COTTON INSECT MANAGEMENT IN TRANSGENIC Bt COTTON IN THE MISSISSIPPI DELTA, 1992-1995

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Abstract

Transgenic Bt cotton cultivars have been tested for 4 years in small plot replicated experiments and larger plot on farm replicated studies to determine efficacy against susceptible cotton pests. Results of this research project showed that transgenic Bt cotton provided excellent control of bollworm and tobacco budworm infestations. Transgenic Bt cotton was highly effective in cabbage looper control and showed significant suppression of beet armyworm. The transgenic Bt cotton cultivars tested showed no greater attractancy for or more susceptibility to tarnished plant bug or cotton aphid than other comparable non-Bt cultivars. Transgenic Bt cotton showed, in some cases, higher square set than other adapted varieties protected with insecticides.

Introduction

Transgenic Bt cotton is a new and promising cotton insect management technique that has been tested by Delta Research and Extension Center at Stoneville, MS. Small plot experiments have been both on the Delta Branch Experiment Station, Stoneville, MS and on grower cooperator farms in Washington County, MS. The following information is a summary of methods and results for this research on transgenic Bt cotton for the 4 years of 1992-95.

All of the research reported herein was done cooperatively with Monsanto Company, which provided seed of cotton lines containing the transgenic Bt trait in a Coker 312 variety background. This work was part of a Mississippi State University, Mississippi Agricultural and Forestry Experiment Station research project with additional support provided by Monsanto Company, and Cotton Incorporated State Support Program.

Provision of non-transgenic Bt cotton borders and adherence to other USDA, EPA, and MDAC Bureau of Plant Industry regulations were done as specified in contractual agreements with Monsanto Co. for each experiment discussed.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:854-859 (1996)
National Cotton Council, Memphis TN

Methods

1992 Treatment Threshold Study. - The objective of the 1992 experiment was to evaluate potential need for insecticide treatment for bollworm/ tobacco budworm (BW/TBW) infestation in transgenic Bt cotton. Treatments were (1) Bt 81 - sprayed for BW/TBW at 5% larval damaged squares, (2) Bt 81 - untreated for BW/TBW, (3) Coker 312 -sprayed as needed for BW/TBW control, and (4) Coker 312 - untreated for BW/TBW. As needed treatments were based on a BW/TBW treatment threshold of 4 or more larvae per 100 plants in 2 or more plots/treatment. Treatments were arranged in a RCB field design replicated 4 times and plots were 8 rows (25.3 ft) wide by 30 ft long planted on 18 May. The entire test area including borders ere sprayed with insecticides as needed for non-Lepidopterous insect pests. The experiment was located at Chatham, MS in south Washington County about 30 miles southwest of Stoneville.

1993 Treatment Threshold Study. - The objective of the 1993 experiment was to evaluate potential need for insecticide treatment for bollworm/ tobacco budworm (BW/TBW) infestation in transgenic Bt cotton. Seed supply was more abundant than in 1992 so more treatment thresholds for BW/TBW insecticide control could be tested. Treatments were (1) Coker 312 - untreated for BW/TBW control, (2) Coker 312 - sprayed as needed for BW/TBW control, (3) Bt 1076 - untreated for BW/TBW control, (4) Bt 1076 - sprayed as needed for BW/TBW control, (5) Bt 1076 - sprayed for BW/TBW control at 2% larval damaged squares, (6) Bt 1076 - sprayed for BW/TBW control at 5% larval damaged squares, (7) Bt 1076 - sprayed for BW/TBW control at 8% larval damaged squares. As needed treatments were based on a BW/TBW treatment threshold of 4 or more larvae per 100 plants in 2 or more plots/treatment. The entire test area including borders were sprayed with insecticides as needed for non-Lepidopterous insect pests. Treatments were arranged in a RCB field design replicated 4 times and plots were 4 rows (12.6 ft) wide by 50 ft long planted on 7 Jun. The experiment was located at Chatham, MS in south Washington County about 30 miles southwest of Stoneville.

