LATE SEASON BEET ARMYWORM (LEPIDOPTERA: NOCTUIDAE) INFESTATIONS ON COTTON: DEFOLIATION, FRUIT DAMAGE, AND YIELD LOSS

V. J. MASCARENHAS[1], D. COOK[2], B. R. LEONARD[3] E. BURRIS[2] AND J. B. GRAVES[1]
Louisiana State University Agricultural Center

[1]Department of Entomology, Baton Rouge, LA 70803

[2]Northeast Research Station, St. Joseph, LA 71366

[3]Macon Ridge Location, Northeast Research Station, Winnsboro, LA 71295

ABSTRACT

Field cage studies were conducted in 1996 and 1997 to measure the effects of late season beet armyworm, *Spodoptera exigua* (Hübner), infestations (0, 1, 3, and 6 egg masses per 5.1 m row) on defoliation, fruit damage, and yield of cotton. Significantly higher light penetration through the cotton canopy was observed in most infested plots compared with non-infested control plots. A trend for higher numbers of damaged fruiting forms (squares and bolls) with increases in egg mass density was observed. There were no significant differences in the number of damaged fruiting forms among treatments, however, plots infested with 1, 3, or 6 egg masses had 2.3, 2.4, and 3.3-fold more damaged fruiting forms than the control plots. In all infested plots, a significantly higher percentage of shed fruiting forms were damaged compared with the control plots in 1996. In 1997, only plots infested with 6 egg masses had a significantly higher percent of the cumulative fruiting forms damaged compared with the control plots. In both years, there were no significant differences in seed cotton yield among treatments.

Key words: *Gossypium hirsutum* L., Plant Damage, Yield Loss, *Spodoptera exigua*

RESUMEN

Se realizaron experimentos en 1996 y 1997 con jaulas en campos de algodón para medir el efecto de infestaciones de fin de temporada de *Spodoptera exigua* (Hübner), (con 0, 1, 3, y 6 masas de huevecillos por cada 5.1 m de hilera) en la defoliación, daño del fruto, y rendimiento del algodón. Se observó una cantidad significativamente más alta de penetración de luz a través del follaje del algodón en la mayoría de las parcelas infestadas en comparación con las parcelas no infestadas. Se observó una correlación positiva entre el número de órganos fructíferos (cuadros y bellotas) dañados y la densidad de masas de huevecillos. No se documentaron diferencias significativas en el número de frutos entre los tratamientos; sin embargo, parcelas infestadas con 1, 3, o 6 masas de huevecillos tenían 2.3, 2.4, y 3.3 veces más de frutos que las parcelas control. En todas las parcelas infestadas, un porcentaje significativamente más alto de frutos tirados estaba dañado por el gusano de *Spodoptera exigua* en comparación con las parcelas control de 1996. En 1997, sólo parcelas infestadas con 6 masas de huevecillos tuvieron un por ciento acumulado significativamente más alto de frutos dañados en comparación con las parcelas control. No hubo ninguna diferencia significativa entre los tratamientos en ambos años en el rendimiento de semilla de algodón.

The beet armyworm, *Spodoptera exigua* (Hübner), has been an occasional pest of cotton in the U.S. since the early 1900s (Sanderson 1905) causing damage primarily as a defoliator (Smith 1989, Leser et al. 1996). Injury to cotton associated with beet armyworm has traditionally been feeding on the foliage and flower buds, as well as etching on the bracts of fruiting forms (Smith 1989). These insects occasionally feed on squares and small bolls late in the growing season, but this injury typically has not resulted in economic yield losses, because fruiting forms that are produced late in the growing season generally do not significantly contribute to yield (Jenkins et al. 1990).

Beet armyworm population outbreaks occurred in the mid to late 1980's in Alabama (Smith 1989) and in 1993 in Mississippi (Layton 1994). In these areas, this pest uniformly infested fields, and larvae fed almost exclusively on squares, flowers, and young bolls during the fruiting stages of plant development rather than on foliage (Smith 1989, Layton 1994). During outbreaks in Alabama and Mississippi, many cotton producers sustained severe yield losses despite extensive control efforts, the cost of which exceeded $371 per hectare in some areas. Similar devastation by beet armyworm outbreaks has occurred in areas of Georgia (Douce & McPherson 1991, 1992) and Texas (Summy et al. 1996).

The economic impact of beet armyworm infestations include yield losses and costs associated with insecticide applications. Beet armyworms are tolerant to most registered classes of insecticides and control costs can become prohibitive when severe outbreaks occur (Layton 1994). The cost of insecticides targeted at beet armyworms exceeded $44 per application per hectare during the beet armyworm outbreaks in the Lower Rio Grande Valley of Texas in 1995 (Williams 1996).

