Effects of Early-Season Loss of Flower Buds on Yield, Quality, and Maturity of Cotton in South Carolina

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ABSTRACT The effect of early-season flower bud damage on yield, quality, and maturity of cotton, *Gossypium hirsutum* L., was determined at Florence and Blackville, SC, from 1989 to 1994. From 1989 to 1991, yields from insecticide-treated plots for *Heliothis virescens* (F.) during June were compared with plots left untreated during June. In all cases from 1989 to 1991, no significant differences in yield were observed between treated and untreated plots. From 1992 to 1994, *H. virescens* damage was simulated by hand-removal of flower buds. In 1992, no significant differences were observed in yield, maturity, or lint quality following removals as high as 100% for 4 consecutive weeks. In 1993, a 1-wk delay in maturity was observed in 'DES 119' and 'Deltapine 90' at both locations following removals of 100% for 3 and 4 wk, and in 1994 at Blackville following removals of 100% for 3 wk. From 1992 to 1994, there were no significant yield effects following any flower bud removal level or duration, but in 1993 at Blackville, there were significant removal × planting date and removal × planting date × cultivar interactions. In this instance, DES 119 planted late (28 May) and grown under irrigated and dryland conditions experienced yield reductions of 30–45% after 100% removal for 3 or 4 wk that extended into mid-July. No other significant interactions with removal occurred, and no differences in lint quality were observed. Our data indicate that cotton compensates adequately for flower bud loss in June in South Carolina, and that insecticides for *H. virescens* seldom are needed early in the season. Opportunities to ameliorate traditional insecticide approaches for cotton insect management are discussed by considering our data in conjunction with the expansion of the Boll Weevil Eradication Program and the deployment of cotton cultivars that contain genes for expression of the delta-endotoxin of *Bacillus thuringiensis* in other areas of the Cotton Belt.

KEY WORDS *Heliothis virescens*, cotton, flower buds

The tobacco budworm, *Heliothis virescens* (F.), and the bollworm, *Helicoverpa zea* (Boddie), are the primary pest species on cotton, *Gossypium hirsutum* L., in South Carolina. In early season (June), *H. virescens* comprises ≈90% of the budworm–bollworm complex, but in midseason (July and August) *H. zea* comprises ≈90% of the complex (Turnipseed et al. 1991). Larvae of *H. virescens* feed on flower buds (squares) of cotton during June (Turnipseed et al. 1991), resulting in abscission of these structures (Mulrooney et al. 1992). Before 1991, growers in South Carolina spent an estimated $2 million per year for pest control to protect early squares (Turnipseed et al. 1991). In addition to monetary losses, applications of pyrethroids in June against *H. virescens* increase the likelihood of insecticide resistance development (Plapp et al. 1990) and decrease population densities of beneficial arthropods (House et al. 1985).

Several studies conducted outside the southeastern United States have indicated that cotton can compensate for early-season square loss by chemical or mechanical means. Pettigrew et al. (1992) in Mississippi reported that cotton can adapt to early-season fruit loss induced by chemicals because of its indeterminate nature. Moreover, Namken and King (1991) in Texas indicated that the removal of early-season squares by chemical means could reduce populations of boll weevils without resulting in economic loss. Research conducted in Arizona (Terry 1992) and Australia (Brook et al. 1992) showed no reduction in yield or fiber quality following early-season chemical or hand removal of squares. Additionally, a 23.5% increase in lint yield was observed in super okra-leaf cotton where squares were removed by hand for 3 consecutive weeks (Kennedy et al. 1986). Montez and Goodell (1994) in California indicated that moderate losses of early squares, simulating *Lygus* spp. damage, resulted in significantly higher yields over plants with no loss. In early studies in Alabama, Gilliland

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(1972) observed that plants from which squares had been removed by hand for 4 consecutive weeks produced yields comparable with those of control plots with no removals. However, cultivars and many cultural practices have changed since this work was completed. In a preliminary study from North Carolina, Ihrig et al. (1996) indicated that early-season loss of first-position fruit had no effect on yield.

Other studies from the mid-South (Mississippi, Louisiana, Arkansas) and California indicate that conservation of early squares is necessary to avoid yield loss (Jenkins et al. 1990a, b; Danforth et al. 1991; Parvin 1992; Keely and Kerby 1993). For example, Jenkins et al. (1990a) in Mississippi stated that 90% of total yield is produced from the lower sympodial branches and would be endangered without early-season insect control.

