TRANSGENIC AND CONVENTIONAL INSECT AND WEED CONTROL SYSTEMS

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Abstract

The Roundup Ready™ system provided similar weed control, but consistently lower yields and net returns as compared with conventional weed control systems.

Three days after insecticide applications were made to cotton in conventional insecticide system plots, unsprayed cotton in the Bollgard™ system showed more worm damage than cotton in the conventional system. However, this damage did not translate to higher yields or net returns for the conventional insect control systems.

Introduction

Roundup Ready™ cotton varieties have been genetically altered to produce EPSPS synthase. This enzyme protects cotton from damage when it is sprayed with herbicides containing the active ingredient glyphosate (Johnson 1996). Roundup Ready varieties were commercially available for the first time in 1997.

Bollgard™ cotton varieties offer protection from heliothines and other caterpillars which attack cotton. These varieties have been genetically altered so that a toxin is produced in each cell of the plant. The toxin, originally from the bacterium *Bacillus thuringiensis*, has activity against several of the caterpillar pests of cotton and is constantly present in the plant tissue (Benedict 1996). Bollgard cotton varieties became commercially available to growers in 1996. Cotton varieties with both Bollgard and Roundup Ready traits became commercially available for the first time in 1998.

These technologies provide options which can be incorporated into a grower's cotton production system. How well the technologies work in a given geographic region and how they can best be integrated to optimize profitability are questions which have not been thoroughly studied. This study was conducted to provide information on the relative effectiveness and economics of transgenic and conventional weed and insect control systems.

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Materials and Methods

This study was composed of 9 treatments, each replicated four times. The treatments were conventional and transgenic seed from 2 parental lines, Paymaster 1220 and DPL 5415 (Bt/Roundup Ready, Bt/conventional herbicide, conventional insecticide/Roundup Ready, and conventional insecticide/conventional herbicide). Stoneville 474 was used as a conventional insecticide/conventional herbicide check. This arrangement was planted at Rohwer in Southeast Arkansas and at Keiser in Northeast Arkansas in plots 40 feet long by 4 rows wide arranged in a Randomized Complete Block Design. Each variety was treated for weed and insect control as appropriate for the pest pressure and varietal characteristics.

Planting dates were 5-5-98 at Rohwer and 5-9-98 at Keiser. Both tests were furrow irrigated; 6 irrigations at Rohwer and 2 irrigations at Keiser. Standard fertilization and irrigation timing were used on all plots at both locations.

At planting, thrips and seedling disease treatments were made to all plots at both locations. At Rohwer, all plots were treated with Temik 15G at 5 lbs/ac and Terrachlor Super X at 7 lbs/ac. At Keiser, all plots were treated with Payload at 6 lbs/ac and Terrachlor Super X at 6 lbs/ac.

The harvest program at Rohwer began with Finish at 2 pts/ac + Folex 6EC at 1 pt/ac on 9-9-98 followed by Folex 6EC at 0.5 pt/ac + Harvade 5F at 0.5 pt/ac + Crop Oil at 1 pt/ac. The Rohwer test was harvested on 9-30-98. At Keiser, Def 6 + Superboll were applied on 9-30-98 followed by Cotton Quick at 2 qts/acre on 10-5-98 and harvest on 10-22-98. Seed cotton samples from both tests were ginned with a plot gin located at Keiser, and lint samples were submitted to the LSU Cotton Fiber Lab for HVI classing. Loan values for the lint were established using the 1998 CCC Loan Values provided by Staplcotn Greenwood, MS.

Weed Control Program

Our test protocol for the Roundup Ready plots dictated the use of a PPI herbicide program, then reliance on Roundup Ultra as much as possible for the remainder of the season. The conventional program was a grower standard approach.

Roundup Ready Cotton

The Roundup Ready plots at Rohwer received Prowl 3.3 EC at 1.8 pts/ac PPI on 5-6-98. Roundup Ultra was then applied at 2 pts/ac (1.0 lb ai/ac) broadcast on 5-28-98. Roundup Ultra was applied a second time at 1.5 pts/ac (0.75 lb ai/ac) post-directed on 6-16-98.