Cotton production in Louisiana has not been threatened by severe beet armyworm outbreaks. Isolated economic infestations have been reported every two to three years since the mid 1980s (Burris et al. 1994), but cotton yield losses associated with beet armyworm injury have been less severe than in other states. However, during the past 4 years, this pest infested more than 500 thousand hectares of cotton in the state (Williams 1994, 1995, 1996, 1997).

Chlorpyrifos and thiodicarb are the only two insecticides currently recommended for beet armyworm control on cotton in Louisiana (Bagwell et al. 1997). Unsatisfactory efficacy of these insecticides against beet armyworm populations has been reported across most of the mid-south and southeastern U.S. (Elzen 1989, Burris et al. 1994, Layton 1994, Smith 1994, Graves et al. 1995, Mascarenhas et al. 1996, Sparks et al. 1996).

A Boll Weevil Eradication Program was implemented in Louisiana in August, 1997. The intensive insecticide regime associated with this program could release beet armyworms from their natural enemies (Evellens et al. 1973, Gaylor & Graham 1991, Ruberson et al. 1994), and cause widespread population outbreaks. The potential yield losses associated with beet armyworm damage to cotton have not been well studied. Therefore, the objective of this study was to determine the combined effects of late-season defoliation and fruit injury by beet armyworm on cotton yields.

Materials and Methods

Studies were conducted at the Northeast Research Station near St. Joseph, Louisiana during 1996 and 1997. Plots consisted of three adjacent rows (approximately 1 m centers) by 1.7 m in length covered by a translucent 32 mesh nylon cage (Synthetic Industries, Greenville, Georgia) measuring 1.7 × 3.4 × 1.7 m. Plots were planted to 'Stoneville 474' cotton, an early maturing variety, on 1 May in 1996 and on 4 June in 1997. In both years, plots were arranged in a randomized block design with 4 replications. Plots were treated as needed with insecticides to minimize defoliation and fruit damage by other insect pests. Insecticides that were selected for these applications were those with negligible activity against beet armyworms and short residual activity. Insecticide applications were initiated at first square and ended 7-10 d before plots were infested. Before covering the plots with cages, a combination of methyl parathion and acephate was applied to reduce populations of natural enemies within the caged area 24 h before artificial infestations.

Field-collected beet armyworm strains were used to infest plots. Beet armyworm larvae collected from cotton in Tift County, Georgia on 20 and 21 June were used in 1996, while larvae collected from cotton near St. Joseph, Louisiana on 7 and 8 August were used in 1997. Field-collected larvae were transported to the Department of Entomology at Louisiana State University Agricultural Center in Baton Rouge, LA and reared using an artificial wheat-germ and soybean protein diet (King & Hartley 1985). Egg masses of the F2 and F1 generation were used in field infestations during 1996 and 1997, respectively.

Cotton plots were infested when plants reached 5 nodes above white flower (NAWF) stage and had accumulated approximately 300 heat units (Oosterhuis et al. 1993). Heat unit accumulation was calculated according to Bagwell & Tugwell (1992). Infestations were made on 2 and 27 August in 1996 and 1997, respectively. The center row of each plot was artificially infested with 0, 1, 3, or 6 egg masses. Egg masses on wax paper oviposition sheets were attached with a paper clip to the lower surface of fully expanded leaves in the middle one-third of the cotton canopy. Larval numbers were thinned to approximately 60-80 insects per egg mass 2-3 d after larval hatching (DAH). Larval survival and development was monitored through the duration of the experiment.

All shed fruiting structures were removed from the soil surface within the cages immediately before infestation. Square and boll damage was estimated by collecting all shed fruiting structures two times per week and examining them for larval feeding. Shed fruiting forms were categorized into two groups based on feeding signs on the fruit. Fruiting forms that were shed but had no signs of fruit feeding were categorized as undamaged, while those that were shed and had signs of fruit feeding were categorized as damaged. Fruiting forms in which the bracts were etched, but no feeding signs were evident on the petals or carpel walls were recorded as undamaged. Fruit damage was monitored until most larvae (>90%) had pupated in the soil (20-22 DAH).