Thus, results from studies on early-season flower bud losses are contradictory, and information is needed that describes the consequences of such losses under a wide range of conditions (i.e., different seasons, degrees of loss, genotypes, dates of planting, and levels of irrigation). Our studies were initiated to determine the need for early-season insecticides to protect initial flower buds from *H. virescens*, and to define the cotton plant's ability to compensate following simulated *H. virescens* feeding injury.

Materials and Methods

Actual *H. virescens* Damage (1989–1991). Tests were conducted at the Edisto Research and Education Center in Blackville, SC, in 1989, at the Pee Dee Research and Education Center in Florence during 1990 and 1991, and near Blackville in 4 growers' fields in 1990 and in 3 in 1991, respectively. Cotton ('Coker 315') was used at the Edisto Rearch and Education Center in 1989. 'DP 90' was used during both seasons at Florence and in all fields in 1990 and 1991 at Blackville. Agronomic practices recommended for cotton production in South Carolina were followed (Lege et al. 1996). The experimental design for each test was a randomized complete block design with 4 replications. Plots at Florence were 16 rows (30.4-m each) (1990) and 8 rows (15.2-m each) (1991) spaced 96.5 cm apart, and plots at Blackville were 16 rows (15.2-m each) spaced 96.5 cm apart.

Test areas were divided into plots treated for *H. virescens* and those left untreated during the early season (June), with treated plots receiving applications of *lambda*-cyhalothrin (Karate 1 EC [emulsifiable concentrate], Zeneca, Wilmington, DE) (0.028 kg [AI]/ha). Insecticide treatments were applied during daylight hours, using a high-clearance sprayer (John Deere 6000). Treatments were initiated in June when larval densities (primarily *H. virescens*) exceeded 6 per 100 plant terminals, followed by a subsequent treatment 5–7 d later. The treatments were continued as needed, based on a threshold of 3 small (<5.0 mm in length) larvae per 100 terminals. All plots were treated with a standard pyrethroid as needed beginning in July for control of 3rd-, 4th-, and 5th-generation *H. zea* and *H. virescens* larvae.

Insecticide treatments were evaluated 3–5 d after each application. Larvae and eggs were counted from 25 randomly selected plants in each plot. The 4 center rows of each plot were machine-picked at harvest maturity. Lint yields were obtained by assuming a gin turnout of 35% of seed cotton weight under South Carolina conditions (Lege et al. 1996).

Simulated *H. virescens* Damage (1992–1994). Tests were conducted at the research sites in Florence and Blackville. In 1992, DP 90 (full season) and 'DES 119' (early maturing) were planted on 23 April (Florence early planting), 20 May (Florence late planting), and 21 May (Blackville late planting). In 1993, DP 90 and DES 119 were planted on 27 April (Florence early planting), 4 May (Blackville early planting), 24 May (Florence late planting), and 28 May (Blackville late planting). All plots were maintained with agronomic practices recommended for production in South Carolina. The early planting at Blackville in 1992 was lost because of an inadequate stand. Tests were conducted under irrigated and nonirrigated regimens at each location. Plots measured 8 rows by 15.24 m (Pee Dee Research and Education Center) and 8 rows by 22.86 m (Edisto Research and Education Center) spaced 96.5 cm apart with 4 replications of each treatment arranged in a randomized complete block design.

At Florence during 1992, larval populations consisting of 90% *H. virescens* and 10% *H. zea* were treated with *Bacillus thuringiensis* var. *kurstaki* (Berliner) (Dipel ES, Abbott, North Chicago, IL) (12 billion International Units [BIU]) in combination with thiodicarb (Larvin 3.2 AF [aqueous flowable], Rhone-Poulenc, Research Triangle Park, NC) (0.28 kg [AI]/ha) on 8, 17, 22, and 26 June and 1 July. During 1993, larval populations consisting of 85% *H. virescens* and 15% *H. zea* were treated with Karate 1 EC (0.028 kg[AI]/ha) on 12, 17, 22, and 25 June and 6 July (Blackville) and 23, 25, and 30 June (Florence). All plots (1992–1994) were treated with Karate 1 EC (0.028 kg [AI]/ha) as needed after early July for control of larval populations consisting of an average of 90% *H. zea* and 10% *H. virescens*.