The Roundup Ready plots at Keiser received Trifluralin 4EC at 1.5 pts/ac (0.75 lb ai/ac) + Cotoran 80DF at 1.0 lb/ac (0.8 lb ai/ac) PPI on 5-4-98. Roundup Ultra was then applied as a broadcast spray at 2 pts/ac (1.0 lb ai/ac) on 5-13-98. Staple was then applied at 0.8 oz/ac (0.045 lb ai/ac) in a 19 inch band on 6-8-98.

Conventional Herbicide Cotton

The conventional herbicide plots at Rohwer received Prowl 3.3 EC at 1.8 pts/ac PPI on 5-6-98 followed by Cotoran 80DF at 0.75 lb/ac (0.6 lb ai/ac) PRE on 5-8-98. Staple was then applied at 0.6 oz/ac (0.032 lb ai/ac) post-directed in a 19 inch band on 5-28-98. Bladex 4L at 1.5 pts/ac (0.75 lb ai/ac) + MSMA 4Lat 2.6 pts/ac (1.3 lb ai/ac) were applied as a layby.

The conventional herbicide plots at Keiser received Trifluralin 4EC at 1.5 pts/ac (0.75 lb ai/ac) + Cotoran 80DF at 1.0 lb/ac (0.8 lb ai/ac) PPI on 5-4-98. Staple was then applied at 0.8 oz/ac (0.045 lb ai/ac) in a 19 inch band on 5-21-98 and 6-8-98.

Foliar Insecticide Program

Early season insect control applications (thrips, boll weevil and plant bug) were made at both locations across all plots. At Rohwer, Vydate C-LV at 8.5 oz/ac and Provado 3.75 oz/ac were applied twice, on 6-4-98 and 6-14-98. At Keiser, Orthene 90S at .25 lb/ac was applied on 6-2-98, Dimethoate 400 at 6.4 oz/ac was applied on 6-15-98, and Vydate C-LV at 6.5 oz/ac was applied on 6-29-98.

Late season insecticide applications were applied as needed to both Bt and conventional insecticide (non-Bt) plots. At Rohwer, a single application was made to all plots (Bt and non-Bt). Baythroid at .028 lbs ai/ac + Lannate LV at 1.33 pt/ac (0.4 lb ai/ac) were applied on 8-15-98. At Keiser, four applications were made on all plots (Bt and non-Bt). Baythroid was applied at .03 lb ai/ac on 8-10-98. Vydate C-LV was applied at 10 oz/ac on 8-13-98. Karate Z was applied at 0.03 lb ai/ac on 8-17-98. And, Guthion 2L was applied at 1 pt/ac on 8-20-98.

Bollgard Cotton Mid-Season

No mid-season applications were made to Bollgard plots in either the Rohwer or the Keiser tests. Insects in the Bollgard plots did not reach threshold levels in either test during mid-season.

Conventional Insecticide (Non-Bt) Cotton Mid-Season

Our test protocol dictated that mid season insect control treatments were to be made on an as needed basis to all plots. Applications were needed only on the conventional insecticide (non-Bt cotton) plots during mid-season.

At Rohwer, Karate Z at 0.03 lb ai/ac was applied on 7-17-98 and Karate Z at 0.03 lb ai/ac + Tracer at 0.053 lb ai/ac were applied on 7-27-98 to the conventional insecticide (non-Bt) plots.

At Keiser, Karate was applied at 0.031 lb ai/ac on 7-30-98 to the conventional insecticide (non-Bt) plots.

Data Collection and Processing

Percent weed control ratings were made on 6-19-98 and 9-21-98 at Rowher.

Three days after mid-season insecticide treatments were made to the conventional insecticide plots at Rowher (non-Bt cotton plots treated on 7-17-98 and 7-27-98); 25 terminals, 25 squares and 25 bolls were examined in each plot. Bollworm eggs, worms (small, medium and large), worm damage, plant bugs and boll weevil damage were counted. Worm damage data only is presented in this paper.

Net returns after weed and insect control costs were paid were obtained by calculating the value of the lint per acre (yield x $0.68/lb) and subtracting the weed and insect control costs/acre for each plot. In these calculations, the technology fees for the transgenic varieties were considered as control costs.

