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Development of Sustainable, Cost-Efficient Strategies for Managing Cotton Insects -- An Interim Report

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INTRODUCTION

To remain viable in the face of increasing production costs and market competition, Mississippi cotton growers need updated insect control strategies. New concepts of pest control, including transgenic cotton and new cl asses of insecticides, can potentially help reduce production costs. There is a critical need to evaluate new cotton insect pest control strategies and develop research-based recommendations and economic benefit data.

In response to this need, the project "Development of Sustainable, Cost-Efficient Strategies for Managing Cotton Insects" was initiated by the Mississippi Agricultural and Forestry Experiment Station in early spring of 1995. Objectives of the project were to: (1) establish a coordinated program of evaluating cotton insect management options in replicated small plots in the Delta and Hill regions of the state; (2) initiate an experimentally sou nd program of evaluating major changes to current recommended strategies in production-level fields; and (3) revitalize a cooperative management-science effort to develop decision-making tools and simulators necessary to introduce new management capabilit ies, guide research projects, and create a proactive approach to developing new cost-effective management options for cotton insects.

One new management option for control of the tobacco budworm (*Heliothis virescens* [F.]) and the bollworm (*Helicoverpa zea* [Bodie]) is the use of transgenic cotton containing the

Bacillus thuringiensis (Bt) gene for production of the cry1-a endotoxin protein (Jenk ins et al., 1993; Harris et al., 1996; Luttrell et al., 1996; Mascarenhas, 1994). Commercial seed increase and mark et planning by the Monsanto Company created a need for an unbiased, large-s cale evaluation of the Bt cotton.

Beginning in 1995, Monsanto supplied seed for planting a total of 200 acres of Bt cotton and its conventional parent variety in field-size research plots at five locations in the cotton-growing areas of Mississippi. Dat a from this cooperative study allow a comparison of the relative economic benefits and costs associated with growing transgenic and common conventional cotton varieties.

The field-size plots were also used in an evaluation of management strategies for controlling the tarnished plant bug (Lygus lineolaris [Palisot de Beauvois]). Conventional tarnished plant bug control recommendat ions were compared to an aggressive early-season strategy. Conventional control consisted of treatments described in the Mississippi Cotton Insect Control Guide. The aggressive strategy included a preventative, early-season treatment of acephate. < p> These studies served to amass an entomological data set that will benefit future research to analyze pest and beneficial insect trends and to evaluate the efficacy of insect control procedures in the major cotton-growin g areas of Mississippi. Future analysis of the data also will provide information that may lead to an increased understanding of factors associated with dramatic pest population growth changes, such as the one that occurred in the 1995 tobacco budworm epi zootic. Much of this research focused on providing data to modify and develop computerized insect control decision-mak ing aids and to revitalize computer models for testing innovative management strategies in a simulated environment.

This bulletin describes results obtained during 1995 and 1996 in the field-size research plots at five Mississippi locations. A detailed report of findings for three years (1995-1997) of research in these plots will follow this publication. The follow-up bulletin also will report on systems research to date and on small-plot research that emphasizes pest control strategies and efficient pesticide use at the Delta Branch Experiment Station in Stone ville and the North Mississippi Branch Experiment Station in Holly Springs.

MATERIALS AND METHODS

Methodology Used in Both Years

Different insecticide management strategies were applied to the field-size research units in 1995 and 1996. Fields were sampled twice a week for insects. Sampling included observation of 25 terminals and 25 squares or b olls in each of 4 sites in each field. In addition, sweep net and/or drop cloth samples were taken to estimate densities of tarnished plant bug and common beneficial insects. Data collected included the percent of terminals with heliothine eggs or larvae, percent of squares infested with larvae, percent damaged squares and bolls, size of heliothine larvae found (small = <¼ inch; medium = >¼ inch, < = ½ inch; and large = >½ inch), percent boll weevil (Anthonomu s grandis grandis Boheman) punctured squares, cotton aphid (Aphis gossipii Glover) density ratings (0 = none, 1 = low, 2 = medium, and 3 = high), presence or absence of whiteflies (Aleyrodidae), the number of "hits" (oviposition sites) of beet armyworm moths (Spodoptera exigua [Hubner]), and the number of fall armyworm (Spodoptera frugiperda [J. E. Smith]) or other lepidopteran larvae found in the sample.