Ten 1-m plots were selected randomly from the 6 middle rows of 8-row plots in 1992 and 1993. Plant stands were thinned to 6 plants per 1-m plot. Within these plots, squares were removed by hand to simulate *H. virescens* damage for 1–4 wk and to determine the effect of early-season loss on maturity, yield, and fiber quality. Initial square removals were made when 2 squares per plant were present and the average diameter of the 1st square was ≥5 mm. Squares were removed from 8 plots the 1st wk, 4 at 50% removal, and 4 at 100%.

For the initial removal of 50%, 1 of the squares on the 1st plant in the plot was chosen randomly for removal. If 1 square was not present on the 1st plant, removals began on the 2nd plant. After this 1st removal, moving from the bottom to the top of each plant, every other square was removed from successive plants to simulate 50% damage from *H. virescens*. Some plants did not have 2 squares, even though the plot averaged 2 squares per plant. Thus, it was necessary to skip a plant to be able to remove every other square. Weekly removals after the initial removal followed a similar pattern.

These removal schedules were designed to produce 100 and 50% square loss from 1 to 4 times at weekly intervals. Two control plots without removal were included. Squares in control plots averaged 2 (week 1), 4 (week 2), 6 (week 3), and 9 (week 4) per plant over all varieties and conditions. Harvest maturity was determined by monitoring plots at weekly intervals after 1 August, with defoliation being initiated at 80% open bolls (total open bolls divided by total number of bolls) in control plots. All plants within subplots were mapped 10–14 d following defoliation by using methods of Jenkins et al. (1990a). Lint yields were determined by multiplying seed cotton weight by gin turnout. Gin turnouts were determined for each plot by dividing the lint weight by seed cotton weight from plants mapped in that plot. Fiber samples were removed randomly from plot samples of the lower, middle, and upper thirds of the cotton plant and analyzed for quality by the United States Department of Agriculture Cotton Fiber Testing Laboratory at Clemson University, using a Spinlab 900 High Volume instrument.

In 1994, tests were conducted at Blackville under both irrigated and dryland conditions using agronomic practices similar to those of 1992 and 1993. DES 119 and DP 90 were planted on 27 April (irrigated and dryland early planting), 15 May (dryland late planting), and 25 May (irrigated late planting). DES 119 planted 15 May was lost because of an inadequate stand. Plots measured 4 rows by 15.24 m spaced 96.5 cm apart with 4 replications of each treatment arranged in a randomized complete block design.

Squares were removed from all plants when 2 squares per plant were present, and the average diameter of the 1st square was ≥5 mm, at rates of 100, 50, 25, and 10%. Removals were performed to provide each of the above damage levels to individual plots at 1-, 2-, and 3-wk intervals, with the most drastic removal level of 100% for 3 wk and the least drastic at 10% for 1 wk. Plants that incurred removals of 10% (1 in every 10 squares removed), 25% (1 in every 4 squares), and 50% (every other square removed) had squares removed by using the alternating technique described previously. One control plot (no square removal) was used for comparison. Maturity was determined by monitoring plots weekly after 1 August, with defoliation being initiated at 80% open bolls in control plots. The 2 center rows of each plot were machine-picked 10–14 d after defoliation. Lint yields were obtained by assuming a gin turnout of 35% of seed cotton weight (Lege et al. 1996).

Table 1. Effect of early-season (June) insecticide treatments for *H. virescens* versus no treatments on lint yield (mean ± SEM [kg/ha]) at Blackville and Florence, SC, from 1989 to 1991

Treatment	1989	1990	1991
		Blackville[a]	
Treated	1,292 ± 165	507 ± 32	1,244 ± 101
Untreated	1,280 ± 132	479 ± 24	1,214 ± 77
		Florence[b]	
Treated	—	884 ± 99	1,303 ± 162
Untreated	—	1,063 ± 115	1,380 ± 190

No significant differences between treatments. Blackville 1989: $F = 2.36$; df = 1, 7; $P = 0.434$. Blackville 1990: $F = 1.32$; df = 1, 7: $P = 0.245$. Blackville 1991: $F = 2.13$; df = 1, 7; $P = 0.187$. Florence 1990: $F = 3.57$; df = 1, 7; $P = 0.292$. Florence 1991: $F = 2.83$; df = 1, 7; $P = 0.347$.