Weed control ratings, insect damage, yield and net return data were processed using ANOVA and LSD at the 5% level of significance.

Results and Discussion

Weed Control Efficacy

Variety/System Comparisons. Weed control efficacy from the Rohwer location is given in Tables 1 and 2. Table 1 shows the percentage of three weeds controlled using specific transgenic and non-transgnic varieties and the weed control systems described above. Few significant differences in weed control among varieties/systems were seen. However, on the 6-19-98 rating, the 1220 conventional grown under a conventional herbicide program gave better pitted morning glory control than did the 1220 BGxRR under a Roundup Ready system.

Across Varieties. A comparison of the Roundup Ready and the conventional systems across varieties is shown in Table 2. As in Table1, few significant differences were seen. The Roundup Ready system gave significantly weaker teaweed control on the 6-19-98 rating, but otherwise no significant differences were seen. Generally, teaweed control tended to be a little better under the conventional herbicide system. Trends with pitted morning glory control were not seen. Trends in barnyard grass control favored the conventional system on the 9-21-98 rating.

Worm Damage

Variety/System Comparisons. Table 3 gives the worm damage seasonal means, three days after insecticide applications were made to the conventional (non-Bt) cotton. Terminal and square damage were generally low. More terminal damage was seen on the 5415 BGxRR than on other varieties/insect control systems. Terminal damage was 1% or lower for the other variety/system combinations.

No significant differences in percentages of worm damaged squares were seen, but 1220 BGxRR, 1220 BG, and 1220 conventional tended to show higher levels of worm damage.

The boll damage data showed that 1220 BGxRR had more boll injury than some of the other varieties/systems. Other treatments which tended to have higher boll damage were 5415 BGxRR, 5415 BG, 5415 conventional, and 1220 BG.

Across Varieties. Table 4 compares Bollgard versus conventional insect control systems across varieties. Cotton grown using the Bollgard system had 3.6-fold greater terminal damage, a non-significant trend toward higher square damage, and 2.6-fold higher boll damage than cotton grown using a conventional worm control system (damage counts taken 3 days after worm control sprays).

Lint Yields

Variety/System Comparisons. Lint yields of the varieties/systems tested are shown in Table 5. High yielding treatments at Rohwer (SE Arkansas) were St 474, PM 1220 BG, DPL 5415 and PM 1220. Numerically, the lowest yielding treatment was DPL 5415 BGxRR, but it was not significantly lower yielding than PM 1220 BgxRR.

At Keiser (NE Arkansas), higher yielding treatments were DPL 5415 BGxRR, DPL 5415 BG, DPL 5415, and DPL 5415 RR. Numerically, the lowest yielding treatment was PM 1220 RR, but it was not significantly lower than PM 1220 BGxRR.

Combining the yield data across both locations, the high yielding treatments were St 474, DPL 5415and PM 1220 BG. Numerically, the lowest yielding treatment was PM 1220 RR, but it was not significantly different from PM 1220 BGxRR, DPL 5415 BGxRR, PM 1220 or DPL 5415 RR.

Across Varieties. To begin addressing the yield value of the transgenic technologies we removed the St 474 data from the data set and evaluated yields across only the DPL 5415 and PM 1220 lines (in which all combinations of BG, RR and conventional weed and insect control options were present).

Conventional weed control systems yielded significantly more lint/ac than did Roundup Ready weed control systems at Rohwer (Table 6). At Keiser and in the combined data from both locations conventional herbicide systems yielded numerically more than Roundup Ready systems, but the differences were not statistically significant.

The comparison of insect control systems (Table 7) was not as clear cut and none of the differences seen were statistically significant. At Rohwer, the conventional systems tended to produce higher yields. At Keiser, however, this trend was reversed with the Bollgard system tending to produce higher yields. When the data from both locations were combined the yields of the two systems were near identical.

Net Returns

Variety/System Comparisons. Net returns of the variety/system treatments are given in Table 8. The yield rankings of the variety/systems treatments in Table 5 was very similar to the net returns data shown here. The highest net returns after weed and insect control costs were paid was seen in the St 474, PM 1220 BG, DPL 5415, and PM 1220 treatments at Rohwer. At Keiser, the highest net returns were seen in the DPL 5415 BGxRR, DPL 5415, DPL 5415 BG and DPL 5415 RR treatments. Combining data from both locations, net returns were best in the St 474, DPL 5415, PM 1220 BG, and DPL 5415 BG treatments.