Defoliation was estimated by measuring the photosynthetically active radiation (PAR) that penetrated through the cotton canopy. A 1-m light ceptometer (Decagon Devices, Inc. Pullman, Washington) probe equipped with 80 independent light sensors was used to measure PAR. All PAR sampling was conducted between the hours of 11:00 am and 1:30 pm to minimize the effects of sun position on PAR data. Six PAR samples were taken above the canopy by placing the ceptometer probe parallel to the top of the cages and perpendicular to the cotton rows. This measurement supplied the base level of PAR inside the cage. PAR samples below the canopy were taken by placing the probe perpendicular to the rows at the base of the cotton plants. Samples below the canopy were taken at 10 different locations within the cage. Sampling PAR above and below the canopy was conducted sequentially within a cage. Light penetration through the canopy was estimated by dividing the PAR below the canopy by the PAR above the canopy and multiplying that number by 100. Visual defoliation ratings after all larvae had pupated also were used to estimate foliage injury by beet armyworms. The percent of the leaf area consumed in infested plots were visually compared to that in the control plots. Cotton yields were determined by manually harvesting the plots and measuring seed cotton weights. Data were analyzed by ANOVA and means were separated according to Fisher's Protected LSD ($P = 0.05$) (SAS Institute 1988). Statistical comparisons ($\alpha = 0.05$) were done within sampling date and across infestation densities.

Results

Defoliation

Light penetration through the cotton canopy was significantly higher in plots infested with beet armyworm eggs masses compared with control plots on most sampling dates (Table 1). In 1996, all beet armyworm infested plots had significantly more (1.5 to 1.7-fold) light penetrating the canopy than the control plots at 9 DAH. At 13 DAH, all infested plots, except for those infested with 3 egg masses, had significantly more light penetration (1.3 to 1.5-fold) than the control plots. At 16 DAH, all infested plots, except for those infested with 1 egg mass, had significantly higher light penetration (1.2 to 1.4-fold) than the control plots. In 1997, only the plots infested with 3 egg masses had significantly more (1.5-fold) light penetrating the canopy than the control plots at 9 DAH. At the remaining sampling dates (12, 16, and 19 DAH), plots infested with 3 and 6 egg masses had significantly more light penetrating through the canopy than the control plots. At 12, 16, and 19 DAH, plots infested with 3 egg masses had 1.6, 1.8, and 1.9-fold more light penetration than the control plots, respectively. Similarly, plots infested with 6 egg masses had 1.6, 1.8, and 2.2-fold more light penetration than the control plots at 12, 16, and 19 DAH, respectively.

Visual defoliation ratings in 1996 showed that only the plots infested with 6 egg masses had significantly higher defoliation (14%) than the control plots (4%) (Table 1). In 1997, there were no significant differences in visual defoliation ratings between infested and control plots, despite a greater range in defoliation estimates.

Fruiting Form Damage 1996

Cumulative numbers of damaged fruiting forms in plots infested with 1, 3, or 6 egg masses was 2.4, 3.0, and 3.3-fold higher than that in the control plots (Fig. 1). Although

TABLE 1. LIGHT PENETRATION IN COTTON PLOTS INFESTED WITH 0, 1, 3, OR 6 BEET ARMYWORM EGG MASSES. PLOTS WERE INFESTED WHEN COTTON REACHED NAWF = 5 PLUS 300 HEAT UNITS.

Number of Egg Masses[1]	% Light Penetration[2] (1996)			% Light Penetration (1997)				Visual % Defoliation	
	9 DAH[3]	13 DAH	16 DAH	9 DAH	12 DAH	16 DAH	19 DAH	1996	1997
0	4.94 b	5.77 b	7.76 b	7.90 b	9.38 b	9.24 b	10.00 b	4.0 b	14.3 a
1	7.78 a	8.44 a	9.44 a	10.52 ab	11.52 ab	10.98 b	13.74 b	7.8 ab	32.5 a
3	7.47 a	7.66 ab	10.42 a	11.61 a	14.86 a	16.72 a	19.37 a	6.3 b	40.0 a
6	8.62 a	8.38 a	10.64 a	9.05 ab	14.86 a	16.67 a	22.37 a	13.8 a	56.7 a
F	3.4	2.8	3.0	2.9	4.7	12.1	14.9	4.2	0.9
df	(3,153)	(3,153)	(3,153)	(3,132)	(3,126)	(3,127)	(3,123)	(3,9)	(3,6)
P	0.02	0.04	0.03	0.04	<0.01	<0.01	<0.01	0.04	0.51

Means within a column not followed by a common letter differ significantly (Fisher's Protected LSD; $P = 0.05$).
[1]Larvae in each egg mass were thinned to 60-80 insects per egg mass.
[2]Light penetration measured in Photosynthetic Active Radiation (PAR) using light ceptometer. % Light penetration = (PAR bottom canopy/PAR top canopy) × 100.
[3]DAH = days after larval hatching.