[a] Edisto Research and Education Center in 1989, mean for 4 growers' fields in 1990, mean for 3 growers' fields in 1991.

[b] Pee Dee Research and Education Center.

To evaluate effects of hand removal on yield, we used a 4-way analysis of variance (AVOVA) (square-removal treatment, irrigation [irrigated or dryland], planting date [early or late], cultivar [DES 119 or DP 90]) with yield as the dependent variable ($\alpha = 0.05$). We were particularly interested in square removal effects and interactions involving square removal. Calculations were performed using the general linear model procedure of Minitab (1996). However, calculations involving effects of insecticide treatments for *H. virescens* control were performed using the ANOVA-2 procedure of MSTAT (Power 1985).

Results

Actual *H. virescens* Damage (1989–1991). Populations of small (<5.0 mm in length) larvae of *H. virescens* (90%) and *H. zea* (10%) peaked at Blackville in untreated plots on 19 June (1989 and 1990) and 14 June (1991) at 32/100 plants, 7/100 plants (average of 4 growers' fields), and 44/100 plants (average of 3 growers' fields), respectively, and in Florence on 10 June (1990) and 21 June (1991) at 12/100 plants and 19/100 plants, respectively. During this time, treatment thresholds were based on 6 small larvae per 100 plants. Pyrethroids applied to treated plots kept populations of large larvae below 3/100 plants. Machine-harvested yields indicated no significant differences between treated and untreated plots in any test at any location (Table 1). However, a 1-wk delay in maturity was detected in untreated plots in 2 of the 3 growers' fields in 1991 in Blackville after total larval populations peaked at 62 and 71/100 plants.

Simulated *H. virescens* Damage (1992–1994). Plots in which squares were removed from plants by hand showed no significant square removal ef-

Table 2. Effect of early-season hand removal of flower buds on lint yield (mean ± SEM) of cotton (DES 119 and DP 90) planted early and late under irrigated and dryland conditions at Blackville and Florence, SC, 1992–1994

Year	Irrigated				Dryland			
	DES 119		DP 90		DES 119		DP 90	
	Early	Late	Early	Late	Early	Late	Early	Late
				Blackville				
1992[a]	NA	20.2 ± 0.38	NA	17.1 ± 0.35	NA	21.5 ± 0.43	NA	18.5 ± 0.30
1993[b]	16.3 ± 0.38	11.5 ± 0.66	12.3 ± 0.27	10.1 ± 0.16	11.5 ± 0.26	7.4 ± 0.51	11.9 ± 0.07	7.7 ± 0.20
1994[c]	1,525 ± 13.5	1,024 ± 10.9	1,442 ± 22.8	1,012 ± 12.5	1,616 ± 15.1	NA	1,515 ± 19.1	1,092 ± 17.1
				Florence				
1992[d]	25.7 ± 0.42	18.9 ± 0.40	25.1 ± 0.42	15.8 ± 0.34	13.6 ± 0.34	13.5 ± 0.32	15.3 ± 0.30	14.4 ± 0.33
1993[e]	14.5 ± 0.35	15.2 ± 0.96	15.1 ± 0.25	14.0 ± 0.38	8.2 ± 0.24	8.3 ± 0.24	8.4 ± 0.26	9.0 ± 0.24

Lint yield given as grams per plant except Blackville 1994 (machine-harvested lint yield [kg/ha]). NA, not available.

[a] There is no square-removal effect ($F = 1.45$; df = 8, 143; $P = 0.185$) and no interactions involving square removal ($P > 0.05$), but there is a significant irrigation effect ($F = 15.89$; df = 1, 143; $P \leq 0.001$) and cultivar effect ($F = 75.29$; df = 1, 143; $P \leq 0.001$).

[b] There is a significant square-removal × planting date interaction ($F = 3.82$; df = 8, 287; $P \leq 0.001$) and square removal × planting date × cultivar interaction ($F = 2.07$; df = 8, 287; $P = 0.040$), but no separate removal effect ($F = 1.31$; df = 8, 287; $P = 0.241$), and no additional interactions involving square removal ($P > 0.05$), but there is a significant planting date effect ($F = 277.52$; df = 1, 287; $P \leq 0.001$), irrigation effect ($F = 162.4$; df = 1, 287; $P \leq 0.001$), and cultivar effect ($F = 27.16$; df = 1, 287; $P \leq 0.001$).