Across Varieties. For purposes of comparing net returns of the transgenic traits, the St 474 net return data were removed and only net return data of the conventional and transgenic DPL 5415 and PM 1220 varieties were compared.

Net returns across varieties (after weed and insect control costs were paid) are compared in Roundup Ready versus conventional herbicide variety/systems treatments in Table 9. Compared with Roundup Ready Systems, conventional herbicide systems gave significantly higher net returns at Rohwer and showed a non-significant trend toward higher net returns at Keiser and in the combined location data.

No statistical differences or consistent trends in net returns (after weed and insect control costs were paid) were seen in the comparison of insect control systems (Table 10).

Conclusions

The Roundup Ready system provided weed control at about the same level as was seen in the conventional system. Some weakness in early season teaweed control and a trend toward weaker late season barnyard grass control were observed. Consistent trends and statistically significant differences supported the conclusion that the Roundup Ready system produced lower yields and net returns than did the conventional system.

Soon after insecticide applications to conventional systems, cotton in the conventional systems had less worm damage than did cotton in untreated Bollgard systems. There was no consistent advantage of either the Bollgard or the conventional insect control systems in yield or net returns after weed and insect control costs were paid, however.

Stoneville 474 conventional gave, numerically, the highest yield and net return at Rohwer and in the combined location data. At Keiser the DPL 5415 line did especially well, with DPL 5415 BGxRR providing, numerically, the highest yield and net return after weed and insect control costs were paid.

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Table 1. Weed control in Roundup Ready and conventional cotton systems[1]. Rohwer, AR. 1998.

Variety	Percentage Weed Control					
	teaweed		pitted morning glory		barnyard grass	
	6-19	9-21	6-19	9-21	6-19	9-21
1220	78 a	94 a	98 a	98 a	65	94 a
5415	81 a	81 a	97 ab	99 a	70	94 a
5415 BG	80 a	80 a	97 ab	99 a	60	82 a
5415 RR	78 a	98 a	96 ab	99 a	50	92 a
5415 BGxRR	79 a	68 a	96 ab	96 a	60	71 a
1220 RR	76 a	81 a	96 ab	99 a	–	80 a
474	82 a	89 a	95 ab	97 a	–	81 a
1220 BG	82 a	84 a	95 ab	98 a	65	84 a
1220 BGxRR	77 a	72 a	94 b	99 a	90	76 a

[1]Means in columns followed by the same letter are not significantly different at the 5% level of significance.

Table 2. Weed control comparing Roundup Ready and conventional herbicide systems across varieties[1]. Rohwer, AR. 1998.

Herbicide System	Percentage Weed Control					
	teaweed		pitted morning glory		barnyard grass	
	6-19	9-21	6-19	9-21	6-19	9-21
Roundup Ready	77 b	80 a	95 a	98 a	67 a	80 a
Conventional	80 a	86 a	96 a	98 a	65 a	87 a

[1]Means in columns followed by the same letter are not significantly different at the 5% level of significance.

Table 3. Seasonal mean worm damage on Bollgard and conventional insecticide cotton systems[1,2]. Rohwer, AR. 1998.

Variety	100 Terminals	100 Squares	100 Bolls
1220 BGxRR	0 a	4 a	5.5 b
474	0 a	1 a	0.5 a
1220 RR	0.5 a	1 a	0.5 a
5415	0.5 a	2.5 a	3.5 ab
1220	0.5 a	3 a	2.5 ab
5415 BG	1 ab	2 a	4.5 ab
5415 RR	1 ab	2 a	1.5 ab
1220 BG	2 b	3.5 a	3 ab
5415 BGxRR	4 c	1.5 a	4.5 ab

[1]Means in columns followed by the same letter are not significantly different at the 5% level of significance.
[2]Counts made 3 days after foliar insecticide sprays on conventional (non-BG) varieties. BG varieties not sprayed.