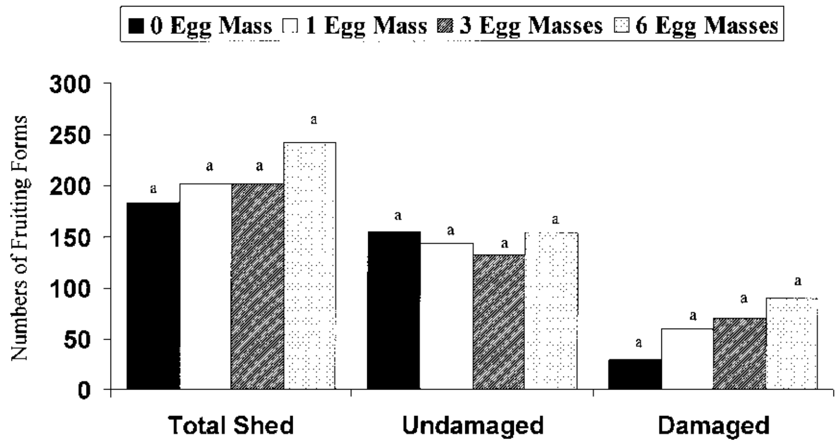

Fig. 1. Numbers of total shed, undamaged, and damaged fruiting forms in plots infested with 0, 1, 3, and 6 beet armyworm masses in 1996. Statistical comparisons within a category were made across egg mass densities. Different letters above bars indicate significant differences LSD ($P = 0.05$).

a trend for increased numbers of damaged fruiting forms with increases in egg mass density was observed, the cumulative numbers of damaged fruiting forms in infested plots were not significantly ($\alpha = 0.05$) different from that in the control. In addition, there were no differences in the cumulative numbers of undamaged or total shed (undamaged + damaged) fruiting forms between infested and control plots (Fig. 1).

In all infested plots, a significantly higher percentage of the shed fruiting forms was damaged compared with the control plots at 6, 9, 13, and 16 DAH (Table 2). In addition, plots infested with 6 egg masses had a significantly higher percentage of shed fruiting forms that were damaged than the plots infested with 1 egg mass at 6 and 16 DAH. No differences were observed in the percentage of shed fruiting forms that were damaged between infested and control plots at 20 DAH. Similar results were obtained in the percentage of cumulative shed fruiting forms that were damaged (Table 2). All infested plots had a significantly higher percentage of the cumulative shed fruiting forms that were damaged than in the control plots.

Fruiting Form Damage 1997

The cumulative numbers of damaged fruiting forms in plots infested with 1, 3, or 6 egg masses were 2.1, 1.8, and 3.3-fold higher than that in the control plots (Fig. 2). Although a trend for increased numbers of cumulative damaged fruiting forms with increases in egg mass density was noted, no significant ($\alpha = 0.05$) differences were observed. In addition, there were no significant differences in the cumulative numbers of undamaged or total shed fruiting forms between infested and control plots (Fig. 2).

The percentage of shed fruiting forms that were damaged tended to increase with increases in egg mass density. However, there were no significant differences among treatments on 3 of the 4 sampling dates. At 12 DAH, plots infested with 6 egg masses had a significantly higher percentage of the shed fruiting forms that were damaged

TABLE 2. PERCENT OF SHED FRUITING FORMS (SQUARES AND BOLLS) DAMAGED BY BEET ARMYWORM LARVAE IN PLOTS INFESTED WITH 0, 1, 3, AND 6 BEAT ARMYWORM EGG MASSES.

No. Egg Masses[1]	% Damaged Fruiting Forms (1996)[2]						% Damaged Fruiting Forms (1997)[2]				
	6 DAH[3]	9 DAH	13 DAH	16 DAH	20 DAH	Cumulative	9 DAH	12 DAH	16 DAH	20 DAH	Cumulative
0	10.9 c	18.4 b	14.7 b	16.5 c	9.9 a	16.3 c	2.4 a	3.2 b	6.4 a	1.0 a	3.2 b
1	18.7 b	36.5 a	35.0 a	29.5 b	15.6 a	31.5 b	10.0 a	3.4 b	33.3 a	25.0 a	6.0 b
3	21.7 ab	38.8 a	39.2 a	38.1 a	22.1 a	36.9 ab	16.4 a	6.7 b	31.3 a	33.3 a	22.2 b
6	25.3 a	36.3 a	42.9 a	40.4 a	19.5 a	38.3 a	26.4 a	36.5 a	25.0 a	41.7 a	54.0 a
F	17.3	12.4	15.6	19.1	1.5	23.3	2.2	.38	0.5	1.5	6.4
df	(3,9)	(3,9)	(3,9)	(3,9)	(3,9)	(3,9)	(3,9)	(3,9)	(3,9)	(3,9)	(3,9)
P	<0.01	<0.01	<0.01	<0.01	0.29	<0.01	0.16	0.05	0.74	0.28	0.01

Means within a column not followed by a common letter differ significantly according to Fisher's Protected LSD ($P = 0.05$).
[1]Numbers of larvae in each egg mass were thinned to 60-80 insects per egg mass.
[2]Percent damage fruiting forms = (No. damaged fruiting forms/No. total shed fruiting forms)* 100.
[3]DAH = days after larval hatching.

