt cultivars. In 1998, the Bt cultivars were able to forego one application of cyhalothrin and one application of cyhalothrin plus spinosad.

Yields were taken from the center two rows of each plot using a mechanical harvester. The plots at NEREC were harvested on 22 Oct. 1998, 15 Oct. 1999 and 2 Oct. 2000. The plots at SEBES were harvested on 30 Sept. 1998 and 15 Oct. 1999. Seed cotton samples were ginned with a plot gin. Lint from each sample was weighed to determine lint yield per plot. Plot yields were averaged across replications and subjected to ANOVA using SAS version 8.1 (SAS Institute, Cary, NC). The means were separated using LSD at the $P = 0.05$.

Per acre costs of insect and weed control were determined for each treatment using the Mississippi State Budget Generator (Laughlin and Spurlock, 1998). Input prices are those used for the Arkansas Cotton Budgets in their respective years (Bryant and Windham, 1997; 1998; 1999). Because individual grades were not available, returns over insect and weed control costs were calculated using the 10 yr average price for cotton lint in Arkansas of \$1.254/kg (\$0.57/lb) (USDA-

Table 3. Herbicide programs for three classes of cotton cultivars at the Southeast Branch Experiment Station in Rohwer, Arkansas, in 1998 and 1999

Timing (days after planting)[y]	Herbicide	Broadcast rate (kg ai/ha)[z]	Herbicide	Broadcast rate (kg ai/ha)[z]	Herbicide	Broadcast rate (kg ai/ha)[z]
	Conventional		Roundup Ready		Bromoxynil tolerant	
1998						
PPI	pendimethalin	0.84	pendimethalin	0.84	not planted	
PRE	fluometuron	0.67				
21	pyrithiobac	0.04**	glyphosate	1.12		
39			glyphosate	0.84*		
Lay-by	MSMA cyanazine	1.45* 0.84*				
1999						
PPI	pendimethalin norflurazon	1.01 0.56	pendimethalin norflurazon	1.01 0.56	pendimethalin norflurazon	1.01 0.56
PRE	fluometuron	0.67				
21			glyphosate	0.84	bromoxynil	0.56

[y] PPI=preplant incorporated; DAP=days after planting.

[z] Herbicides were broadcast unless noted otherwise. * = applied post-direct; ** = applied on a band post-direct.

Table 4. Insecticide programs for Bt and non-Bt cotton cultivars at the Northeast Research and Extension Center at Keiser, Arkansas, in 1998, 1999 and 2000

Timing (days after planting)	Non-Bt cotton cultivars		Bt cotton cultivars	
	Insecticide	Broadcast rate (kg ai/ha)	Insecticide	Broadcast rate (kg ai/ha)
1998				
25	acephate	0.252	acephate	0.252
38	dimethoate	0.224	dimethoate	0.224
52	oxamyl	0.213	oxamyl	0.213
83	cyhalothrin	0.035	--	--
94	cyfluthrin	0.034	cyfluthrin	0.034
97	oxamyl	0.325	oxamyl	0.325
101	cyhalothrin	0.034	cyhalothrin	0.034
104	azinphosmethyl	0.280	azinphosmethyl	0.280
1999				
41	oxamyl	0.325	oxamyl	0.325
84	cyhalothrin	0.029	cyhalothrin	0.029
2000				
25	acephate	0.403	acephate	0.403
55	oxamyl	0.280	oxamyl	0.280
83	bifenthrin	0.090	bifenthrin	0.090
96	cyfluthrin	0.032	cyfluthrin	0.032
101	cyfluthrin	0.032	cyfluthrin	0.032

Table 5. Insecticide programs for Bt and non-Bt cotton cultivars at the Southeast Branch Experiment Station in Rohwer, Arkansas, in 1998 and 1999

Timing (days after planting)	Non-Bt cotton cultivars		Bt cotton cultivars	
	Insecticide	Broadcast rate (kg ai/ha)	Insecticide	Broadcast rate (kg ai/ha)
1998				
30	oxamyl imidacloprid	0.280 0.053	oxamyl imidacloprid	0.280 0.053
40	oxamyl imidacloprid	0.280 0.053	oxamyl imidacloprid	0.280 0.053
73	cyhalothrin	0.034	--	--
83	cyhalothrin spinosad	0.034 0.059	--	--
102	cyfluthrin methomyl	0.031 0.448	cyfluthrin methomyl	0.031 0.448
1999				
30	oxamyl imidacloprid	0.280 0.053	oxamyl imidacloprid	0.280 0.053
73	cyhalothrin	0.034	cyhalothrin	0.034

NASS, 2003). Ignoring fiber quality could skew the economic results. Where significant differences in fiber quality exist, parameters that incur discounts will decrease gross returns, and may affect the ranking of economic returns among cultivars.