Fields were located in Lee, Leflore, Madison, Tallahatchie, and Yazoo counties in 1995, and in Itawamba, Leflore, Madison, Tallahatchie, and Yazoo counties in 1996. The Leflore County site included four field-sized rep licates of each treatment to allow estimation of variability within a single farm relative to variability across regions. All other locations included only one replicate of each treatment. Thus, there were a total of eight replicates at five different loc ations spanning the cotton-growing region of the state. Although an effort was made to locate all treatments within each site in adjacent fields, variations in fields did exist because of location. Fields at both Hill locations were different in slope and soil characteristics and were typically more closely associated with woods and wild flowers than the Delta locations.

The growers maintained plot maintenance records, including planting date, insecticide application dates and rates, plant growth regulator application information, defoliation and harvest dates, and yield. In Itawamba Co unty, however, yield for each field was estimated based on the area required to produce a single module. The weight of the cotton module was obtained from the gin report. The area required to produce the module was calculated by counting and measuring the rows and converting the row-feet included in the area to acres. Seed cotton obtained from a second picking in Itawamba County was weighed in the boll buggy or cotton wagon by use of truck scales under each wheel, and the weight of lint was computed based on the gin turn out reported from the first picking. Yield data were used to compare total insecticide cost and cost of controlling heliothine larvae and tarnished plant bug based on the estimated cost of insecticides reported in the 1997 Delta Planning Budgets.

1995 Insecticide Management Strategy

Plots of approximately 25 acres were located on farms in two Hill counties (Lee and Madison) and three Delta counties (Leflore, Yazoo, and Tallahatchie). The study included four treatments: (1) transgenic Bt cotton (NuCotn 33B) managed for insect pests according to the Mississippi Cotton Insect Control Guide (MCICG); (2) DPL 5415 (parent variety of NuCotn 33B lacking the BollgardTM gene) managed for insect pests according to the MCICG; (3) a grower's-choice variety (GV) (Table 1) treated with an aggressive, early-season pesticide program for tarnished plant bug management; and (4) the grower's choice variety treated according to the MCICG for tarnished plant bug management.

The aggressive tarnished plant bug control strategy consisted of a prophylactic application of acephate (Orthene 90S) at 0.33 pound (active ingredient) per acre at the fourth-true-leaf stage of plant development. A seco nd treatment was applied during the first week of squaring if 2 plant bugs were found per 100 sweeps with a 15-inch diameter sweep net. During the second week of squaring, a third application was used if 4 plant bugs were found per 100 sweeps. Subsequent control of all insects was based on the MCICG. This treatment is designated as GV-ETPBO (Early Tarnished Plant Bug - Orthene).

At three locations, (Leflore, Yazoo, and Tallahatchie counties), additional fields of conventional cotton *were treated with a similar aggressive tarnished plant bug strategy. However, in these treatments a pyrethroid wa s used rather than acephate. This approach was designated as GV-ETPBP (Early Tarnished Plant Bug - Pyrethroid). All treatments at the Leflore County location were replicated four times, and plots within each replicate were adjacent to each other.*

1996 Insecticide Management Strategy

Treatments for 1996 included NuCotn 33B (Bt) under an aggressive strategy for tarnished plant bug control (BT-ETPBO). NuCotn 33B also was managed according to the MCICG (BT-MCICG). These treatments were compared to conventional cotton of the grower's choice managed according to the MCICG (GV-MCICG).

The aggressive tarnished plant bug management strategy for 1996 was similar to that used in 1995. However, unlike the 1995 strategy, follow-up applications were not triggered by tarnished plant bug thresholds. Orthene 9 0S was applied at 0.33 pound (active ingredient) per acre beginning at the 4th true leaf stage. Two subsequent applications were made at 7-day intervals after the prophylactic treatment. This change was made so that other parameters, such as the effect of these sprays on beneficial insects, could still be monitored even if plant bug populations were too low to trigger an application.

In 1996, the Bt cotton fields at the Itawamba and Tallahatchie locations were separated from the conventional (GV-MCICG) fields by at least 1 mile. Thus, the assumption that each field within these locations is subject to the same insect populations and population densities may be questionable. Fields located at Madison and Yazoo counties were adjacent, and the fields at Leflore County within each replicate were located close to each other.

RESULTS FROM 1995 AND 1996

1995 Insecticide Management Study Results

Table 2 summarizes several variables for the five locations and the different management strategies: number of insecticide applications; yield, measured in pounds of lint cotton per acre; total ins ecticide cost; cost of insecticides for heliothine control, including \$32 for Bollgard^{TM} license; and the pounds of lint gained per each dollar spent on insecticide for heliothine control.