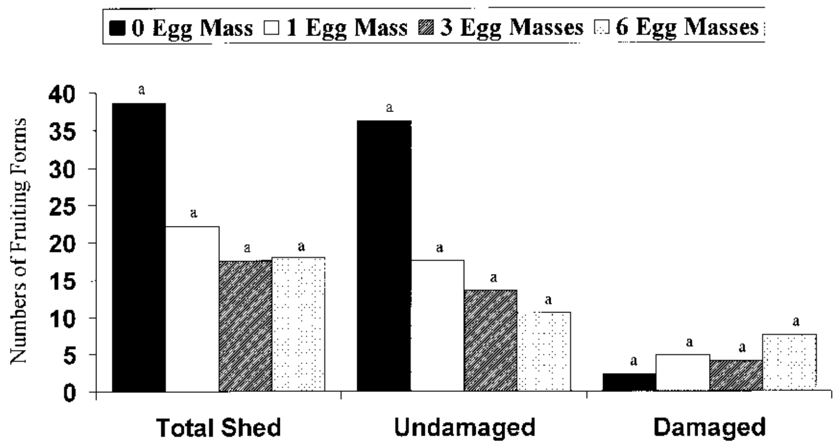

Fig. 2. Numbers of total shed, undamaged, and damaged from fruiting forms in plots infested with 0, 1, 3, and 6 beet armyworm egg masses in 1997. Statistical comparisons within a category were made across egg mass densities. Different letters above bars indicate significant differences LSD (P = 0.05).

than control plots, as well as plots infested with 1 or 3 egg masses (Table 2). Similar results were obtained in the percentage of cumulative numbers of shed fruiting forms that were damaged. Plots infested with 6 egg masses had a significantly higher percentage of the cumulative shed fruiting forms that were damaged than the control plots and those infested with 1 or 3 egg masses.

Yield

There were no significant differences (∝ = 0.05) in seed cotton yield between infested and non-infested control plots in 1996 or 1997 (Fig. 3).

Larval Development and Survival

Larval development and survival was normal in both years. Egg masses hatched 2-3 d after they were pinned to the leaves. Neonate larvae fed gregariously on the underside of leaves near the egg mass. Larvae began to disperse throughout the infested plant 3-4 d after they hatched, and 8 d after hatching, larvae were found throughout the cage environment. Larval survival to pupation was estimated at greater than 50%.

DISCUSSION

Yield losses associated with beet armyworm damage may result from direct damage to fruiting forms, as well as indirect damage from larvae feeding on foliage. Foliage feeding can indirectly affect yield by reducing the leaf area that produces photosynthates required to mature bolls. In previous studies, Kerby et al. (1988) showed that cotton can withstand up to 57% defoliation (artificial removal of leaves) before first square without significant reduction in lint yield. Additionally, Russell et al. (1993) conducted simulated defoliation studies in which cotton was repeatedly de-

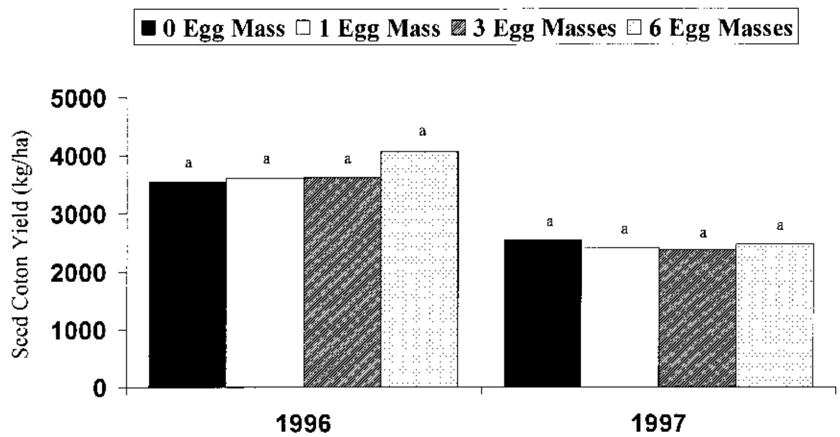

Fig. 3. Seed cotton yield in plots infested with 0, 3, and 6 beet armyworm egg masses in 1996 and 1997. Statistical comparisons were made across egg mass densities. Different letters above bars indicate significant differences LSD ($P = 0.05$).

foliated (20%) over a period of 7 consecutive weeks, from early squaring to mid-bloom, with no effect on yield. However, Russell et al. (1993) suggested that severe defoliation (>20%) during boll maturation could significantly impact yield by reducing the production of photosynthates in leaves necessary for maximum boll development.