Transgenic technology is leased to growers for 1yr by means of a contract and fee. In 1998, technology fees were assessed on a per hectare basis, so $74.10/ha ($30/ac) for all treatments using a Bollgard (Bt) cultivar and $22.23/ha ($9.00/ac) for all treatments using a glyphosate-resistant cultivar were included. In 1999 and 2000, the basis of the technology fees and seed premium costs were charged per bag of seed purchased. Therefore technology fees were calculated based on a 13.44 kg/ha (12 lb/ac) seeding rate at NEREC and 11.20 kg/ha (10 lb/ac) seeding rate at SEBES.

RESULTS

Yields, costs and returns for the nine treatments in Northeast Arkansas in 1998 are displayed in Table 6. They are ranked from the highest yield to the lowest yield. Notice that returns follow the same trend as yields, but yields for seven of the nine treatments were not significantly different. If yields were not different, then the least expensive treatment would also be the most profitable treatment. In Table 6, the conventional cultivars are the least expensive, meaning that the glyphosate-resistant and Bt technologies did not reduce costs sufficiently to compensate for their respective technology fees.

The same information for Southeast Arkansas in 1998 is displayed in Table 7, which shows that returns followed yields. The three conventional cultivars and one of the Bt cultivars had the greatest returns and their yields were not significantly different from each other at the 95% level of confidence. The cultivars with both Bt and glyphosate-resistance (so-called "stack gene") had the lowest pest management costs, meaning that the glyphosate-resistant and Bt technologies did reduce costs sufficiently to recover their respective technology fees. Yields of the Bt plus glyphosate-resistant cultivars were statistically lower ($P \leq 0.05$) than the other treatments.

Yields, costs, and returns in 1999 are displayed in Tables 8 and 9. Neither yields nor returns were significantly different at either location ($P \leq 0.05$), but the trend in returns follows the trend in yields. Insect pressure was very light at the NREC and SEREC locations in 1999. All of the plots at both locations received one early-season application for boll weevil and one late-season application for lepidopoterous larvae. Additional sprays on the conventional cultivars, as opposed to the Bt cultivars, were not deemed necessary at either location. The conventional cultivars had the least pest management costs at both locations.

Yields, costs, and returns in 2000 are displayed in Table 10. Yields were significantly different among the cultivars ($P \leq 0.05$). The trend in returns follows the trend in yields, except the cultivars 'ST474' and

Table 6. Lint yield, weed control cost, insect control cost, and returns for cotton production systems cultivars at the Northeast Research and Extension Center at Keiser, Arkansas, in 1998

Cultivar[x]	Lint yield[y] (kg/ha)	Herbicides plus application ($/ha)	Insecticides plus application ($/ha)	Seed costs and technology fee ($/ha)	Total specified costs ($/ha)	Returns[z] ($/ha)
DP5415 BGRR	1288 a	151	143	123	417	1,198
DPNuCOTN 33B	1234 a	141	143	101	385	1,163
DP5415	1212 a	141	173	26	339	1,180
DP5415 RR	1204 a	151	173	48	372	1,138
PM1220 BG	1184 ab	141	143	101	385	1,100
ST 474	1172 ab	141	173	26	339	1,130
PM H1220	1102 abc	141	173	26	339	1,043
PM1220 BGRR	1028 bc	151	143	123	417	872
PM1220 RR	958 c	151	173	48	372	829

[x] Cultivars designated as BG or B contain the Bt gene; cultivars designated with RR contain the glyphosate resistance gene; cultivars designated with BG and RR contain both genes.

[y] Mean yields followed by the same letter are not significantly different according to LSD ($P \leq 0.05$).

[z] Returns over seed, weed control and insect control costs assuming a cotton price of $1.254/kg ($0.57/lb).