1994 Mixed Seed Study. - The objective of the 1994 mixed seed experiment was to evaluate the effect of various seed mixtures (transgenic Bt seed mixed with various proportions of non-transgenic Bt seed) on Lepidopterous insect pest control and yield. Mixing non-transgenic Bt plants with transgenic Bt plants in crops of transgenic Bt cotton was being tested at other locations both by empirical and simulation methods as a means of providing refuge for development of bollworms and tobacco budworms that were not selected for resistance to the transgenic Bt protein. Treatments included in the experiment were (1) Bt 531 (100% Bt), (2) Bt 531 (90% Bt, 10% non-Bt), (3) Bt 531 (85% Bt, 15% non-Bt), (4) Bt 531 (80% Bt, 20% non-Bt), (5) Bt 531 (75% Bt, 25% non-Bt), (6) Coker 312, (7) Coker

312 treated as needed for bollworm/tobacco budworm control. All treatments, except treatment 7, were untreated for bollworm/tobacco budworm control. The entire test area including borders was treated as needed for non-Lepidopterous insect pests. Treatments were arranged in a RCB field design replicated 6 times and plots were 4 rows (13.3 ft) wide by 40 ft long and planted on 6 May. Bollworm (Helicoverpa zea) eggs were purchased from the USDA Southern Field Crops Insect Management Laboratory at Stoneville, MS for infesting plots. Eggs were mixed with dry corn cob grits, allowed to hatch, and distributed in terminals of plants on center two rows of each plot. Plots were infested at weekly intervals from 23 Jun to 8 Jul. Infestation and yield data were obtained on these two infested rows. The experiment was located on Delta Branch Experiment Station at Stoneville, MS.

1995 Transgenic Bt Cotton and Other Variety Comparison. - The objective of this study was to compare cost of insect control and yield of transgenic Bt cotton in an improved variety with that of other cotton varieties. However, this discussion will be limited to insect infestation and damage comparisons because analyses of other data is not complete. Varieties entered in the experiment were (1) DES 119 ne "nectariless", (2) Deltapine 5415, (3) Hartz 1215, (4) NuCotn 33, (5) Sure Grow 125, (6) Stoneville 474, and (7) Deltapine 5409. Variety entries in the experiment were arranged in a RCB field design replicated 4 times. Two replications were planted on one farm south of Leland, MS and two replications were planted on another farm adjacent to Delta Branch Experiment Station at Stoneville, MS. Deltapine 5407 occurred in only 2 blocks on one farm. Each plot was approximately 2.5 acres in size. Plots south of Leland were planted on 17 Apr and plots near Stoneville were planted on 28 Apr. Plots were sprayed on an as-needed basis when the average for the 2 plots of variety exceeded the recommended threshold (Mississippi Cooperative Extension Service Cotton Insect Control Guide) for a pest species.

Results and Discussion

1992 Treatment Threshold Study. - Emergence ratings are summarized in Figure 1 for the 1992 experiment. Cultivar data are combined for two rating dates and show especially poor emergence by Bt 81. Poor seed quality in Bt 81 and poor seedbed tilth and moisture resulted in very low plant density for both Bt 81 and Coker 312, even though Coker showed significantly higher emergence rating. The poor plant population hindered full achievement of the test objective, but some valuable information was obtained.

Means of bollworm/tobacco budworm larval damaged squares averaged over 11 observation dates are shown in Figure 2. The mean percent damaged squares in both BW/TBW treated and BW/TBW non-treated Bt 81 were significantly lower than in Coker 312 treatments. Mean differences between BW/TBW treated and non-treated within cotton lines were not significant even in the non-Bt Coker 312. BW/TBW insecticide spray schedule is shown in Table 1. Differences in mean BW/TBW larval damaged squares between Bt and non-Bt treatments are not as great as the differences appeared during on-site observation of the plots. A low level beet armyworm infestation may have caused some square damage indistinguishable from BW/TBW damage. Also, square damage sufficient to be counted was less severe in Bt 81 than in Coker 312.

A low level infestation density of cabbage looper occurred in mid July in the experiment and larval counts were not made because of the low numbers. Leaf damage occurred and subsequent relatively low level beet armyworm infestations resulted in sufficient accumulated leaf damage for a damage rating by mid August. Mean ratings on 20 Aug of percent leaves damaged by both cabbage looper and beet armyworm are shown in Figure 3. Most of the damage may be attributed to beet armyworm larval feeding. Bt 81 treatments showed mean percent damage ratings near 1% and Coker 312 treatments showed mean ratings above 60%. These data suggest that significant control or suppression of both cabbage looper and beet armyworm might be provided by transgenic Bt cotton.