Population densities of tarnished plant bugs were low in all locations during 1995. Based on means of the five locations, DPL 5415 and grower's-choice conventional cotton fields managed by the MCICG collectively averaged 0.8 applications of insecticide for tarnished plant bug management. Conventional cotton receiving the aggressive plant bug treatments averaged 1.1 applications, and the NuCotn 33B (BT-MCICG) averaged 1.4 applications. Mean yields across all five locations were similar for both the MCICG tarnished plant bug management strategy (GV-MCICG) and the early-season acephate treatment (GV-ETPBO). GV-MCICG fields yielded 813 pounds of lint, while GV-ETPBO yielded 820 pounds.

Averaged over all locations, insecticide cost for the transgenic cotton fields was less than half the cost of heliothine control for the conventional varieties managed under MCICG guidelines. Economic benefit was statistically similar (LSD; p = 0.05) for all of the treatments in the study when averaged across all locations. Yield ranged from 19.5 pounds of cotton lint produced per dollar invested in insecticide in the GV-MCICG fields to 25.3 p ounds per dollar invested in the BT-MCICG fields. The DPL5415, GV-ETPBO, and GV-ETPBP fields returned 23, 21.6, and 23 pounds of lint, respectively, per dollar spent on heliothine control.

Cotton in the Leflore County GV-MCICG and GV-ETPBO treatments was harvested as one field in each replicate, which made it impossible to separate any effects based on yield from the two treatments. The field with these same treatments in Lee County was damaged by hail on July 7, 1995. Although the two treatments were in the same field, the damage in both treatments may not have been equal. In addition, Lee County suffered severely from the tobacco budworm infestation. Unexpectedly high insecticide use in the Midsouth caused a sho rt supply of preferred insecticides for budworm control late in the growing season, compounding *the problem in Lee County. This insecticide shortage, combined with the occasional inability to spray at close intervals because of rain or other factors, resu lted in drastically reduced yields in all conventional cotton at the Lee County location.*

Average yield and standard deviation (SD) from GV-MCICG and GV-ETPBO fields at the other four locations were essentially equal. Average yield for GV-MCICG fields was 813 (SD 127.3) pounds of lint per acre; for GV-ETPBO fields, 820 pounds (SD 71.2). When Lee County is included in the overall calculation, the mean yield is reduced to 681 (SD 283.4) pounds of lint for the GV-MCICG treatment and 665 pounds (SD 313.7) for the GV-ETPBO treatment. In comparison, fields in Lefl ore, Tallahatchie, and Yazoo counties that used pyrethroids for plant bug control (GV-ETPBP) averaged 840 (SD 45.3) pounds of lint per acre when averaged by location (three means). The average of the six replicates (four in Leflore County, one each in Yaz oo and Tallahatchie counties) was 824 (SD 128.4) pounds of lint per acre.

Averaged across locations, mean yield was 833 (SD 166.7) pounds of lint per acre for the BT-MCICG fields and 622 (SD 229.7) pounds for the DPL5415 fields. BT-MCICG and DPL5415 yields averaged by the eight replicates, in stead of by location, resulted in 840 (SD 139.3) and 645 (SD 204.0) pounds of lint cotton per acre, respectively. Yields from four locations (using the mean of the four replicates at Leflore County and excluding the low yield of the Lee County location) f or the BT-MCICG and DPL5415 fields were 886 (SD 135.4) and 714 (SD 117) pounds of lint, respectively. Although results from Lee County appeared to be an outlier, as compared to other locations in the study, it is nonetheless a valid indication of the budw orm problem in this area in 1995 as documented by Luttrell et al., 1997.

Some of the insect sampling data for 1995 from the five locations are summarized in Table 3. The population density of tarnished plant bugs was low in all fields, but transgenic cotton averaged 0. 48 (SD 0.794) tarnished plant bugs per 25 sweeps season-long over all locations, and conventional cotton averaged 0.23 (SD 1.445). This difference was statistically significant (ANOVA; p = 0.0001). The number of tarnished plant bugs in all fields in the b oll weevil eradication zone, which included Lee County, may have been reduced by the multiple applications of ULV malathion used by the eradication program.

