COMPARISON OF COTTON PLANT RESPONSE TO SQUARE LOSS FOLLOWING MANUAL REMOVAL OR TARNISHED PLANT BUG FEEDING – RESULTS FROM FIELD TRIALS IN 2000

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Abstract

Effects of early square removal on cotton (*Gossypium hirsutum* L.) development were evaluated in normal, late and extremely late plantings in Arkansas. Squares were removed either by feeding by tarnished plant bug (*Lygus lineolaris* Palisot de Beauvois) or manually by crushing. Injury treatments were initiated when first squares were visible, approximately 36 days after planting and continued for 2 to 3 weeks. All visible squares were crushed on each treatment date. For plant bug treatments, 3 nymphs, 2nd to 3rd instar, were released per plant. Plant response was monitored using COTMAN in-season with final plant mapping done using COTMAP. Square shed of 1st position squares at 1st flowers ranged from 4% in uninjured (protected) cotton to 40 and 50% following Bug or Crush treatments. Significant crop delay as measured by days to physiological cutout (nodes above white flower = 5) was noted for insect induced injury compared to plants protected by insecticide in 2 of the 3 dates of planting. There was no significant difference in days to cutout between manual injury and protected treatments. Time-dependent compensation was measurable by yield in 2 of 3 dates of planting. Differences in final plant structure and crop compensation following plant bug induced square abscission compared to manual square removal are discussed.

Introduction

How a cotton crop compensates from insect induced loss of squares and bolls varies with the pest and growing conditions. Sadras (1995) described 3 scenarios for crop compensation after loss of fruiting structures: 1) cotton plants under compensate for losses and lose yield, 2) they over compensate by producing more bolls and lint than uninjured plants, or 3) they fully adjust and produce fiber weights equal that of normal, undisturbed plants. Which of these 3 scenarios occurs often seems to be left to *the lucky roll of the dice*. Perhaps this is why so many crop advisors and growers consider a crop protection strategy based on compensation too risky – likened to a trip to a Mississippi gambling house. Unfortunately, this view often leads to a extreme risk-averse production strategy, one with little tolerance for any insect induced loss of squares and bolls. It is a costly strategy, heavily dependent on insecticides.

Crop advisors and growers need a crop monitoring system that provides real-time data showing whether their crop is doing well, even without protective sprays. The system must be a workable method of information synthesis that can be used for rapid communication among growers, their support groups and the farm manager. Research in Arkansas and other states has been directed at developing such a system – COTMAN (Danforth and O'Leary 1998). It includes monitoring responses of the cotton plant to injury occurring at different stages of plant development (Bagwell and Tugwell, 1992, Holman, 1996), and it is capable of integrating crop management and pest management tactics (Bernhardt et al. 1986; Bourland et al. 1992; Zhang et al; 1994; Cochran et al. 1995; Oosterhuis et al. 1996; O'Leary et al.1996; King et al. 1996; Teague et al.1999).

A current focus in COTMAN research is development of decision rules for managing square retention prior to first flowers, concentrating on how retention affects crop carrying capacity and yield potential. Hearn and Constable (1984) described crop carrying capacity as the boll load that slows terminal growth and the production of new squares to zero. Assuming good growing conditions, one can glean information on boll loading from a measure of the slowing of terminal growth after first flowers. A count of squaring **N**odes **A**bove the 1st position **W**hite **F**lower (NAWF) will provide a measure of boll filling stress (Figure 1). We believe this stress can be anticipated because square retention prior to first flowers should reflect potential strain that will result in metabolic stress associated with boll filling. The connection between potential strain and actual strain that leads to metabolic stress is a result of complex nutritional and hormonal influences and is poorly understood (reviewed by Sadras 1995). We do know that if retention is high when first flowers appear, the cotton plant's natural feed-back mechanisms will alter strain by causing small bolls and tiny squares to shed during boll filling (Mauney 1979, Guinn 1979, Room and Hearn 1979 and others).

Insect pests that feed on cotton fruiting structures typically induce abscission of the damaged organ. When insects such as tarnished plant bug (*Lygus lineolaris* (Palisot de Beauvois)), Heliothine larvae, or boll weevil (*Anthonomus grandis* Boheman) threaten square shedding, decisions to intervene can affect square retention and therefore alter potential strain. Researchers have studied crop response to loss of fruiting structures by manually removing squares and bolls to simulate insect injury (Pitman et al. 2000, Herbert et al. 1999, Mann et al. 1997, Phelps et al. 1997, Ihrig et al. 1996, Montez and Goodell, 1994, Brook et al. 1992, Lentz 1990, Ungar et al. 1987, and others).

Plant responses to damage by different species may not be as straightforward as manual removal because of differences in time and duration of attack, feeding habits and production of toxins (Sadras 1995). For example, feeding by boll weevil and Heliothine larvae generally result in square abscission, but this is not necessarily the case for injury by tarnished plant bug. Small squares will shed following tarnished plant bug feeding, but larger ones typically are more tolerant.

The probability of square abscission following tarnished plant bug feeding is a function of anther size (Pack and Tugwell 1976). When anthers are hardly visible, the bug feeds on the totality of the floral bud. Most of the digestive enzyme activity in tarnished plant bug originates in its salivary gland complex (Agusti and Cohen 2000). Enzyme activity associated with feeding on these small buds (<3mm) likely results in abscission. As the square grows, the anthers reach a large enough size for the bug to feed on the individual pollen sack. When tarnished plant bug feeding is localized on the anthers, shed rarely happens; however, squares with extensive anther damage may shed as bolls (Pack and Tugwell 1976).