1993 Treatment Threshold Study. - The 1993 test was planted late, 7 Jun, and seed quality was good. Mean seedling emergence counts (seedlings/ 10 row ft) are summarized in Figure 4. Means are over the 4 replications and all entries for the two cotton lines and show excellent plant population for both Bt 1076 and Coker 312.

There were some early notions that the transgenic Bt trait in cotton carried susceptibility to tarnished plant bug. Data summarized in Figure 5 show bloom rate (blooms/10 row ft) in late July, early August, and late August for Coker 312 and Bt 1976. These data indicate a significant delay in blooming in Bt 1076 compared to Coker 312. Tarnished plant bug counts in the test on 6 dates in August and early September show no evidence of higher plant bugs in Bt 1076 but rather that there was no difference in the two cultivars or that Coker 312 showed slightly higher tarnished plant bug counts. Therefore, the inherently later flowering of these transgenic Bt lines with a Coker background may have been mistakenly interpreted as susceptibility to tarnished plant bug injury.

Cotton aphid counts (aphids/leaf) averaged over all replications and cotton line treatments are shown in Figure 6. These data show no difference in Coker 312 and Bt 1076 in level of cotton aphid infestation on 2 observa-tion dates.

Cabbage looper larval damaged plants per 20 plants observed per plot on 27 Jul are summarized in Figure 7. These means show a significant reduction in cabbage looper damage by Bt 1076. Beet armyworm larval counts (mean larvae/12 row ft) are summarized in Figure 8 for

observations on 14 Sep and in Figure 9 for obserations on 21 Sep. There appears to be significant beet armyworm suppression by all Bt 1076 treatments compared to Coker 312 treatments on both observation dates, except for the anomaly in mean larvae/12 row ft in the Bt 1076 (non-treated) on 14 Sep.

Bollworm/tobacco budworm larval damaged squares data are summarized in Figure 10 as percent damaged squares averaged over 9 observation dates. These data show a significant insecticide effect in Coker 312 but not in Bt 1076. BW/TBW insecticide spray schedule for the treatments is shown in Table 2. The difference between untreated Coker 312 and all the Bt 1076 treatments was significant but not as great as plot appearance would suggest. The relatively heavy 1993 beet armyworm infestation in the plots may have again caused square damage that was not distin-guishable from BW/TBW square damage in these observations.

Yield data are summarized in Figure 11. The seed cotton yields (lbs/acre) for treatments harvested on 27 Oct are very low and are the result of late planting and poor temperature conditions for maturing a late crop in 1993. Bt 1076 yielded significantly lower than Coker 312. Insecticide treatments within cultivars showed no effects.

1994 Mixed Seed Study. - Bollworm/tobacco budworm infestation was generally low in the plots in spite of the weekly artificial infestation with laboratory reared bollworm larvae. Data from two observation dates with significant mean differences were selected and are summarized in Figure 12. Differences in mean BW/TBW larval damage (%) to squares in trans-genic Bt 531 (pure and mixed seed plantings) compared to Coker 312 were significant on the two dates presented in Figure 12. The low counts in transgenic Bt 531 treatments are more representative of the appearance in on-site observations than was the case in the 1992 and 1993 studies. There was no beet armyworm infestation in the 1994 test to contribute to square damage and thus inflate BW/TBW square damage data as likely occurred in 1992 and 1993.

A square set phenomenon was observed in the 1994 experiment which may be a factor in increased yields in improved commercial transgenic cotton lines compared to the backcross parent (Harris et al. 1995). Percent square set data on 11 Jul generated by COTMAN version 2.0 (Anonymous 1995) for top 5 nodes and all nodes are summarized in Figure 13. Mean percent square set was significantly higher in transgenic Bt treatments that were 100% Bt 531 and 90% Bt 531 than in the Coker 312 treatment that had been sprayed with insecticide for BW/TBW control on 1 Jul. We speculate that this response was due to less feeding by BW/TBW larvae on early squares, even when the infestation was below insecticide treatment threshold levels.

Seed cotton yield data for the treatments harvested on 7 Oct are sum-marized in Figure 14. Mean seed cotton yield per acre was reduced by the various seed mixtures of non-Bt cotton with Bt 531 (10 - 25% non-Bt). A large increase in seed cotton yield in Coker 312 resulted from 3 insecticide applications for BW/TBW control. The 3 insecticide applications to treat-ment 7 (Coker 312 treated as needed for BW/TBW control) were tralomethrin + acephate (0.024 + 0.5 lb ai/acre), applied on 1 and 11 Jul and 11 Aug.