The ability of Bt cotton to prevent damage from the tobacco budworm is strongly indicated by the damaged square data. Based on the data in Table 3, transgenic cotton sustained a seasonal average of 0.98% damaged squares, fourfold less than the average of all conventional varieties (3.92%). Such a dramatic difference was measured despite the fact that conventional cotton was managed with conventional insecticides according to current Extension recom mendations for lepidopteran pests. Season-long averages of percent damaged squares in conventional cotton varied greatly in each county: Lee, 9.6% (SD 1.40); Madison, 1.5% (SD 0.38); Tallahatchie, 6.8% (SD 1.10); Yazoo, 2.3% (SD 1.13); and Leflore, 0.2% (SD 2.55). These data indicate the severity of the epizootic of tobacco budworm during 1995 in both Lee and Tallahatchie counties.

Throughout the season in these counties, mean percent of terminals of all varieties with heliothine eggs was 5.72% (SD 3.34). Bt cotton averaged 7.6% (SD 3.09) infested terminals, and the conventional cotton averaged 5. 2% (SD 3.3). These differences were statistically significant (ANOVA, p = 0.018) and may reflect adult mortality resulting from insecticidal sprays in conventional cotton.

1996 Insecticide Management Study Results

Population densities of the tarnished plant bug in cotton were low in all test locations during 1996 (Table 5). The mean number of applications directed at the tarnished plant bug in the BT-MCICG, GV-MCICG, or BT-ETPBO fields was 1.6, 1.4, and 4, respectively. As in 1995, tarnished plant bug population density increased toward the l atter part of the growing season in all locations and fields. Yield from the different treatments averaged across locations indicated that under 1996 conditions, there was no yield benefit to the early-season treatments for the tarnished plant bug (Table 4).

When the cost of the Bollgard^{TM} license is included in the cost of Bt cotton, 1996 insecticide expenditures for heliothine larvae control was higher in transgenic cotton fields than in conventional cotton fields (Table 4). The average cost for heliothine-directed insecticides was $37.56 for the BT-MCICG fields, $23.14 for the GV-MCICG fields, and $36.04 for the BT-ETPBO fields. These values demonstrate that transgenic cotton may not *be as co st effective as conventional cottons when larval densities are very low. It certainly was cost effective under the high tobacco budworm densities seen in 1995.*

CONCLUSIONS

Many factors associated with this study varied widely between years or among locations. Populations of tobacco budworm and bollworm were low in 1996 and high in 1995, particularly in the Lee County research plots. Insec t control efforts in Lee County were limited by the inability to obtain critical insecticides later in the season, as well as the difficulty in making timely applications at short intervals. Yield, number of insecticide applications, and insect densities may have been influenced by many other factors in the study, including the distance between plots within locations, proximity of wild hosts or over-wintering habitat for pests, slope and soil characteristics of the different fields, and a wide range of agronomic and economic variables (Luttrell et al., 1997). These factors contributed a robust evaluation of both of the strategies tested.

The average number of insecticide applications made per location for tarnished plant bug control during the 2-year period in ETPBO fields was 4.15 applications. Those managed strictly according to the Mississippi Cot ton Insect Control Guide received an average of 1.35 applications. Results of the first 2 years of research indicated that tarnished plant bug population densities were low in all fields in the five locations. Under such conditions, the strategy of ea rly-season scheduled or aggressive management of tarnished plant bugs with applications of Orthene 90S provided no benefit in yield. When the tarnished plant bug population is low, these results indicate no need to alter current management recommendations for this pest.

There were no statistical differences in yield, total insecticide cost, or heliothine insecticide cost between the MCICG-based transgenic and conventional cotton treatments when summarized over the 2-year period (ANOVA; p = 0.05) (Table 6). These mean values incorporate data from a year of high heliothine populations and a year of relatively low heliothine numbers. Data from individual years suggest that the Bollgard-protected cotton would p rovide a greater return than conventional cotton in years of high-budworm pressure, while the reverse would be true in years of low-budworm pressure.

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Table 1. Conventional cotton varieties planted at each location in 1995 and 1996.

County	Conventional cotton varieties	
	1995	1996
Itawamba	--	DP5409
Lee	DP50	--
Leflore	LA887	ST474
Madison	SG125	SG125
Tallahatchie	LA887	ST495
Yazoo	SG125	SG125

Table 2. Insecticide costs, cotton lint yields, and economic benefits of various insecticide treatments at five Mississippi locations in 1995.