[c] There is no square removal effect ($F = 1.51$; df = 12, 363; $P = 0.121$) and no interactions involving square removal ($P > 0.05$), but there is a significant date effect ($F = 660.29$; df = 1, 363; $P \leq 0.001$), irrigation effect ($F = 17.01$; df = 1, 363; $P \leq 0.001$), and cultivar effect ($F = 7.80$; df = 1, 363; $P = 0.006$).

[d] There is no square-removal effect ($F = 1.34$; df = 8, 287; $P = 0.227$), no interactions involving square removal ($P > 0.05$), and no cultivar effect ($F = 1.13$; df = 1, 287; $P = 0.290$), but there is a significant planting date effect ($F = 294.75$; df = 1, 287; $P \leq 0.001$) and irrigation effect ($F = 826.59$; df = 1, 287; $P \leq 0.001$).

[e] There is no square-removal effect ($F = 1.45$; df = 8, 287; $P = 0.177$), no interactions involving square removal ($P > 0.05$), no planting date effect ($F = 0.21$; df = 1, 287; $P = 0.646$), and no cultivar effect ($F = 0.10$; df = 1, 287; $P = 0.746$), but there is a significant irrigation effect ($F = 589.00$; df = 1, 287; $P \leq 0.001$).

fect on lint yield at either Blackville or Florence (Table 2). In 1992, mean ± SEM lint yield (grams per plant) among all removal rates and durations ranged (minimum–maximum) from 15.8 ± 1.9 (100%, 2 wk, irrigated, DP 90) to 23.4 ± 1.9 (50%, 3 wk, dryland, DES 119) at Blackville, and from 12.0 ± 1.9 (50%, 2 wk, dryland, DES 119, early) to 27.6 ± 3.1 (50%, 1 wk, irrigated, DES 119, early) at Florence. In 1993, values ranged from 4.5 ± 1.6 (100%, 3 wk, dryland, DES 119, late) to 17.9 ± 0.9 (50%, 3 wk, irrigated, DES 119, early) at Blackville and from 7.3 ± 1.6 (50%, 4 wk, dryland, DES 119, early) to 17.8 ± 2.1 (50%, 4 wk, irrigated, DES 119, late) at Florence. In 1994 at Blackville, where all plants in 4-row plots incurred removals, cotton was picked by machine rather than by hand and results, again, were similar with no significant square removal effect (Table 2). Mean (± SEM) lint yield (kg/ha) in machine-harvested plots ranged from 948 ± 152 (25%, 3 wk, irrigated, DES 119, late) to 1,717 ± 162 (100%, 1 wk, dryland, DES 119, early). No differences in cotton fiber quality were detected between plots at any square removal level and those without removals. Because defoliation was triggered by 80% open bolls in control plots, these plots would be favored by any delay in maturity caused by severe removals (50 or 100% for 3 or 4 wk).

Although cotton plants compensated for even the most severe square losses under most circumstances, maturity was delayed ≈1 wk in 1993 at both locations in all plots that incurred removals of 100% for 3 or 4 wk. At Blackville in 1993, interactions involving square removal by planting date and square removal by planting date by cultivar were significant (Table 2). At these severe removal levels, cultivar DES 119 planted late (28 May) and grown under irrigated and dryland conditions produced the lowest yields (irrigated: 7.6 ± 1.7 g per plant at 100% removal, 3 wk; 8.7 ± 1.5 g per plant at 100%, 4 wk; [12.7 ± 1.1 g per plant without removal]; dryland: 4.5 ± 1.6 g per plant at 100%, 3 wk; 5.1 ± 2.0 g per plant at 100%, 4 wk; [8.4 ± 2.6 g per plant without removal]). In contrast, plants of the full-season cultivar DP 90 under the same conditions produced similar yields regardless of removal level or duration (irrigated: 10.3 ± 1.2 g per plant at 100% removal, 3 wk; 10.5 ± 1.5 g per plant at 100%, 4 wk; [10.1 ± 1.8 g per plant without removal]; dryland: 7.6 ± 3.0 g per plant at 100%, 3 wk; 7.2 ± 2.6 g per plant at 100%, 4 wk; [7.7 ± 3.6 g per plant without removal]). The late planting date caused removals to extend until the 2nd week of July and, when combined with the early maturing nature of DES 119, probably affected the compensatory process. Also, the only extreme drought in the 6-yr study was during 1993 (May–September rainfall ≈23 cm below normal accompanied by above normal temperatures), which stressed irrigation systems and contributed to low yields. In Florence the same year, no square removal effects or interactions involving square removal were significant. Nonetheless, the trend was similar; DES 119 planted late (24 May) and grown under irrigated conditions produced the lowest yields (9.2 ± 3.1 g per plant at 100%, 3 wk; 11.4 ± 3.6 g per plant at 100%, 4 wk; [16.3 ± 3.0 g per plant without removal]).