1995 Transgenic Bt Cotton and Other Variety Comparison. - Presentation of results from this test conducted in 1995 will be limited to tarnished plant bug infestation data and BW/TBW larval damaged squares data. The study will be repeated in 1996 and probably in 1997. Tarnished plant bug infestation data (adults per 100 sweeps) are summarized in Figure 15 as means over 4 replications and 14 observation dates for the 7 cotton lines tested. Counts showed low average numbers of tarnished plant bugs, and no specific observation date showed much different infestation level, with no significant mean differences. These data indicate no preference of tarnished plant bug for the transgenic Bt, NuCotn 33.

BW/TBW larval damaged squares data (%) are summarized inFigure 16 as means over 4 replications and 12 observation dates. These means show superior BW/TBW control efficacy of transgenic Bt NuCotn 33 untreated for BW/TBW control compared to non-Bt commercial varieties treated as needed with insecticides for BW/TBW control.

Conclusions

Transgenic Bt cotton lines studied in field trials from 1992 through 1995 provided highly efficacious control of natural mixed infestations of bollworm and tobacco budworm and of an artificial infestation in one test with laboratory reared bollworms. Transgenic Bt cotton lines provided excellent control of cabbage looper infestations and provided a high level of beet armyworm infestation suppression in tests where these pest species occurred. Transgenic Bt cotton lines tested in these trials showed no greater attractancy for or susceptibility to cotton aphid or tarnished plant bug. A transgenic Bt cotton line in one test showed higher percent early square set than the background variety protected with insecticides for BW/TBW control.

Results of the series of tests reported here and of other studies reported by Harris et al. 1994 and Harris et al. 1995 show that transgenic Bt cotton is an effective technique for control of bollworm, tobacco budworm and other Lepidopterous pest species and promises to be an important cotton insect pest management tactic.

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Table 1: Bollworm/tobacco budworm insecticide spray schedule—1992 experiment, Chatham, MS.

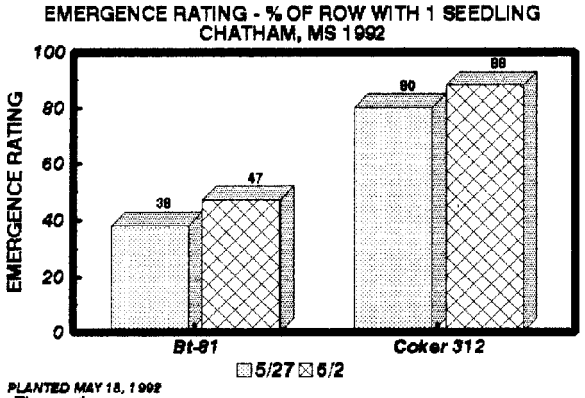
Cotton Line (Insecticide Treatment)	Dates: Insecticide (lb ai/acre)
Bt-81 (Spray 5%)[1/]	8/19: Cyhalothrin (.025) + thiodicarb (.25) 8/25: Cyhalothrin (.025) + thiodicarb (.25) 9/2: Cypermethrin (.06) + thiodicarb (.25) 9/8: Cypermethrin (.06) + thiodicarb (.25) 9/16: Cyhalothrin (.025)
Bt-81 (No Insecticide)	No spray for bollworm/tobacco budworm.
Coker 312 (Spray 5%)[1/]	Same as Bt-81 (Spray 5%) above
Coker 312 (No Insecticide)	No spray for bollworm/tobacco budworm

[1/]Spray 5% indicated a spray threshold of 5% or more damaged squares in 2 or more plots/treatments.

Table 2: Bollworm/tobacco budworm insecticide spray schedule—1993 experiment, Chatham, MS