Treatment[1]	Total insecticides		Heliothine insecticides		Tarnished plant bug insecticides		Yield[2]	Economic benefit[3]
	N[4]	Cost[5]	N[4]	Cost[6]	N[4]	Cost		
		dol.		dol.		dol.	lb/A	
Lee County								
BT-MCICG	4.0	64.48	1.0	32.00	0.0	0.00	621	19.4
DPL5415	11.0	108.98	10.0	86.57	0.0	0.00	253[7]	2.9
GV-ETPBO	11.0	81.83	9.0	56.07	1.0	3.36	265	4.7
GV-MCICG	10.0	78.47	9.0	56.07	0.0	0.00	221[7]	3.9
Leflore County [8]								
BT-MCICG	7.3	54.46	1.0	32.00	0.8	2.52	987	30.8
DPL5415	13.3	83.47	5.5	49.29	0.0	0.00	685	13.9
GV-ETPBO	14.3	78.30	5.8	47.98	1.3	4.18	810[9]	16.9
GV-ETPBP	13.2	78.84	5.5	46.61	1.3	7.29	809	17.4
GV-MCICG	13.0	72.22	5.3	44.73	0.3	0.84	810[9]	18.1
Madison County								
BT-MCICG	14.0	79.94	1.0	38.27	4.0	15.43	703	18.4
DPL5415	26.0	152.06	15.0	117.54	2.0	6.71	670	5.7

GV-ETPBO	23.0	95.71	10.0	54.08	1.0	3.36	740	13.7
GV-MCICG	23.0	132.01	13.0	99.06	2.0	6.71	666	6.7
Tallahatchie County								
BT-MCICG	6.0	52.31	1.0	32.00	1.0	3.36	864	27.0
DPL5415	7.0	27.72	2.0	7.48	2.0	6.71	616	82.4
GV-ETPBO	6.0	36.52	4.0	21.21	1.0	3.36	877	41.4
GV-ETPBP	7.0	40.11	4.0	21.21	0.0	0.00	892	42.1
GV-MCICG	7.0	33.17	4.0	21.21	0.0	0.00	885	41.7
Yazoo County								
BT-MCICG	15.0	120.31	1.0	32.00	1.0	2.62	990	30.9
DPL5415	19.0	135.84	12.0	86.13	0.0	0.00	884	10.3
GV-ETPBO	19.0	130.60	12.0	86.13	1.0	3.36	842	9.7
GV-ETPBP	19.0	130.60	12.0	86.13	1.0	3.36	819	9.5
GV-MCICG	18.0	127.25	12.0	86.13	0.0	0.00	888	10.3
Summary Means								
BT-MCICG	9.3	74.30	1.0	32.00	1.4	4.78	833	25.3
DPL5415	15.3	101.61	8.9	69.40	0.8	2.69	714	23.0
GV-ETPBO	16.0	87.61	8.7	53.81	1.1	3.52	820	21.6
GV-ETPBP	13.1	83.18	7.2	51.32	0.5	1.51	840	23.0
GV-MCICG	16.0	97.48	9.7	68.80	0.8	3.54	813	19.6

[1]BT = NuCotn 33B. GV = Grower's Choice Variety. MCICG = *Mississippi Cotton Insect Control Guide*. ETPBO = Early Tarnished Plant Bug - Orthene strategy. ETPBP = Early Tarnished Plant Bug - Pyrethroid strategy. DPL541 5 = Nontransgenic parent variety of NuCotn 33B.

[2]Pounds of cotton lint per acre.

[3]Pounds of lint per dollar spent on heliothine insecticides.

[4]N = Number of insecticides applied including each constituent of mixtures and the Bollgard™ gene.

[5]Includes $32 per acre license fee for the NuCotn 33B cotton variety.

[6]Contains only the cost of insecticides used for heliothine larval control.

[7]These plots were badly damaged by hail in July. Data are not included in summary report calculations.

[8]Values for Leflore County are means of four replicates. Costs are computed only for the cost of insecticide based on estimated pesticide prices in the 1997 Delta Planning Budget (Ag. Economics Report 81).

[9]These plots were harvested together as a single field. Yield from the field was 810 pounds of lint. Data from these fields are not included in summary report calculations.

Table 3. Seasonal means for percent of terminals with heliothine eggs and larvae, percent larva-damaged squares, and tarnished plant bugs per 25 sweeps for five Mississippi locations in 1995.