Plants of DP 90 under irrigated conditions at Florence in 1993 compensated by adding ≈2 times

Table 3. Effect of early-season hand removal of flower buds on lint yield (grams per position) of cotton cultivar DP 90 planted 24 May 1993 and grown under irrigated conditions at Florence, SC

100% removal, 4 wk[a]						No removal[b]						50% removal, 4 wk[c]					
Node[d]	Position[e]					Node[d]	Position[e]					Node[d]	Position[e]				
	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5
F16	—	—	—	—	—	F16	—	—	—	—	—	F16	—	—	—	—	—
F15	0.1	—	—	—	—	F15	—	—	—	—	—	F15	—	—	—	—	—
F14	0.1	—	—	—	—	F14	—	—	—	—	—	F14	—	—	—	—	—
F13	0.1	0.1	—	—	—	F13	0.1	—	—	—	—	F13	0.1	—	—	—	—
F12	0.1	0.3	—	—	—	F12	0.1	—	—	—	—	F12	0.1	0.1	—	—	—
F11	0.2	0.4	0.1	—	—	F11	0.1	0.1	—	—	—	F11	0.2	0.1	—	—	—
F10	0.3	0.4	0.2	—	—	F10	0.1	0.1	—	—	—	F10	0.2	0.1	0.1	—	—
F9	0.8	0.5	0.3	—	—	F9	0.2	0.1	0.1	—	—	F9	0.4	0.2	0.1	—	—
F8	0.9	0.6	0.3	—	—	F8	0.3	0.2	0.1	—	—	F8	0.6	0.2	0.1	—	—
F7	1.1	0.7	0.4	—	—	F7	0.4	0.4	0.1	—	—	F7	0.7	0.8	0.2	—	—
F6	1.2	0.9	0.6	—	—	F6	0.7	0.3	0.1	—	—	F6	0.8	0.7	0.3	—	—
F5	R	R	R	—	—	F5	0.7	0.5	0.2	—	—	F5	R	0.9	R	—	—
F4	R	R	R	—	—	F4	0.9	0.6	0.2	—	—	F4	0.2	R	0.5	—	—
F3	R	R	R	—	—	F3	1.0	0.6	0.2	—	—	F3	R	1.1	R	—	—
F2	R	R	R	—	—	F2	1.0	0.8	0.3	—	—	F2	1.3	R	0.4	—	—
F1	R	R	R	—	—	F1	A	0.9	0.4	—	—	F1	R	R	R	—	—
V	4.4	—	—	—	—	V	2.1	—	—	—	—	V	4.1	—	—	—	—

A single plant was selected to illustrate a response representative of the 24 plants per treatment.
[a] Lint yield of selected single plant, 15.1 g; 24-plant average, 15.4 g.
[b] Lint yield of selected single plant, 13.7 g; 24-plant average, 13.5 g.
[c] Lint yield of selected single plant, 15.6 g; 24-plant average, 15.0 g.
[d] Fruiting node 1 (F1), 1st fruiting node on plant; V, total weight of lint taken from vegetative branches on plant.
[e] A, a flower bud that was naturally abscised; R, a flower bud that was removed by hand.

more yield on vegetative branches, adding yield at nodes above removal sites to fruit that apparently matured faster, and adding more on higher nodes compared with plants without removal (Table 3). Compensation was similar at 50% removal, and sites adjacent to those incurring square removal contributed more to yield compared with the same sites in plants without removals.