Table 4. Summary of seasonal mean worm damage on Bollgard and conventional insecticide cotton systems[1,2]. Rohwer, AR. 1998.

Insect Control System	100 Terminals	100 Squares	100Bolls
Bollgard	1.8 a	2.8 a	4.4 a
Conventional	0.5 b	1.9 a	1.7 b

[1]Means in columns followed by the same letter are not significantly different at the 5% level of significance.
[2]Counts made 3 days after foliar insecticide sprays on conventional (non-BG) varieties. BG varieties not sprayed.

Table 5. Lint yield of varieties/systems tested[1]. Rohwer and Keiser, AR. 1998.

Varieties	Rohwer	Keiser	Combined
St 474	911 a	1046 ab	978 a
DPL 5415	789 ab	1082 ab	935 ab
PM 1220 BG	798 ab	1057 ab	927 ab
DPL 5415 BG	712 b	1102 a	907 abc
DPL 5415 RR	696 b	1075 a	885 abcd
PM 1220	781 ab	984 ab	883 abcd
DPL 5415 BGxRR	521 c	1150 a	835 bcd
PM 1220 BGxRR	637 bc	918 bc	778 cd
PM 1220 RR	690 b	855 c	773 d

[1]Means in columns followed by the same letter are not significantly different at the 5% level of significance.

Table 6. Yield of Roundup Ready versus conventional (non-RR) cotton systems[1,2]. Rohwer and Keiser, AR. 1998.

Herbicide System	Rohwer	Keiser	Combined
Conventional	770 a	1056 a	913 a
Roundup Ready	636 b	999 a	817 a

[1]Means in columns followed by the same letter are not significantly different at the 5% level of significance.
[2]Only varieties of the DPL 5415 and PM 1220 lines were included in this analysis.

Table 7. Yield of Bollgard versus conventional (non-Bollgard) cotton[1,2].

Insect Control System	Rowher	Keiser	Combined
Conventional	739 a	999 a	869 a
Bollgard	667 a	1056 a	862 a

[1]Means in columns followed by the same letter are not significantly different at the 5% level of significance.
[2]Only varieties of the DPL 5415 and PM 1220 lines were included in this analysis.

Table 8. Net returns of varieties/systems tested[1,2]. Rohwer and Keiser, AR. 1998.

Varieties/Systems	$/ac		
	Rohwer	Keiser	Combined
St 474	442.35 a	583.93 ab	513.14 a
DPL 5415	359.56 ab	608.23 a	483.90 ab
PM 1220 BG	370.42 ab	574.02 ab	472.22 ab
DPL 5415 BG	312.28 b	604.19 a	458.23 ab
PM 1220	353.78 ab	542.03 abc	447.90 abc
DPL 5415 RR	305.05 b	590.26 a	447.66 abc
DPL 5415 BGxRR	190.96 c	623.61 a	407.29 bc
PM 1220 RR	300.97 b	441.12 c	371.04 c
PM 1220 BGxRR	269.67 bc	466.46 bc	368.06 c

[1]Means in columns followed by the same letter are not significantly different at the 5% level of significance.
[2]Net returns over insect and weed control costs.

Table 9. Net returns of Roundup Ready versus conventional weed control systems across varieties[1,2,3]. Rohwer and Keiser, AR. 1998.

Herbicide System	$/ac		
	Rohwer	Keiser	Combined
Conventional	349.01 a	582.12 a	465.59 a
Roundup Ready	266.66 b	530.36 a	398.51 a

[1]Means in columns followed by the same letter are not significantly different at the 5% level of significance.
[2]Net returns over insect and weed control costs.
[3]Only varieties of the DPL 5415 and PM 1220 lines were included in this analysis.

Table 10. Net returns of Bollgard versus conventional insect control systems across varieties[1,2,3]. Rohwer and Keiser, AR. 1998.

Insect Control System	$/ac		
	Rohwer	Keiser	Combined
Conventional	329.84 a	543.16 a	437.63 a
Bollgard	285.83 a	567.07 a	426.45 a

[1]Means in columns followed by the same letter are not significantly different at the 5% level of significance.
[2]Net returns over insect and weed control costs.
[3]Only varieties of the DPL 5415 and PM 1220 lines were included in this analysis.