Treatment[1]	Pct. terminals w/ heliothine eggs			Pct. terminals w/ heliothine larvae		
	N[2]	Mean	SD[3]	N[2]	Mean	SD[3]

Leflore County[4]						
BT-MCICG	352	10.5	28.14	352	2.0	6.48
DPL5415	356	8.0	18.06	356	5.1	12.03
GV-MCICG	260	4.4	7.99	260	3.3	6.43
GV-ETPBO	364	8.0	15.71	364	7.4	12.96
GV-ETPBP	268	3.0	6.69	268	3.1	5.94
Lee County						
BT-MCICG	92	11.3	17.29	92	2.2	9.04
DPL5415	104	12.2	17.02	104	5.1	15.37
GV-MCICG	98	9.5	12.84	98	3.4	7.44
GV-ETPBO	97	11.5	16.13	97	4.2	11.60
GV-ETPBP	0	--	--	0	--	--
Madison County						
BT-MCICG	109	6.4	14.37	109	3.0	6.32
DPL5415	109	5.3	12.65	109	3.5	6.80
GV-MCICG	109	5.2	12.94	109	2.5	4.39
GV-ETPBO	109	4.6	12.11	109	4.1	6.16
GV-ETPBP	0	--	--	0	--	--
Tallahatchie County						
BT-MCICG	48	4.9	7.34	52	0.7	1.53
DPL5415	48	4.2	7.62	52	3.4	5.90
GV-MCICG	32	3.0	6.66	36	2.0	3.38
GV-ETPBO	32	1.8	4.65	36	1.0	2.76
GV-ETPBP	32	2.0	4.19	36	2.3	3.22
Yazoo County						
BT-MCICG	36	4.9	7.34	36	0.7	1.53
DPL5415	36	4.2	7.62	36	3.4	5.90
GV-MCICG	36	3.0	6.66	36	2.0	3.38
GV-ETPBO	36	1.7	4.65	36	1.0	2.77
GV-ETPBP	36	2.0	4.19	36	2.3	3.22

[1]BT = NuCotn 33B. GV = Grower's Choice Variety. MCICG = *Mississippi Cotton Insect Control Guide*. ETPBO = Early Tarnished Plant Bug - Orthene strategy. ETPBP = Early Tarnished Plant Bug - Pyrethroid strategy. DPL541 5 = Nontransgenic parent variety of NuCotn 33B.

[2]N = number of samples determining mean.

[3]SD = Standard Deviation.

[4]Means for Leflore County include four replicates.

Table 3. Continued.

Table 3. Seasonal means for percent of terminals with heliothine eggs and larvae, percent larva-damaged squares, and tarnished plant bugs per 25 sweeps for five Mississippi locations in 1995.						
Treatment[1]	**Pct. larvae damaged squares**			**Plant bugs per 25 sweeps**		
	N[2]	**Mean**	**SD[3]**	**N[2]**	**Mean**	**SD[3]**
Leflore County[4]						
BT-MCICG	352	0.0	0.18	248	0.2	0.50
DPL5415	356	0.2	0.63	283	0.3	1.10
GV-MCICG	260	0.2	0.40	222	0.1	0.37
GV-ETPBO	364	0.4	0.92	223	0.1	0.42
GV-ETPBP	268	0.1	0.35	253	0.2	0.78
Lee County						
BT-MCICG	92	2.1	4.21	92	0.1	0.46
DPL5415	104	8.3	10.55	104	0.0	0.17
GV-MCICG	98	10.0	12.43	98	0.1	0.26
GV-ETPBO	97	10.6	10.94	97	0.1	0.24
GV-ETPBP	0	--	--	0	--	--
Madison County						
BT-MCICG	109	0.5	1.51	109	0.2	0.68
DPL5415	109	1.6	3.45	109	0.0	0.19
GV-MCICG	109	1.6	3.36	109	0.1	0.44
GV-ETPBO	109	1.4	2.85	109	0.1	0.34
GV-ETPBP	0	--	--	0	--	--
Tallahatchie County						
BT-MCICG	48	1.0	6.88	36	0.0	0.17
DPL5415	48	4.8	3.91	36	0.0	0.00
GV-MCICG	32	7.8	8.18	36	0.1	0.32
GV-ETPBO	32	6.9	6.27	36	0.2	0.55
GV-ETPBP	32	7.6	6.63	36	0.2	0.45
Yazoo County						
BT-MCICG	48	1.3	2.02	36	0.2	0.33
DPL5415	48	2.3	3.16	36	0.2	0.39
GV-MCICG	32	1.8	1.93	36	0.0	0.00
GV-ETPBO	32	2.8	3.15	36	0.1	0.31
GV-ETPBP	32	2.3	2.35	36	0.1	0.26

[1]BT = NuCotn 33B. GV = Grower's Choice Variety. MCICG = *Mississippi Cotton Insect Control Guide*. ETPBO = Early Tarnished Plant Bug - Orthene strategy. ETPBP = Early Tarnished Plant Bug - Pyrethroid strategy. DPL541 5 = Nontransgenic parent variety of NuCotn 33B.