The shorter-season DES 119 cultivar planted late in 1993 demonstrated the lowest level of compensation at Blackville and Florence. At Florence (Table 4) under irrigated conditions, removal of all

Table 4. Effect of early-season hand removal of flower buds on lint yield (grams per position) of cotton cultivar DES 119 planted 24 May 1993 and grown under irrigated conditions at Florence, SC

100% removal, 4 wk[a]						No removal[b]						50% removal, 4 wk[c]					
Node[d]	Position[e]					Node[d]	Position[e]					Node[d]	Position[e]				
	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5
F16	—	—	—	—	—	F16	—	—	—	—	—	F16	—	—	—	—	—
F15	0.1	—	—	—	—	F15	—	—	—	—	—	F15	—	—	—	—	—
F14	0.1	—	—	—	—	F14	—	—	—	—	—	F14	0.1	—	—	—	—
F13	0.2	0.1	—	—	—	F13	—	—	—	—	—	F13	0.2	—	—	—	—
F12	0.3	0.3	—	—	—	F12	0.1	—	—	—	—	F12	0.3	—	—	—	—
F11	0.5	0.4	0.1	—	—	F11	0.1	—	—	—	—	F11	0.4	0.1	—	—	—
F10	0.7	0.4	0.2	—	—	F10	0.1	0.1	—	—	—	F10	0.5	0.2	—	—	—
F9	0.7	0.5	0.3	—	—	F9	0.4	0.2	—	—	—	F9	0.6	0.3	0.1	—	—
F8	0.8	0.6	0.3	—	—	F8	0.5	0.4	—	—	—	F8	0.7	0.4	0.1	—	—
F7	1.1	0.7	0.4	—	—	F7	0.8	0.5	0.1	—	—	F7	0.8	0.6	0.1	—	—
F6	R	A	0.5	—	—	F6	0.9	0.7	0.1	—	—	F6	1.0	0.8	0.2	—	—
F5	R	R	0.6	—	—	F5	0.9	0.8	0.2	—	—	F5	1.2	1.0	0.3	—	—
F4	R	R	R	—	—	F4	1.1	0.4	0.2	—	—	F4	R	A	0.3	—	—
F3	R	R	R	—	—	F3	1.3	A	0.3	—	—	F3	R	R	0.4	—	—
F2	R	R	R	0.1	—	F2	1.6	0.8	0.4	—	—	F2	R	1.4	0.4	—	—
F1	R	R	R	R	—	F1	A	1.0	0.5	—	—	F1	1.8	R	0.7	0.1	—
V	3.4	—	—	—	—	V	1.5	—	—	—	—	V	3.8	—	—	—	—

A single plant was selected to illustrate a response representative of the 24 plants per treatment.
[a] Lint yield of selected single plant, 12.2 g; 24-plant average, 11.4 g.
[b] Lint yield of selected single plant, 16.6 g; 24-plant average, 16.3 g.
[c] Lint yield of selected single plant, 19.1 g; 24-plant average, 17.8 g.
[d] Fruiting node 1 (F1), first fruiting node on plant; V, total weight of lint taken from vegetative branches on plant.
[e] A, a flower bud that was naturally abscised; R, a flower bud that was removed by hand.

initial fruit for 4 wk in late June and early July resulted in a yield loss of ≈30%. However, at 50% removal, yields of DES 119 were ≈10% higher than without removals, which was similar to DP 90 (Table 3). Although these treatment differences in DES 119 at Florence in 1993 were not significant, results closely followed those at Blackville, where a significant square removal × date × cultivar interaction occurred (Table 2).

Discussion

Our results from 1989 to 1994 demonstrate that cotton in South Carolina has an exceptional ability to compensate for square loss in early season without adversely affecting the crop. In cotton planted early (by 4 May), there were no differences in yield or lint quality following even the most drastic removals of all squares for 4 consecutive weeks. Earliness of the crop was affected in only 2 instances, with maturity (80% open bolls) being delayed ≈1 wk in 1991 only when *H. virescens* populations were exceptionally high (62 and 71 larvae per 100 plants in June), and in 1993 in both DP 90 and DES 119, but only following 100% removals for 3 and 4 wk. In cotton planted early, there was no significant square removal effect on yield in any test. However, in 1993 at Blackville, there was a significant square removal × date × cultivar interaction (Table 2) wherein 100% removals for 3 or 4 wk resulted in yield reductions of ≈35% in irrigated and 43% in dryland cotton, but only in late-planted DES 119. Also, in 1993 at Florence, although square removal interactions were not significant, yields of DES 119 planted 24 May and irrigated with similar removals were ≈37% lower than without removal. Such drastic fruit loss is seldom encountered and should be remedied by insecticidal intervention before it extends into July, particularly when a short-season variety is grown.