The beet armyworm densities used in these studies ranged from 2.7 to 16.7-fold higher than the threshold of 6 hits (egg masses or clusters of small larvae) per 91.5 meter of row currently recommended in Louisiana (Bagwell et al. 1997). At the infestation densities used in these studies, a significant increase in the amount of light penetrating the canopy was generally observed in plots infested with 3 or 6 egg masses, which suggests a significant decrease in leaf area in those plots. Visual defoliation ratings in plots infested with 1, 3, or 6 egg masses were an average (1996 and 1997) of 2.1, 2.2, and 3.8-fold higher than the control plots, respectively. However, these levels of foliage loss at NAWF ≤ 5 plus 300 heat units were not sufficient to reduce yield in these plots compared with the control plots. These data are similar to research by Guitierrez et al. (1975), that showed cotton defoliation by beet armyworms and cabbage looper, *Trichoplusia ni* (Hübner), late in the growing season had little effect on yield. Similar results also were reported by Torrey et al. (1997) where removal of all foliage from the bottom 1/3 of the cotton canopy (33% defoliation) did not significantly reduce yields when plant development was at NAWF ≤ 5 plus 350 heat units. Results obtained in this study could have been caused by a compensatory effect (Oosterhuis et al. 1991), where plants were able to produce new leaf material at a rate in which the demands for photosynthates by the maturing bolls were met. Thus, no reduction in yield was observed. Alternatively, defoliation at this late stage of plant maturity (NAWF ≤ 5 plus 300 heat units) may not have affected yield because there was sufficient leaf area remaining to mature bolls. Cotton plants appear relatively unaffected by moderate (<40%) defoliation from early season to mid-flowering (Kerby et al. 1988, Russell et al. 1993). After plants have reached 5 NAWF and have accumulated heat units in excess of 300, late season defoliation low in the canopy also has little effect on yields (Torrey et al. 1997).

Although beet armyworms historically are recognized as defoliators, their direct feeding on fruiting forms often is of a much greater yield consequence (Smith 1989, Layton 1994). In 1996, a definite trend for increasing fruit damage occurred with increases in egg mass density. During the period that this study was conducted (one larval cycle or approximately 22 d), larvae in plots infested with 1, 3, or 6 egg masses damaged approximately 60, 70, and 90 fruiting forms, respectively (Fig. 1). However, these levels of fruit damage observed (1996) had no significant effect on yield. In fact, a trend for slight seed cotton yield increases with increased egg mass density was observed in 1996 (Table 1). A similar trend also was observed in the cumulative number of total shed fruiting forms (Fig. 1). In these studies, some level of fruit abscission may have occurred due to shading effects caused by the cage. Inside the cage, the light intensity was 60% of that recorded outside of the cage under direct sunlight. Guinn (1982) reported high rates (>90%) of fruit abscission when cotton plants were exposed to dim light (4 $\mu Em^{-2}s^{-1}$) for 3 d. Although abscission rates for young bolls (4-8 d old) was near 100%, abscission rates declined very rapidly for older bolls. Bolls that were 15 d past anthesis when exposed to dim light were virtually immune to abscission (Guinn 1982). In this study, a significant portion of undamaged young bolls did abscise in all treatments (Fig. 1). However, most of the older bolls were sufficiently matured (> 8 d old) and were not likely to abscise due to the shading caused by the cages. By having a slightly higher incidence of shed fruiting forms, plants in infested plots may have been able to concentrate their photosynthate resources on older fruiting forms, thus producing slightly bigger bolls than produced in the control plots. Small fruit abscission can be beneficial because it allows for the maturation of bigger bolls which the plant already has invested time and energy (Hake et al. 1989). The lack of differences in the cumulative numbers of total shed fruiting forms (Fig. 1), and the significantly higher percentage of shed fruiting forms damaged in infested plots (Table 2), indicates that the majority of the fruiting forms damaged by beet armyworm larvae were those that the plant would have naturally shed in the absence of insect damage.

The trends observed in fruit shedding and damage during 1996 were not repeated during 1997. A combination of late planting, poor early season growing conditions, and abnormally hot and dry late season growing conditions in 1997 likely impacted the outcome of this study. The overall yield potential of the plants was probably reduced due to stresses during the seedling and boll development stages. Differences in plant condition (fruit load and canopy mass) between 1996 and 1997 likely had some influence on the feeding behavior of beet armyworms.