Cotton Line (Insecticide Treatment)	Dates: Insecticide (lb ai/acre)
Coker 312 (No Insecticide)	No spray for bollworm/tobacco budworm
Coker 312 (Spray As Needed)[1/]	8/5: Tralomethrin (.025)+ thiodicarb(.25) 8/12:Tralomethrin(.025)+profenofos (.25) 8/25:Tralomethin (.025) + profenofos(.25) 9/1: Tralomethrin (.025) + profenofos (.25) 9/9: Tralomethrin (.025) + profenofos (.25) 9/17: Esfenvalerate (.03) + thiodicarb (.25)
Bt-1076 (No Insecticide)	No spray for bollworm/tobacco budworm
Bt-1076 (Spray As Needed)[1/]	8/25:Tralomethrin (.025) + profenofos (.25) 9/1: Tralomethrin (.025) + profenofos (.25) 9/9: Tralomethrin (.025) + profenofos (.25) 9/17: Esfenvalerate (.03) + thiodicarb (.25)
Bt-1076 (Spray 2%)	Same as Coker 312 (Spray As Needed)
Bt-1076 (Spray 5%)	8/25:Tralomethrin (.025) + profenofos (.25) 9/1: Tralomethrin (.025) + profenofos (.25) 9/17: Esfenvalerate (.03) + thiodicarb (.25)
Bt-1076 (Spray 8%)	No spray for bollworm/tobacco budworm

[1/]Spray as needed indicated a spray threshold of 4 larvae per 100 plants in 2 or more plots treated.
[2/]Spray 2%, spray 5%, or spray 8% indicated treatment spray thresholds of percent damaged squares in 2 or more plots/treatments.



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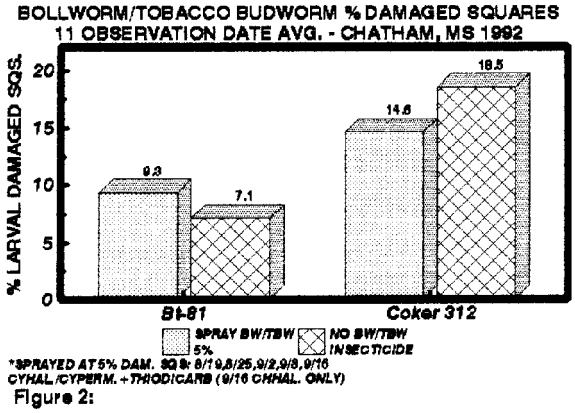

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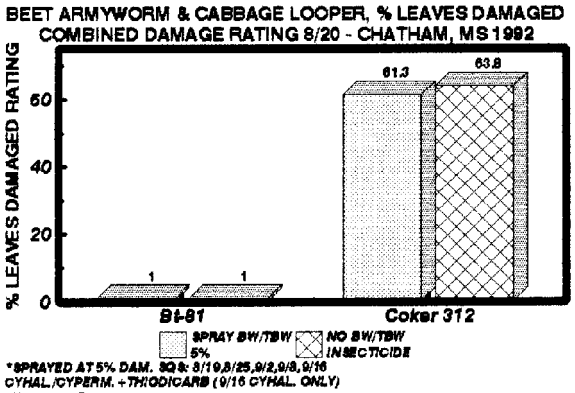

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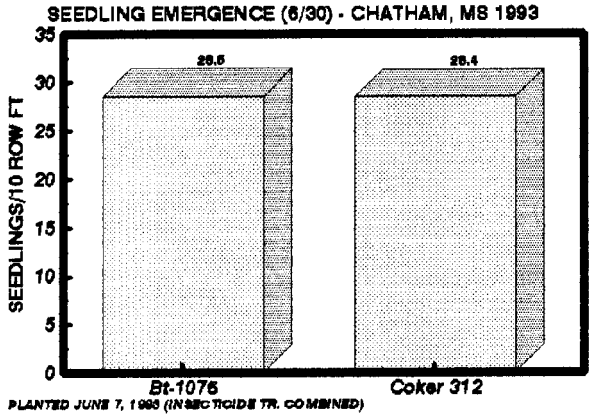

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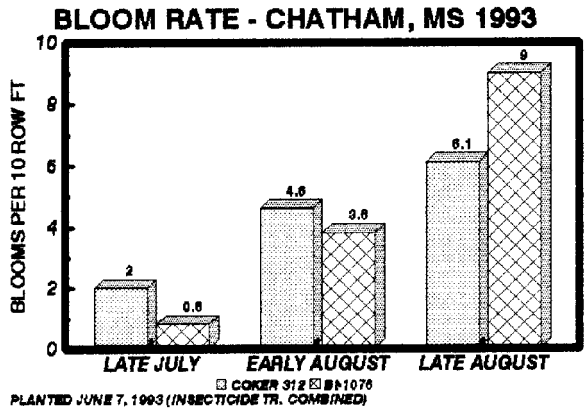

