Published January, 1986

Yield Response of Two Cotton Cultivars to Tobacco Budworm Infestation[1]

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ABSTRACT

Two cotton, *Gossypium hirsutum* L., cultivars were artifically infested with tobacco budworm, *Heliothis virescens* (F.), larvae for different time intervals during the first 8 weeks of fruiting to determine impact on yield reduction and maturity delay. The cultivars tested were 'Stoneville 213' (full-season) and 'Tamcot CAMD-E' (short-season) grown in 1 × 13.7 m long single row plots in a two-planted one-skip row pattern during the 1982 and 1983 growing seasons on a Leeper silty clay loam (fine, montmorillonitic, nonacid, thermic Vertic Haplaquepts). Treatments consisted of applying 12 first instar larvae in the terminal area of each plant, once per week for the following combination of weeks after fruiting had begun: none (control), Weeks 1 to 2, 1 to 4, 1 to 6, 1 to 8, 7 to 8, 5 to 8, 3 to 8, 3 to 4, 5 to 6, and 3 to 6. When larvae were not applied in a given week, plots were protected with an insecticide. Plots were machine harvested three times for yield determinations and delays in maturity. All treatments involving larval applications the first 2 weeks of fruiting resulted in significant reductions in yield, compared with the control, for both cultivars at first harvest. Tamcot CAMD-E with larval treatments produced a larger percentage of its total yield at first harvest than did Stoneville 213. When first and second harvest were accumulated, the same trends were apparent. Total yield of Stoneville 213 was significantly reduced only when larvae were applied for at least a 4-week time period. The same trend was apparent with Tamcot CAMD-E: timing of applications (rather than length of time) had the greatest effects; however, reduction in yield was not significant. Subclass regression analysis of yield as a function of larval application indicated that yield reduction trends averaged over years were significant and the responses of the two cultivars were found to be significantly different from each other as tested by homogeneity of slopes. The yield of Tamcot CAMD-E was not reduced or delayed as much as that of Stoneville 213 when tobacco budworm larvae were applied during early-, mid-, and full-season. The application of larvae during the early stage of fruiting had a greater impact on reducing yield and delaying maturity than when larvae were applied during mid- and late-season.

***Additional index words:* Gossypium hirsutum L., Heliothis virescens (F.), Host-plant resistance, Lint yield, Short-season cultivar.**

THE tobacco budworm, *Heliothis virescens* (F.), is an important pest on cotton, *Gossypium hirsutum* L., throughout the rain-grown Cotton Belt. It has developed high levels of resistance to most of the insecticides used for its control in cotton (Harris et al. 1972). The tobacco budworm now poses a serious and wiespread annual threat to the economic production of cotton in the mid-South (Stadelbacher and Martin 1980).

Tobacco budworm overwinters as diapausing pupae in the Delta of Mississippi. Emergence of adults in early spring and their first generation larval progeny are dependent on early-season wild host plants. The first generation adults migrate from wild host plants and infest cotton in June, Stadelbacker (1981). However, according to Young (1969), the first major flight into cotton in Mississippi usually occurs in mid-July.

Considerable effort has been devoted to assessment of damage and establishment of economic thresholds (Graham et al., 1972; Walker et al., 1979; and Phillips et al., 1979). Several studies have attempted to simulate insect damage by removing squares from plants. Early square removal did not reduce yields, Hamner (1941) and Dunnam et al. (1943). Significant reductions occurred, however, if square removal occurred later in the season (Dunnam et al. 1943). Similarly, Kincade et al. (1970) indicated relatively heavy infestations of tobacco budworms in the mid- and late-season were required for yield reductions. Maturity effects were not measured.

Wilson et al. (1982) confined females and males of *Heliothis zea* (Boddie) in field screen cages during five time periods from early squaring to late boll maturation. They reported that 'Acala SJ 2' cotton can compensate for high levels of bollworm damage up to late July when grown under irrigated conditions; however, they did not report effects on maturity.

The objective of this study was to evaluate the importance of early-, mid-, late-, and full-season infestations of tobacco budworms on an early- and a full-season cotton cultivar. Delay in maturity and total lint yield were the criteria used for the evaluation.

MATERIALS AND METHODS

Two cotton cultivars were artificially infested with tobacco budworm larvae (according to the method of Jenkins et al., 1982) for various time periods during two growing seasons. 'Tamcot CAMD-E' (CAMD-E) a short-season, and 'Stoneville 213' (ST-213) a full-season cultivar were planted in 1 × 13.7 m long, single row plots in a two-planted and one-skip row pattern. The plant density was one plant per hill spaced 20 cm apart. The two cultivars were planted at Mississippi State in a Leeper silty clay loam (fine, montmorillonitic, nonacid, thermic Vertic Haplaquepts) soil on 4 May 1982 and 5 May 1983. The experimental design was a split-plot arrangement replicated six times with main unit treatment and subunit cultivar.