[2]N = number of samples determining mean.
[3]SD = Standard Deviation.
[4]Means for Leflore County include four replicates.

Table 4. Insecticide costs, cotton lint yields, and economic benefits of various insecticide treatments at five Mississippi locations in 1996.								
Treatment [1]	**Total insecticides**		**Heliothine insecticides**		**Tarnished plant bug insecticides**		**Yield[2]**	**Economic benefit[3]**
	N[4]	**Cost[5]**	**N[4]**	**Cost[6]**	**N[4]**	**Cost**		
		dol.		**dol.**		**dol.**	**lb/A**	
Itawamba County								
BT-MCICG	3.0	36.03	1.0	32.00	0.0	0.00	1,116	34.8
BT-ETPBO	4.0	40.73	1.0	32.00	2.0	6.72	1,222	38.2
GV-MCICG	4.0	23.13	2.0	19.10	0.0	0.00	979	51.3
Leflore County[7]								
BT-MCICG	10.0	92.19	2.0	44.26	3.0	25.52	910	20.6
BT-ETPBO	13.0	101.81	2.0	44.26	6.0	36.09	849	19.2
GV-MCICG	13.5	92.75	4.5	40.80	3.6	30.03	813	19.9
Madison County								
BT-MCICG	18.0	53.06	1.0	32.00	2.0	3.78	935	29.2
BT-ETPBO	17.0	58.02	1.0	32.00	5.0	16.80	746	26.7
GV-MCICG	20.0	69.62	4.0	29.78	1.0	3.36	794	31.4
Tallahatchie County								
BT-MCICG	9.0	72.48	4.0	47.55	0.0	0.00	940	19.8
BT-ETPBO	8.0	64.18	2.0	39.94	2.0	6.72	910	22.8
GV-MCICG	6.0	28.53	3.0	15.01	0.0	0.00	850	56.6
Yazoo County								
BT-MCICG	5.0	44.38	1.0	32.00	0.0	0.00	504	15.8
BT-ETPBO	8.0	52.66	1.0	32.00	2.0	6.72	560	17.5
GV-MCICG	5.0	19.47	2.0	10.99	0.0	0.00	700	63.7
Summary Means								
BT-MCICG	9.0	59.63	1.8	37.56	1.0	5.86	881	24.04
BT-ETPBO	10.0	63.48	1.4	36.04	3.4	14.61	857	24.88

GV-MCICG	9.7	46.70	3.1	23.14	0.9	6.68	827	44.58

[1]BT = NuCotn 33B. GV = Grower's Choice Variety. MCICG = *Mississippi Cotton Insect Control Guide*. ETPBO = Early Tarnished Plant Bug - Orthene strategy. ETPBP = Early Tarnished Plant Bug - Pyrethroid strategy. DPL541 5 = Nontransgenic parent variety of NuCotn 33B.

[2]Pounds of lint per acre.

[3]Pounds of lint per dollar spent on heliothine insecticides.

[4]N = Number of insecticides applied including each constituent of mixtures and the Bollgard TM gene.

[5]Includes $32 per acre license fee for the NuCotn 33B cotton variety.

[6]Contains only the cost of insecticides used for heliothine larval control.

[7]Values for Leflore County are means of four replicates. Costs are computed only for the cost of insecticide based on estimated pesticide prices in the 1997 Delta Planning Budget (Ag. Economics Report 81).

Table 5. Seasonal means for percent of terminals with heliothine eggs and larvae, percent larva-damaged squares, and tarnished plant bugs per 25 sweeps for five Mississippi locations in 1996.