Based on our results, treatment thresholds for control of *H. virescens* in early season (June) in South Carolina were elevated from 6 small larvae per 100 plants to 10 in 1992 and to 15 in 1996. Currently, our cotton producers have eliminated most June sprays and recognize that early-season control of *H. virescens* to protect initial squares is not essential.

Certain harvesting economics models (Parvin et al. 1987), using data from the mid-South, assume that loss of some early-season fruit to insects directly affects earliness by delaying maturity. However, Sheng and Hopper (1988) indicated that quantitative estimates of the effects from early-season insect injury must be available before this effect can be incorporated into harvest economics models that recommend insect control to advance cotton maturity. The loss of squares at initial sites from actual or simulated *H. virescens* damage in our study extended cotton maturity by ≈1 wk in only 2 instances during the 6 yr involved and only following exceptionally high tobacco budworm pressure (60–70 larvae per 100 plants) or drastic square removals (100% × 3 or 4 wk). This extreme loss of initial fruit is rare in cotton production. Recent work in North Carolina (Ihrig et al. 1996) indicated that early-season loss of first-position fruiting sites had no effect on yield. We expect that results from our study would be applicable to most of the coastal plain of the southeastern United States where pests and production conditions are similar. However, pests and conditions are different in other areas of the Cotton Belt.

Earliness is important in cotton production, but delays in maturity could have greater impact in the mid-South than in the southeastern United States because of rainfall patterns. For example, average rainfall at Greenville, MS, from 1990 to 1995 was 10 cm less during August and September than at Columbia, SC, whereas it was 5 cm more during October (Southern Regional Climate Center, Louisiana State University). The economic consequences of harvest delays are likely to be compounded by late rains in the mid-South, particularly when combined with the high moisture-holding capacity of heavier delta soils.

In much of the Cotton Belt, broad-spectrum insecticides are applied early in the season and midseason to protect fruiting structures from major insect pests such as the boll weevil, *Anthonomus grandis grandis* (Boheman), and *H. virescens*. Insecticides also are used in many areas of the Cotton Belt to control plant bugs, *Lygus* spp. Their feeding causes plants to abscise squares (Tingey and Pillemer 1977) and contributes to delayed maturity and reduced yields in certain areas (Parrot et al. 1985, Scott et al. 1986). These early-season insecticides disrupt beneficial arthropods and reduce their effectiveness in regulating pest populations later in the season.

In South Carolina, insecticidal applications are seldom needed to protect initial squares in early season. This situation exists because the success of the Boll Weevil Eradication Program has reduced *A. grandis* to subeconomic status, and extensive loss to initial squares in early season does not compromise maturity, yield, or quality of the cotton crop (data from current study). Thus, we can develop new approaches to insect management in cotton that exploit the potential of beneficial arthropods in the absence of early-season (i.e., June) insecticides.

Equally effective and stable systems that use beneficials fully in pest management soon may be feasible in other areas of the Cotton Belt. This feasibility is predicated on the continued expansion and success of the Boll Weevil Eradication Program, and the expanding use of cotton cultivars that contain genes for expression of the delta-endotoxin of *B. thuringiensis*. These 2 technological advances will result in a sharp decline in insecticide use against major cotton pests (i.e., *A. grandis*, *H. virescens*, and *H. zea*). However, their maximum benefits can be realized only if synthetic broad-spectrum insecticides are used judiciously in early season against secondary pests. Effective treatment thresholds are needed for secondary pests, particularly where they have been controlled fortuitously by synthetic insecticides applied routinely for *A. grandis*, *H. virescens*, and *H. zea*. Secondary pests that damage initial fruiting sites (i.e., *Lygus* spp.) will require special attention. Quantitative estimates of the effects of these pests should clarify the relationship of pest level to fruit loss, maturity, and yield. We suggest that such studies be completed in regions where problems exist to understand better the loss of early fruit on the economics of cotton production.

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