The first 8 weeks of fruiting after square initiation were divided into 2-week time intervals. Treatments 1 through 11 consisted of applying 12 first instar larvae in the terminal area of each plant once per week for the following time intervals after fruiting had begun: none (control), Weeks 1 to 2, 1 to 4, 1 to 6, 1 to 8, 7 to 8, 5 to 8, 3 to 8, 3 to 4, 5 to 6, and 3 to 6. The first larval application was made when small squares were visible on the two cultivars; this occurred the third week of June for each of the 2 yrs. When larvae were not applied in a given week, plots were sprayed with a synthetic pyrethroid during that week to control natural infestations of *Heliothis* and other pest insects.

The plots were machine harvested three times for yield determinations. Boll samples were hand picked and ginned to determine lint percentage which was used in calculating

[1] Cooperative investigation of USDA-ARS and the Mississippi Agric. and Forestry Exp. Stn. Journal paper 6078 of the Mississippi Agric., and Forestry Exp. Stn., Mississippi State, MS. Received 4 Apr. 1985.

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lint yields. Analyses of variance and subclass regression of yield as a function of larval treatments were used to determine yield loss effects by testing for homogeneity of slopes.

RESULTS AND DISCUSSION

The application of tobacco budworm larvae for different time intervals during the first 8 weeks of fruiting significantly affected yield at first, second, and third harvest (Table 1). The short-season cultivar, CAMD-E, produced significantly more lint cotton at first harvest when averaged over treatments and years; 560 vs. 391 kg ha^{-1} for ST-213. However, at second harvest the full-season ST-213 yielded significantly more than CAMD-E; 665 vs. 458 kg ha^{-1} of lint, respectively. At the third harvest ST-213 again produced significantly more lint cotton than CAMD-E; 309 vs. 131 kg ha^{-1}. Total yields were 1365 vs. 1149 kg ha^{-1} for ST-213 and CAMD-E. Years-by-cultivar interaction for total yield was not significant, indicating consistent results for the 2 yrs of the test.

The mean lint yields for the two cultivars are presented in Table 2. All treatments which involved larval applications the first 2 weeks of fruiting resulted in significant reductions in yield at first harvest for both cultivars when compared with the yield from zero larval application (control). Additionally, the percentage of the total yield at first harvest was also reduced in these treatments (Table 3). The short season cultivar, CAMD-E, produced a larger percentage of its total yield at first harvest even with larval treatments.

When first and second harvest were cumulated, the same results were obtained for ST-213 and the same trend was apparent for CAMD-E. The ST-213 cultivar continued to show a greater delay than CAMD-E. Total yield of ST-213 was significantly reduced only when larvae were applied for at least a 4-week time period. Similar trends were apparent for CAMD-E; however, the reduction in yield was not significant.

Analysis of variance with subclass treatment regression was used to evaluate the trends in yield reduction due to the application of larvae. The regression coefficients are presented in Table 4. Only treatments for Weeks 1 to 2, 1 to 4, 1 to 6, and 1 to 8 were included in the regression analysis. In 1982 and 1983, the same trend existed for both cultivars at first harvest; i.e., the slopes (B_i) were not significant from each other but were different from zero. However, when first and second harvest were cumulated the slopes were different for the two cultivars and also different from zero. Regression analysis for total harvest (first plus second plus third) was conducted over years and the trend indicated that ST-213 ($Y = 1717 - 73X$) and CAMD-E ($Y = 1290 - 24X$) responded differently (the slopes were significant from each other and from zero) when tobacco budworm larvae were applied for additional 2-week time periods. The r^2

Table 1. Mean squares for lint yield at various harvest combinations of two cotton cultivars infested for different time intervals with tobacco budworm larvae during 1982 and 1983.

Source	df	Harvest 1st	2nd	3rd	1 + 2	1 + 2 + 3
Replication	5	65 054	115 526**	53 007**	340 442**	633 906**
Treatment (T)	11	431 533**	195 942**	52 075**	799 882**	706 646**
Error *a*	55	46 769	29 409	14 862	110 412	140 222
Cultivar (C)	1	2 053 326**	3 070 360**	2 278 080**	101 953	3 343 897**
$C \times T$	11	8 733	112 346**	18 933	157 068	202 844**
Pooled error *b*	60	17 369	10 103	13 721	60 593	56 885
Year (Y)	1	3 581 661**	2 582 658**	8 269	81 489	141 675
$Y \times T$	11	64 558	77 418	23 163*	115 479	118 974
$Y \times C$	1	218 873**	39 383	258 059**	72 569	56 934
$Y \times T \times C$	11	19 917	12 222	10 562	35 252	28 794
Pooled error *c*	120	36 900	18 892	12 263	72 520	90 333

*,** Significant at the 0.05 and 0.01 levels of probability, respectively.