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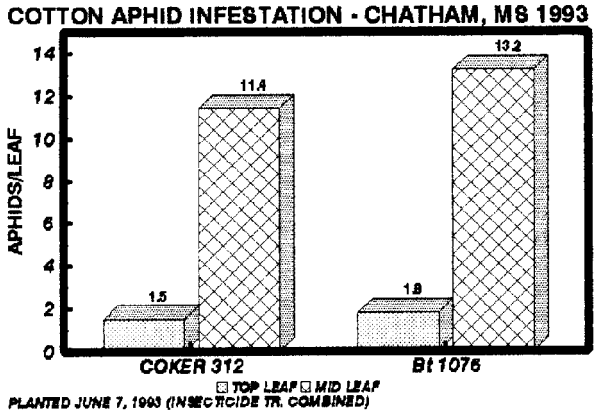

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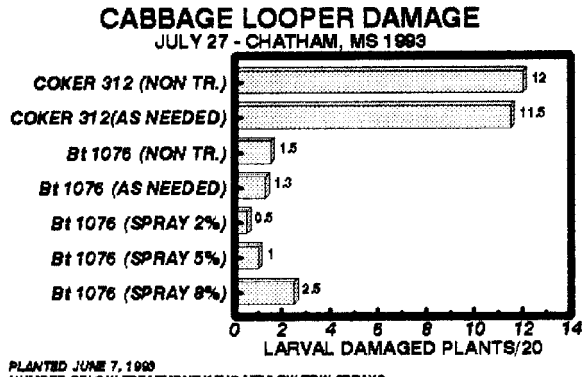

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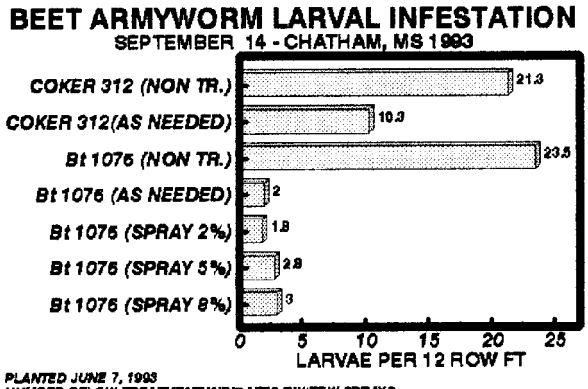

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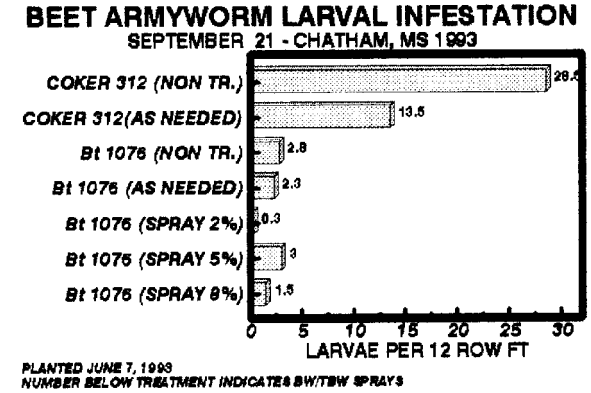

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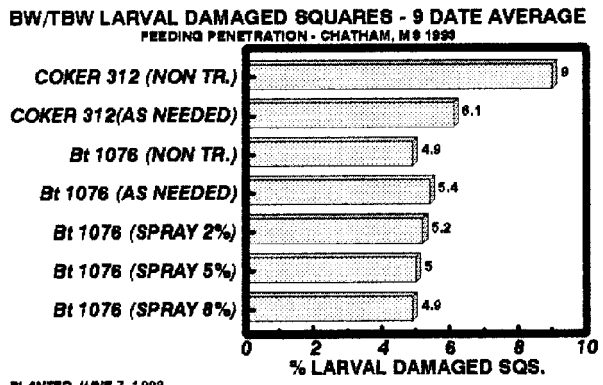

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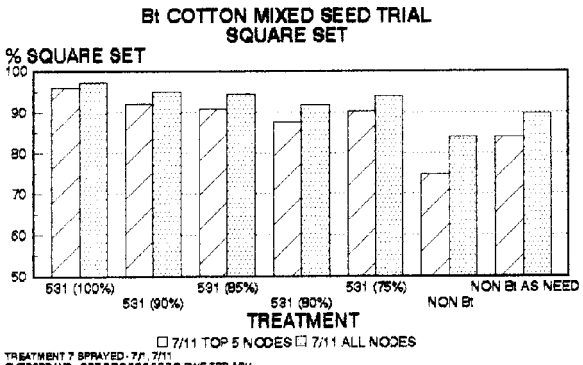