Table 7. Lint yield, weed control cost, insect control cost, and returns for cotton production systems at the Southeast Branch Experiment Station in Rohwer, Arkansas, in 1998

Cultivar[x]	Lint Yield[y] (kg/ha)	Herbicides plus application ($/ha)	Insecticides plus application ($/ha)	Seed costs and technology fee ($/ha)	Total specified costs ($/ha)	Returns[z] ($/ha)
ST474	1,020 a	166	272	21	459	821
PM1220 BG	894 ab	166	188	96	450	671
DP5415	884 ab	166	272	21	459	649
PMH1220	875 ab	166	272	21	459	638
DPNuCOTN 33B	797 b	166	188	96	450	550
DP5415 RR	780 b	121	272	44	436	541
PM1220 RR	773 b	121	272	44	436	533
PM1220 BGRR	713 bc	121	188	119	427	467
DP5415 BGRR	584 c	121	188	119	427	304

[x] Cultivars designated as BG or B contain the Bt gene; cultivars designated with RR contain the glyphosate resistance gene; cultivars designated with BG and RR contain both genes.

[y] Mean yields followed by the same letter are not significantly different according to LSD ($P \leq 0.05$).

[z] Returns over seed, weed control and insect control costs assuming a cotton price of $1.254/kg ($0.57/lb).

'PSC355' had slightly greater returns than 'PM1218BR'. This difference may be attributed to the technology fee associated with the transgenic cultivar and the lack of pressure from lepidopterous larvae. Of the four top yielding cultivars, which were not statistically different, one was conventional, one was glyphosate-resistant only, one was Bt only, and one was stacked gene. Of these four cultivars, the glyphosate-resistant cultivar had the least cost, followed by the conventional cultivar, the stacked gene cultivar, and the Bt cultivar.

Table 8. Per hectare lint yield, weed control cost, insect control cost and returns for cotton production systems at the Northeast Research and Extension Center at Keiser, Arkansas, in 1999

Cultivar[x]	Lint yield (kg/ha)	Herbicides plus application ($/ha)	Insecticides plus application ($/ha)	Seed costs and technology fee ($/ha)	Total specified costs ($/ha)	Returns[z] ($/ha)
PM1218 BGRR	1,559	68	47	144	260	1,695
ST BXN47	1,422	75	47	58	181	1,603
DP5415 RR	1,342	68	47	63	179	1,504
ST474	1,313	64	47	44	156	1,490
DP5415	1,279	64	47	40	152	1,452
DP5111	1,268	64	47	40	152	1,438
PM1560 BG	1,257	64	47	120	231	1,344
DP458 B/RR	1,216	68	47	135	250	1,275
DPNUCOTN 33B	1,207	64	47	115	226	1,288
PM 1220RR	1,088	68	47	72	187	1,176

[x] Cultivars designated as BG or B contain the Bt gene; cultivars designated with RR contain the glyphosate resistance gene; cultivars designated with BG and RR contain both genes; cultivars designated with BXN contain the bromoxynil resistance gene.

[y] Mean yields are not significantly different ($P \leq 0.05$).

[z] Returns over seed, weed control and insect control costs assuming a cotton price of $1.254/kg ($0.57/lb).

Table 9. Per hectare lint yield, weed control cost, insect control cost and returns for cotton production system at the Southeast Branch Experiment Station in Rohwer, Arkansas, in 1999

Cultivar[x]	Lint yield[y] (kg/ha)	Herbicides plus application ($/ha)	Insecticides plus application ($/ha)	Seed costs and technology fee ($/ha)	Total specified costs ($/ha)	Returns[z] ($/ha)
ST 474	1,291	77	75	41	194	1,425
DP 5415RR	1,286	87	75	57	219	1,393
DPNuCOTN 33B	1,206	77	75	106	259	1,254
PM 1560BG	1,192	77	75	110	263	1,231
PM 1220RR	1,169	87	75	64	226	1,240
ST BXN47	1,164	94	75	51	221	1,239
PM1218 BGRR	1,156	87	75	131	293	1,156
DP 5415	1,105	77	75	38	191	1,195
DP 5111	1,070	77	75	38	191	1,150
DP 458B/RR	1,056	87	75	123	285	1,039

[x] Cultivars designated as BG or B contain the Bt gene; cultivars designated with RR contain the glyphosate resistance gene; cultivars designated with BG and RR contain both genes; cultivars designated with BXN contain the bromoxynil resistance gene.

[y] Mean yields are not significantly different ($P \leq 0.05$).

[z] Returns over seed, weed control and insect control costs assuming a cotton price of $1.254/kg ($0.57/lb).