Treatment [1]	Pct. terminals w/ heliothine eggs			Pct. terminals w/ heliothine larvae		
	N[2]	Mean	SD[3]	N[2]	Mean	SD[3]
Itawamba County						
BT-MCICG	88	4.1	5.89	88	0.0	0.00
GV-MCICG	88	3.8	6.03	88	1.1	2.48
BT-ETPBO	88	3.1	4.32	88	0.4	1.22
Leflore County[4]						
BT-MCICG	300	13.0	19.65	408	1.3	3.45
GV-MCICG	320	11.7	16.74	428	2.9	6.23
BT-ETPBO	292	13.6	21.03	386	1.6	4.19
Madison County						
BT-MCICG	80	3.3	4.18	80	0.3	1.47
GV-MCICG	84	3.9	5.46	84	1.7	2.79
BT-ETPBO	80	2.0	3.92	80	0.1	0.45
Tallahatchie County						
BT-MCICG	16	9.3	9.09	4	0.0	0.00
GV-MCICG	16	1.0	2.31	4	3.0	2.00
BT-ETPBO	16	12.0	9.80	4	0.0	0.00
Yazoo County						
BT-MCICG	12	1.3	2.61	8	0.0	0.00
GV-MCICG	12	2.3	3.60	8	1.0	1.85
BT-ETPBO	12	2.7	2.61	8	1.5	2.98

[1]BT = NuCotn 33B. GV = Grower's Choice Variety. MCICG = *Mississippi Cotton Insect Control Guide*. ETPBO = Early Tarnished Plant Bug - Orthene strategy. ETPBP = Early Tarnished Plant Bug - Pyrethroid strategy. DPL541 5 = Nontransgenic parent variety of NuCotn 33B.

[2]N = number of samples determining mean.

[3]SD = Standard Deviation.
[4]Means for Leflore County include four replicates.

Table 5. Continued.

Table 5. Seasonal means for percent of terminals with heliothine eggs and larvae, percent larva-damaged squares, and tarnished plant bugs per 25 sweeps for five Mississippi locations in 1996.						
Treatment [1]	**Pct. larva-damaged squares**			**Plant bugs per 25 sweeps**		
	N[2]	**Mean**	**SD[3]**	**N[2]**	**Mean**	**SD[3]**
Itawamba County						
BT-MCICG	89	1.1	3.01	148	0.4	0.81
GV-MCICG	88	3.5	5.92	148	0.1	0.27
BT-ETPBO	88	1.2	3.80	148	0.4	1.72
Leflore County[4]						
BT-MCICG	300	2.0	5.07	290	0.7	1.55
GV-MCICG	320	3.1	5.39	314	0.8	2.00
BT-ETPBO	292	2.3	5.91	279	0.5	1.25
Madison County						
BT-MCICG	80	0.1	0.63	167	0.5	0.95
GV-MCICG	84	0.3	1.27	172	0.5	0.96
BT-ETPBO	80	0.1	0.63	172	0.4	0.97
Tallahatchie County						
BT-MCICG	12	0.0	0.00	20	3.3	5.13
GV-MCICG	12	3.3	3.34	20	0.3	0.64
BT-ETPBO	12	1.7	3.98	20	2.1	4.45
Yazoo County						
BT-MCICG	8	0.0	0.00	12	0.5	0.80
GV-MCICG	8	0.0	0.00	12	0.3	0.62
BT-ETPBO	8	6.5	9.78	12	0.2	0.58

[1]BT = NuCotn 33B. GV = Grower's Choice Variety. MCICG = *Mississippi Cotton Insect Control Guide*. ETPBO = Early Tarnished Plant Bug - Orthene strategy. ETPBP = Early Tarnished Plant Bug - Pyrethroid strategy. DPL541 5 = Nontransgenic parent variety of NuCotn 33B.
[2]N = number of samples determining mean.
[3]SD = Standard Deviation.
[4]Means for Leflore County include four replicates.

Table 6. Mean total insecticide costs, heliothine insecticide costs, and seed cotton yield for transgenic and conventional varieties in 1995 and 1996. [1]			
Treatment[2]	**Total insecticide cost[4] (SD [3])**	**Heliothine insecticide cost (SD [3])**	**Yield (SD [3])**
	dol.	**dol.**	**lb/A**
BT-MCICG	66.96 (25.206)	35.41 (5.919)	857 (189.01)
GV-MCICG	64.92 (41.597)	42.29 (30.195)	822 (102.71)

[1]Data for GV-MCICG fields for Lee and Leflore counties are not included for 1995 data.
[2]BT = NuCotn 33B. GV = Grower's choice of variety. MCICG = *Mississippi Cotton Insect Control Guide.*
[3]SD = Standard Deviation.
[4]Total costs do not include application costs or adjuvants.