Table 2. Mean lint yield of ST-213 and CAMD-E averaged over 1982 and 1983 when tobacco budworm larvae were applied for different time intervals during the first 8 weeks of fruiting.

Weeks larvae applied	No. of larvae applications	Harvest: 1st ST-213	1st CAMD-E	1st + 2nd ST-213	1st + 2nd CAMD-E	Total ST-213	Total CAMD-E
		kg ha^{-1}					
0	0	569	713	1421	1137	1712	1220
1-2	2	281*	482*	1104*	1112	1499	1257
3-4	2	479	660	1156	1110	1496	1250
5-6	2	488	680	1289	1153	1571	1274
7-8	2	484	608	1141*	989	1493	1071
1-4	4	222*	460*	845*	1042	1258*	1226
3-6	4	363*	566	921*	981	1218*	1123
5-8	4	499	613	1118*	969	1309*	1048
1-6	6	187*	344*	732*	828*	1090*	1030
3-8	6	377*	537	890*	905	1132*	1022
1-8	8	174*	363*	632*	831*	900*	1013
LSD 0.05 within column		176		271		306	
LSD 0.05 between columns within harvest		108		201		195	

* Indicates treatment was different from the 0 larval application within a column based on LSD at the 0.05 level of probability.

Table 3. Percentage of yield that was harvested at first pick and first plus second pick averaged over years 1982 and 1983.

Weeks larvae applied	No. of larvae applications	Harvest 1st ST-213	1st CAMD-E	1st + 2nd ST-213	1st + 2nd CAMD-E
		%			
0	0	32.2	58.3	83.0	93.1
1–2	2	18.0*	37.4*	73.7*	88.3
3–4	2	30.7	53.1	76.9	88.6
5–6	2	31.6	53.8	82.0	90.3
7–8	2	34.4	58.2	79.8	92.6
1–4	4	16.4*	36.5*	65.8*	84.5*
3–6	4	28.3	48.4*	74.6*	86.7*
5–8	4	37.9	59.1	85.0	92.4
1–6	6	16.5*	32.2*	65.8*	79.4*
3–8	6	32.0	52.1	78.2	88.2*
1–8	8	18.9*	34.1*	70.0*	81.1*
LSD 0.05 within column		8.3		4.8	
LSD 0.05 between column		4.7		3.8	

* Indicates treatment was different from the 0 larval application within a column based on LSD at the 0.05 level of probability.

Table 4. Regression analysis for lint yield (kg ha^{-1}) when larvae were applied for Weeks 1 through 2, 1 through 4, 1 through 6, and 1 through 8 of fruiting.

Year	Harvest	ST-213 a	ST-213 b	CAMD-E a	CAMD-E b	F test between b values	r^2
1	1st	336	−15**	463	−20**	NS	0.65
1	1st + 2nd	1297	−56**	1086	−30**	*	0.62
1	Total	1571	−57**	1201	−21*	*	0.56
2	1st	587	−45**	820	−38**	NS	0.70
2	1st + 2nd	1425	−84**	1284	−37**	**	0.69
2	Total	1864	−90**	1380	−28*	**	0.70
1 & 2	Total	1717	−73**	1290	−24**	**	0.57

*,** Significant at the 0.05 and 0.01 level, respectively.
$Y = A + bX$ where Y = predicted lint yield; a = Y-intercept; b = slope of the line; and X = number of 2-week periods of larval infestations. Year 1 = 1982; Year 2 = 1983.

for total harvest was 0.57.

The data presented indicate that time of infestation is important in both reducing yield and delaying maturity. When larvae are applied during the early part of the fruiting period, they tend to have a greater impact on reducing yield and delaying maturity than when larvae are applied during mid- and late-season. Verhalen et al. (1975), reported that as the season progressed, the percentage of bolls set decreased. In essence, the potential for new boll set is reduced as the season progresses and as the plant fulfills its potential as determined by both genotype and environment.

The greatest reduction in yield occurred when larvae were applied throughout the season thus indicating the inability of the plant to recover due to constant presence of insects. The full-season cultivar, ST-213, exhibited a greater loss in yield than CAMD-E, the short-season cultivar, when larvae were applied during early-, mid-, and full-season. According to Walker et al. (1979), shortening the growing season of cotton through reduced inputs and use of genotypes developed for rapid fruit set has decreased the *Heliothis* problem in Texas since the mid-1970s.