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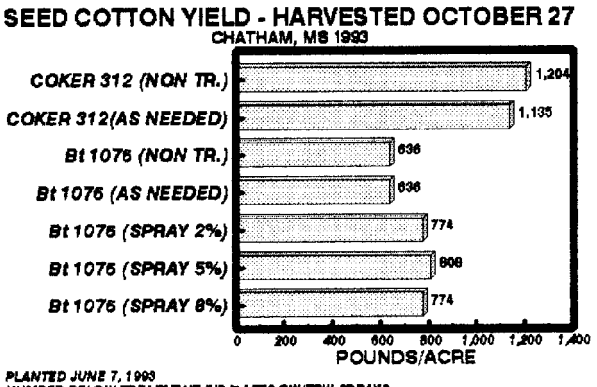

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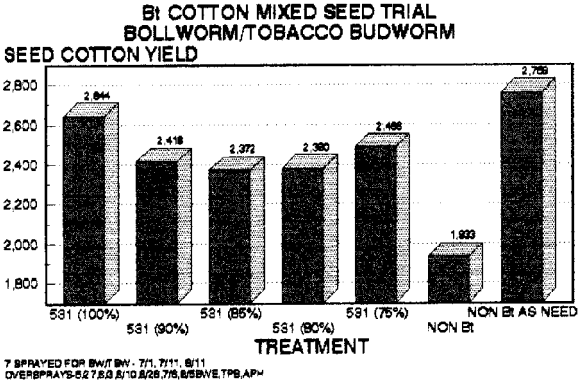

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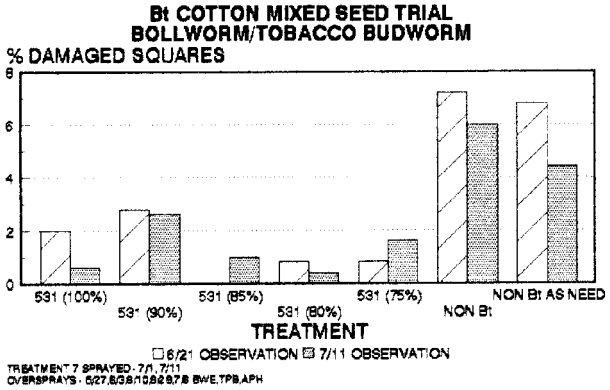

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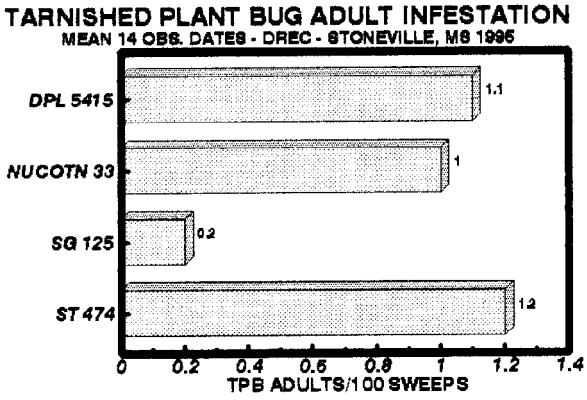

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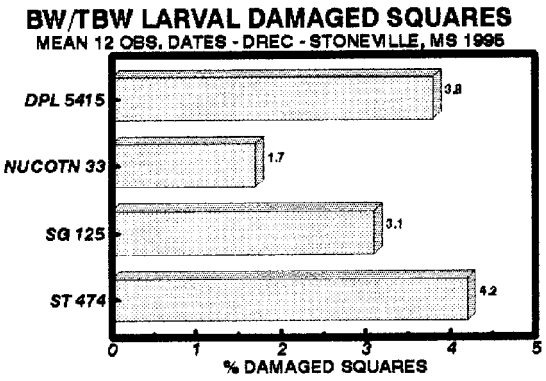
BW/TBW LARVAL DAMAGED SQUARES
MEAN 12 OBS. DATES - DREC - STONEVILLE, MS 1995
DPL 5415
NUCOTN 33
SG 125
ST 474
3.8
1.7
3.1
4.2
0
1
2
3
4
5
% DAMAGED SQUARES

Figure 16.