CONCLUSIONS

Over 5 site-yr in Arkansas, yield was the factor most closely associated with profitability at each site in each year. In 3 of the 5 site-yr, yields were not statistically different for most or all of the cultivars tested. In the other two site years, the highest yield-

Table 10. Per hectare lint yield, weed control cost, insect control cost and returns for cotton production systems at the Northeast Research and Extension Center at Keiser, Arkansas, in 2000

Cultivar [w]	Lint yield [x] (kg/ha)	Herbicides plus application [y] ($/ha)	Insecticides plus application ($/ha)	Seed costs and technology fee ($/ha)	Total specified costs ($/ha)	Returns [z] ($/ha)
SG 747	1118 a	182	121	50	352	1,049
SG 215BR	1089 ab	142	121	146	408	957
STV 9903RR	1016 abc	142	121	76	338	935
ST 4691B	997 abc	182	121	127	429	821
PM 1560BG	969 bcd	182	121	125	427	788
PM 1218BR	925 cde	142	121	144	406	754
ST 474	904 cde	182	121	51	354	780
Phytogen 355	897 cde	182	121	48	351	774
ST BXN47	896 cde	189	121	66	376	747
DP 5415RR	834 def	142	121	76	339	709
DP 436RR	803 ef	142	121	73	336	671
DP 458BR	794 ef	142	121	162	424	572
DP 5415	724 f	182	121	48	351	557
DPNuCotn 33B	715 f	182	121	132	435	461

[w] Cultivars designated as BG or B contain the Bt gene; cultivars designated with RR contain the glyphosate resistance gene; cultivars designated with BG and RR contain both genes; cultivars designated with BXN contain the bromoxynil resistance gene.

[x] The cost of two burndown applications prior to planting are not included.

[y] Mean yields followed by the same letter are not significantly different according to LSD ($P \leq 0.05$).

[z] Returns over seed, weed control and insect control costs assuming a cotton price of $1.254/kg ($0.57/lb).

ing cultivar and those not significantly different from the highest yielding cultivar included glyphosate-resistant, Bt, stacked-gene and conventional cultivars. Large technology fees can be offset by high yields, but producers should avoid cultivars that have large technology fees and low yield potentials. When yields for several cultivars are the same, the cultivar with the least cost will result in the greatest returns. Fiber quality was not measured in this research, but significant differences in fiber quality, which include parameters that incur discounts, will decrease gross returns, and may affect the ranking of economic returns among cultivars. Therefore, growers may lose revenue by planting cultivars that have good yields and favorable pest management costs, but that are discounted for low fiber quality. When selecting culitvars, growers must consider all cultivar-related factors that may impact returns and costs, including yield, fiber quality characters, and pest management costs, in order to maximize returns.

Although the same cultivars were used at both locations within each year for the first 2 yr, the cultivars tested changed over the duration of the test, in part because some cultivars were no longer sold commercially during the testing period. Although several different cultivars of each type were represented over the test period, no single type of cultivar stands out as always yielding near the top in all 5 site-yr. For example, focusing on the top three yielding cultivars in each site-year, 1) a cultivar containing a Bt gene shows up six out of 15 times (three single gene cultivars and three stacked-gene cultivars), 2) a cultivar containing the glyphosate-resistant gene shows up six out of 15 times (three single gene cultivars and three stacked-gene cultivars), 3) a conventional cultivar shows up five out of 15 times, and 4) a bromoxynil tolerant cultivar shows up one out of 15 times. These results suggest that the full genetic complement of a cultivar has a much greater effect on yield expression than the presence or absence of a single gene modification. Such a conclusion is fully consistent with the principles of plant improvement. Yield is commonly understood to be a quantitatively determined trait resulting from the effects and interaction of many genes. It is unlikely that insertion of a single gene, followed by a minimum of three backcrosses would result in a line with yields that differ substantially from that of the backcross parent.

In 3 of the 5 site-yr, the conventional cultivars had the least pest management costs. In Southeast Arkansas in 1998, the stacked-gene cultivars had the least cost, and in Northeast Arkansas in 2000, the glyphosate-resistant cultivars had the least pest-management costs. Of the 3 yr in Northeast Arkansas, the Bt cultivars were never cost effective. In 2000, of the top four cultivars that did not differ significantly in yield, two were Bt cultivars.

These results indicate that profit maximization is associated primarily with yield and secondarily with costs of pest control, which are the two principal characteristics of the cultivars that were compared in this research. Also, cultivar selection for profit maximization must be done on a cultivar-by-cultivar basis with the emphasis focused on yield potential. Comparisons among the cultivars tested in this work, suggest that the currently available cultivars, offer ample opportunities to identify high-yielding cultivars within the non-transgenic, Bt, herbicide-resistant, or stacked gene categories.

ACKNOWLEDGEMENT

This research supported in part by Cotton Incorporated.