The numbers of total shed fruiting forms was extremely different between the 1996 and 1997 studies. In the control plots, the number of total shed (undamaged + damaged) fruiting forms in 1996 was 4.8-fold higher than in 1997. Similarly, in plots infested with 1, 3, or 6 egg masses, the number of total shed fruiting forms in 1996 was 9.5, 11.5, and 13.5-fold higher than in 1997, respectively. Some of the fruiting forms in the 1997 test plots had suffered considerable damage from other insects and were aborted before cages were in place. This decreased the available numbers of fruiting forms susceptible to damage and shed from beet armyworm feeding. Most fruit shedding occurred at the first two sampling dates in all plots. After those fruiting forms were shed, remaining bolls may have been mature enough to avoid damage by beet armyworm larvae (Adamczyk et al. 1998). Nevertheless, there was a general trend for increased numbers of damaged fruiting forms with increases in egg mass density in 1997 (Fig. 2). However, no significant differences among treatments in seed cotton yield were observed in either year.

In summary, results indicate that neither defoliation nor fruit damage caused by late season beet armyworm infestation levels as high as 16.7 times the current threshold of 6 hits per 91.5 meters of row significantly affected cotton yields in these studies. Further research is needed to determine the consequences of beet armyworm infestations that may occur earlier in the growing season, when cotton bolls may be more susceptible to damage by this pest. In addition, this research was conducted during only a single generation of the larval stage of this insect pest. Continuous damage caused by overlapping generations of beet armyworms can be considerably greater than that tested herein, thus potentially resulting in economic yield losses.

ENDNOTE

The financial support of Cotton Incorporated is gratefully acknowledged. We thank Dr. Gary Herzog and Russ Ottens for supplying field-collected insects. The critical review of this manuscript by Dr. Blake Layton, and Dr. Alton Sparks is gratefully acknowledged. We also thank Larry Daigle, Chad Comeaux, David Nyagah, and Shae Robinson for their help in insect rearing. This manuscript is approved for publication by the Director of the Louisiana Agricultural Experiment Station as Manuscript No. 98-76-0069.

REFERENCES CITED

ADAMCZYK, J. J., JR., V. J. MASCARENHAS, G. E. CHURCH, B. R. LEONARD, AND J. B. GRAVES. 1998. Cotton boll susceptibility to fall armyworm and beet armyworm injury (in press). *In* Proc. Beltwide Cotton Prod. Res. Conf., National Cotton Council, Memphis, Tennessee.

BAGWELL, R. D., AND N. P. TUGWELL. 1992. Defining the period of boll susceptibility to insect damage in heat-unit from flower, pp. 767-770. *In* Proc. Beltwide Cotton Prod. Res. Conf., National Cotton Council, Memphis, Tennessee.

BAGWELL, R. D., J. L. BALDWIN, D. C. RESTER, J. B. GRAVES, E. BURRIS, S. MICINSKI, AND B. R. LEONARD. 1997. Control cotton insects 1997. Louisiana Cooperative Extension Service, Louisiana State University Agricultural Center. Publ. 1083.

BURRIS, E., J. B. GRAVES, B. R. LEONARD, AND C. A. WHITE. 1994. Beet armyworms (Lepidoptera: Noctuidae) in northeast Louisiana: observations on an uncommon insect pest. Florida Entomol. 77: 454-459.

DOUCE, G. K., AND R. M. MCPHERSON. 1991. Summary losses from insect damage and cost of control in Georgia, 1989. Georgia Agr. Exp. Sta. Spec. Publ. 70.

DOUCE, G. K., AND R. M. MCPHERSON. 1992. Summary losses from insect damage and cost of control in Georgia, 1990. Georgia Agr. Exp. Sta. Spec. Publ. 77.

ELZEN, G. W. 1989. Beet armyworm control, 1988. Insecticide and Acaricide Tests. 14: 231.

EVELLENS, K. G., R. VAN DEN BOSCH, AND L. E. EHLER. 1973. Secondary outbreak induction of beet armyworms by experimental insecticide applications in cotton in California. Environ. Entomol. 2: 497-503.

GAYLOR, M. J., AND L. C. GRAHAM. 1991. Beet armyworm populations in cotton treated with diflubenzuron and cyhalothrin for *Helicoverpa* spp. control, pp. 775-776. *In* Proc. Beltwide Cotton Prod. Res. Conf., National Cotton Council, Memphis, Tennessee.

GRAVES, J. B., B. R. LEONARD, AND C. A. WHITE. 1995. Efficacy of selected commercial and experimental insecticides against late season populations of beet armyworm, soybean looper, and tobacco budworm, 1994. Arthropod Management Tests. 20: 197-198.

GUINN, G. 1982. Fruit age and changes in abscisic acid content, ethylene production, and abscission rate of cotton fruits. Plant Physiol. 69: 439-352.