It has been reported frequently in the literature that cotton has the ability to compensate for fruit loss during early season. The cotton plant sets excessive fruiting forms and physiologically adjusts the final number of mature sites in response to the total environment. This is not a compensating act but is the natural fruiting pattern of cotton. Our data do not support the concept of compensation but rather the concept that the cotton plant can tolerate a large amount of fruit loss, due to its fruiting habit, and still produce acceptable yields; however, these yields are produced later in the season. The amount of fruit loss that can be tolerated without yield loss or delays in maturity depends on the cultivar's fruiting rate, time of fruit loss, and the environmental conditions present during the growing season. Delays in maturity are often as important as reductions in yield.

The regression analysis over 2 yrs indicated that ST-213 and CAMD-E both are damaged about the same during early fruit set (slopes equal but different from zero at first harvest). However, later harvest data indicated ST-213 and CAMD-E have different lengths of "susceptible" periods. The ST-213 cultivar continues to be damaged longer than CAMD-E and slopes for first plus second and total harvest are significantly different from each other. This difference is probably due to the relative maturities of the two cultivars. The CAMD-E cultivar begins to fruit slightly earlier than ST-213 and fruits at a faster rate than the full season cultivar. When later harvests are considered the two cultivars are different with respect to damage induced by tobacco budworms.

In this study, the yield of the short-season cultivar, CAMD-E, was not delayed or reduced as much as that of ST-213 when tobacco budworm larvae were applied during early-, mid-, and full-season. The concept of being able to tolerate fruit loss, delays in maturity, and escape from economic yield loss are important components in a crop management system. This research shows that cultivars are different in how they interact in this crop management system.

REFERENCES

Dunnam, E.W., J.C. Clark, and S.L. Calhoun. 1943. Effect of the removal of squares on yield of upland cotton. J. Econ. Entomol. 36:896–900.

Graham, H.M., P.D. Lingren, Charles Lincoln, and P.L. Adkisson. 1972. The economic threshold of infestations for *Heliothis* spp. on cotton. p. 7–17. *In* Distribution abundance and control of *Heliothis* species in cotton and other host plants. Southern Coop. Series Bull. 169.

Hamner, A.L. 1941. Fruiting of cotton in relation to cotton fleahopper and other insects. Mississippi Agric. Exp. Stn. Bull. 360.

Harris, F.A., J.B. Graves, S.J. Nemic, S.B. Vinson, and D.A. Wolfenbarger. 1972. Insecticides resistance. p. 17–27. *In* Distribution abundance and control of *Heliothis* species in cotton and other host plants. Southern Coop., Series Bull. 169.

Jenkins, J.N., W.L. Parrott, J.C. McCarty, Jr., and W.H. White. 1982. Breeding cotton for resistance to the tobacco budworm: Techniques to achieve uniform field infestations. Crop Sci. 22:400–404.

Kincade, R.T., M.L. Laster, and J.R. Brazzel. 1970. Effect on cotton yield of various levels of simulated *Heliothis* damage to squares and bolls. J. Econ. Entomol. 63:613–615.

Phillips, J.R., D.F. Clower, A.R. Hopkins, and T.R. Pfrimmer. 1979. Economic thresholds of *Heliothis* species on indeterminate cottons. p. 44–50. *In* W.L. Sterling (ed.) Economic thresholds and sampling of *Heliothis* species on cotton, corn, soybeans and other host plants. Southern Coop. Series Bull. 231.

Stadelbacher, E.A. 1981. Role of early-season wild and naturalized host plants in the buildup of the F_1 generation of *Heliothis zea* and *H. virescens* in the Delta of Mississippi. Environ. Entomol. 10:766–770.

----, and D.F. Martin. 1980. Fall diapause, winter mortality and spring emergence of the tobacco budworm in the Delta of Mississippi. Environ. Entomol. 9:553–556.

Verhalen, L.M., Reza Mamaghani, W.C. Morrison, and R.W. McNew. 1975. Effect of blooming date on boll retention and fiber properties in cotton. Crop Sci. 15:47–52.

Walker, J.K., R.E. Frisbie, and G.A. Niles. 1979. *Heliothis* species in short-season cottons in Texas. p. 31–43. *In* W.L. Sterling (ed.) Economic thresholds and sampling of *Heliothis* species on cotton, corn, soybeans and other host plants. Southern Coop. Series Bull. 231.

Wilson, L.T., D. Gonzalez, and T.F. Leigh. 1982. Bollworm damage and yield of cotton infested at different time periods. J. Econ. Entomol. 75:520–523.

Young, D.F., Jr. 1969. Cotton insect control. Oxmoore House, Birmingham.