REFERENCES

Bryant, Kelly J., William C. Robertson, Gus M. Lorenz, Rob Ihrig, George Hackman. 2002. Six years of transgenic cotton in Arkansas. *In* Proc. Beltwide Cotton Conf., Atlanta, GA. 9-12 Jan. 2002. Natl. Cotton Counc. Am., Memphis, TN.

Bryant, Kelly J. and Tony E. Windham. 1997. Estimating 1998 Costs of Production: Cotton, AG 502-509, Nov. 1997. University of Arkansas, Division of Agriculture Cooperative Extension Service, Little Rock, AR.

Bryant, Kelly J. and Tony E. Windham. 1998. Estimating 1999 Costs of Production: Cotton, AG 528-537, Nov. 1998. University of Arkansas, Division of Agriculture Cooperative Extension Service, Little Rock, AR.

Bryant, Kelly J. and Tony E. Windham. 1999. Estimating 2000 Production Costs in Arkansas: Cotton, AG 563-582, Dec. 1999. University of Arkansas, Division of Agriculture Cooperative Extension Service, Little Rock, AR.

Cooke, Fred T. Jr., William P. Scott, Steven W. Martin, and David W. Parvin. 2001. The economics of Bt cotton in the Mississippi delta: 1997-2000. p. 175-177. *In* Proc. Beltwide Cotton Conf., Anaheim, CA. 9-13 Jan. 2001. Natl. Cotton Counc. Am., Memphis, TN.

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

Head, Robert B. 1991. Cotton Insect Losses-1990. p. 602-607. *In* Proc. Beltwide Cotton Conf., Jan. 1991. Natl. Cotton Counc. Am., Memphis, TN.

Head, Robert B. 1992. Cotton Insect Losses-1991. p. 621-625. *In* Proc. Beltwide Cotton Conf., Nashville, TN. 6-10 Jan. 1992. Natl. Cotton Counc. Am., Memphis, TN.

Head, Robert B. 1993. Cotton Insect Losses-1992. p. 655-660. *In* Proc. Beltwide Cotton Conf., New Orleans, LA. 10-14 Jan. 1993. Natl. Cotton Counc. Am., Memphis, TN.

Hubbell, Bryan J., Michele C. Marra and Gerald A. Carlson. 2000. Estimating the demand for a new technology: Bt cotton and insecticide policies. Am. J. Agric. Econ. 82(1): 118-132.

Laughlin, David H. and Stan R. Spurlock. 1997. Mississippi State Budget Generator Users Guide [On-line]. Available at http://www.agecon.msstate.edu/laughlin/msbg.php (verified 17 Nov. 2003).

Marra, Michele C., Philip G. Pardey and Julian M. Alston. 2002. The payoffs to transgenic field crops: an assessment of the evidence. AgBioForum 5(2): 43-50.

May, L.O., R.L. Nichols, T. Kerby, S. Brown, and J. Silvertooth. 2000. Proposed guidelines for pre-commercial evaluation of transgenic and conventional cotton cultivars. p. 503-507. *In* Proc. Beltwide Cotton Conf., San Antonio, TX. 4-8 Jan. 2000. Natl Cotton Counc. Am., Memphis, TN.

May, L.O., F. Bourland, and R.L. Nichols. 2003. Challenges in evaluating transgenic and non-transgenic cotton cultivars. Crop Sci. 43: 1594-1601.

USDA – National Agricultural Statistics Service (NASS). 2003. Historic data for cotton [On-line]. Available at http://www.nass.usda.gov/ar/histcotn.PDF (verified 17 Nov. 2003).

Vencil, W.K. (ed.) 2002. Herbicide Handbook, 8th ed. Weed Science Society of America, Lawrence, KS.

Wilcut, J.W., R.M. Hayes, R.L, Nichols, S.B. Clewis, J. Summerlin, D.K. Miller, A. Kendig, J.M. Chandler, D.C. Bridges, B. Brecke, C.E. Snipes, and S.M. Brown. 2003. Weed management in transgenic cotton. Tech. Bull. 319. North Carolina State Univeristy, Raleigh, NC.

Williams, Michael R. 1994. Cotton Insect Losses-1993. p. 743-763. *In* Proc. Beltwide Cotton Conf., San Diego, CA. 5-8 Jan. 1994. Natl. Cotton Counc. Am., Memphis, TN.

Williams, Michael R. 1995. Cotton Insect Losses-1994. p. 746-757. *In* Proc. Beltwide Cotton Conf., San Antonio, TX. 4-7 Jan. 1995. Natl. Cotton Counc. Am., Memphis, TN.