GUTIERREZ, A. P., L. A. FALCON, W. LOEW, P. A. LEIPZIG, AND R. VAN DEN BOSCH. 1975. An analysis of cotton production in California: a model for Acala cotton and the effects of defoliators on its yield. Environ. Entomol. 4: 125-136.

HAKE, K., G. GUINN, AND D. OOSTERHUIS. 1989. Environmental causes of shed. Physiology Today. Tech. Services. National Cotton Council, Memphis, Tennessee. Dec. 1989.

JENKINS, J. N., J. C. MCCARTY, JR., AND W. L. PARROT. 1990. Effectiveness of fruiting sites in cotton: yield. Crop Sci. 30: 365-369.

KERBY, T. A., S. JOHNSON, AND M. KEELY. 1988. Early season factors and their impact on emergence, growth and yield, pp. 14-16. *In* Proc. Beltwide Cotton Prod. Res. Conf., National Cotton Council, Memphis, Tennessee.

KING, E. G., AND G. G. HARTLEY. 1985. Diatraea saccharalis. *In* P. Singh and R. F. Moore [eds.] Handbook of Insect Rearing, Vol. 2. Amsterdam, Elsevier, pp. 265-270.

LAYTON, M. B. 1994. The 1993 beet armyworm outbreak in Mississippi and future management guidelines, pp. 854-856. *In* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, Tennessee.

LESER, J. F., M. A. KARNER, C. R. WARD, AND J. K. WALKER. 1996. Insect and mite pest management in the southwest, pp. 695-739. *In* E. G. King, J. R. Phillips, and R. J. Coleman [eds.] Cotton Insects and Mites: Characterization and Management. The Cotton Foundation, Memphis, Tennessee.

MASCARENHAS, V. J., B. R. LEONARD, E. BURRIS, AND J. B. GRAVES. 1996. Beet armyworm (Lepidoptera: Noctuidae) control on cotton in Louisiana. Fla. Entomol. 79: 336-343.

OOSTERHUIS, D. M., K. HAKE, AND C. BURMESTER. 1991. Foliar feeding cotton. Physiology Today. vol. 2 (8), National Cotton Council, Memphis, Tennessee.

OOSTERHUIS, D. M., F. M. BOURLAND, N. P. TUGWELL, AND M. J. COCHRAN. 1993. Terminology and concepts related to crop monitoring, maturity and defoliation, pp. 239-249. *In* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, Tennessee.

RUBERSON, J. R., G. A. HERZOG, W. R. LAMBERT, AND W. L. LEWIS. 1994. Management of the beet armyworm in cotton: role of natural enemies. Fla. Entomol. 77: 440-453.

RUSSELL, D. A., S. M. RADWAN, N. S. IRVING, K. A. JONES, AND M. C. A. DOWNHAM. 1993. Experimental assessment of the impact of defoliation by Spodoptera littoralis on the growth and yield of Giza '75 cotton. Crop Protection. 12: 303-309.

SANDERSON, E. D. 1905. Miscellaneous cotton insects in Texas. USDA Farm. Bull. 223: 14-15.

SAS INSTITUTE. 1988. SAS/STAT users guide, version 6.03 [ed.] SAS Institute, Cary, North Carolina. 1028.

SMITH, R. H. 1989. Experiences with beet armyworm control in 1988, pp. 273-275. *In* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, Tennessee.

SMITH, R. H. 1994. Beet armyworm: A costly caterpillar, pp. 13-14. *In* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, Tennessee.

SPARKS, A. N., JR., J. W. NORMAN, JR., AND D. A. WOLFENBARGER. 1996. Efficacy of selected insecticides against the beet armyworm, *Spodoptera exigua*—field and laboratory evaluations, pp. 844-846. *In* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, Tennessee.

SUMMY, K. R., J. R. RAULSON, D. SPURGEON, AND J. VARGAS. 1996. An analysis of beet armyworm outbreak on cotton in the lower Rio Grande Valley of Texas during the 1995 production season, pp. 837-842. *In* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, Tennessee.

TORREY, K., H. FIFE, B. R. LEONARD, R. D. BAGWELL, E. BURRIS, AND D. COOK. 1997. Late season insecticide termination studies in northeast Louisiana during 1997. *In* Cotton Insect Pest Management Studies in Louisiana. LAES Mimeo Series No. 121.

WILLIAMS, M. R. 1994. Cotton insect losses 1993, pp. 743-763. *In* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, Tennessee.

WILLIAMS, M. R. 1995. Cotton insect losses 1994, pp. 746-757. *In* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, Tennessee.

WILLIAMS, M. R. 1996. Cotton insect losses 1995, pp. 670-689. *In* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, Tennessee.

WILLIAMS, M. R. 1997. Cotton insect losses 1996, pp. 834-853. *In* Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, Tennessee.