Tarnished plant bug is a key pest in Midsouth cotton, and the perception by growers and crop advisors of its importance as a pest is likely to increase with boll weevil eradication and with widespread use of Bt transgenic cotton. It is unknown if results from crop compensation studies that have used manual square removal methods adequately simulate plant bug injury. The objectives of the experiment reported here were 1) to compare square losses caused by plant bugs and by manual removal and 2) to assess plant responses with standardized procedures that synthesize information involving many potentially interacting factors affecting strain and metabolic stress relations and crop carrying capacity.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:1149-1157 (2001)
National Cotton Council, Memphis TN

Materials and Methods

The experiment was conducted on the University of Arkansas Cotton Branch Experiment Station in Marianna which lies in the Mississippi River Delta production region. The growing season in the study area is May through October. The latest possible cutout date for this production area – that date with a 50% or 85% probability of attaining 850 DD60s from cutout is August 14 and August 9, respectively (Zang et al. 1994 and Danforth and O'Leary 1996).

Cultivar Sure-grow 125 was seeded on 3 dates, May 16, June 1, and June 12 using a John Deere air planter in rows spaced 38 inches apart. Temik 15G (aldicarb) was applied in furrow at planting at 3.5 lb formulation per acre. The soil was a Calloway silt loam. Furrow irrigation was initiated one week prior to flower in the earliest planting, and continued at weekly intervals until mid September. Rainfall in May, June, July, August, September and October was 4.92, 3.21, 0.27, 0.35, 1.12, 0.27 inches respectively. Defoliant was applied on 3 October to all plots.

Injury Treatments

There were 3 injury treatments: 1) artificial infestations of tarnished plant bug nymphs (Bug), 2) manual crushing of squares (Crush) and 3) no injury and sprayed with insecticide (Protected). Dates of planting were randomized within the field and regarded as main plots with square injury treatments considered sub-plots. Each treatment was replicated 3 times. Sub-plots were 8 rows wide, 25 ft long with 2 unplanted rows between plots 8 ft separating plots. Three rows, each 10 ft long, were selected in each plot for injury treatments. Tarnished plant bugs were obtained from a colony maintained on artificial diet at the USDA-ARS Biological Control and Mass Rearing Research Unit at Mississippi State, MS (Cohen et al. 2000).

In Bug treatment plots, artificial infestation procedures were standardized similar to the method outlined by Tugwell et al. (1976). The bugs were transferred to the field at daybreak. Three tarnished plant bug nymphs (2nd and 3rd instar) were aspirated from rearing containers into a 1.5 inch long section of black tubing (Dayco One Fuel Line Hose 5/16" I.D.; Kargo Automotive Whse, 4350 Stockton Dr., Little Rock, AR). Tubes were taped to the base of each plant's main stem. Bugs were released on June 22 and 29, and July 7 in the May 16 date of planting, July 7 and July 14 in the June 1 date of planting and July 17 and 24 in the June 12 planting. On these same dates, all visible squares on plants in the Crush treatment were crushed using forceps. Care was taken to minimize touching the plants. Insecticide applications in the protected plots were made weekly through July. Leverage 2.7 EC (imidacloprid + cyfluthrin) was applied at 0.00634 lb ai/ac using a back-pack sprayer equipped with an 8-row boom . One week after the final application of bugs on July 24, a regular schedule of insecticide applications was initiated across all plots. Leverage was applied 2 times weekly until 15 August at which time ULV malathion applications for boll weevil eradication began. This was the first year for boll weevil eradication in this region, and sprays were applied every 5 to 8 days through October.

Plants were monitored in each plot from the early squaring period through cutout using the COTMAN system. Five consecutive plants in 2 treatment rows were monitored weekly. Prior to first flowers sampling included measurement of plant height, number of squaring nodes, and sheds of first position squares. Square shed data were divided into 3 categories of square size: total, large and small. Total squares were all first position squares. Small squares were 1st position squares located in the top 3 sympodial nodes, and large squares were 1st position squares located in sympodial node 4 and below. After first flowers, nodes above white flower were monitored. In all plant monitoring activities, samplers touched the plants as little as possible to minimize possible thigmonastic effects.

Final plant mapping was performed on October 10 using COTMAP (Bourland and Watson 1990). Ten plants per plot were examined for node number of first (lowest) sympodial branch on the main axis, no. of monopodia, and no. of bolls on sympodia arising from monopodia. Bolls located on main stem sympodia (1st and 2nd position) were recorded as well as bolls located on the outer positions on sympodial nodes (>2nd position). The highest sympodium with 2 nodal positions and no. of bolls on sympodia located on secondary axillary positions were also noted. Plant height was measured as distance from soil to apex.

Plots were hand harvested 3 times – 7, 17 and 24 days after defoliant application. Lint samples were taken for each harvest date for each sample and sent to the Texas Tech Fiber Testing Laboratory, Lubbock, TX for quality analysis.

Results and Discussion

Natural infestations of tarnished plant bugs and caterpillars were negligible during the season and can be disregarded. Boll weevil numbers were at treatment level in some nearby fields that were adjacent to overwintering habitat, but regular insecticide applications in those areas prevented movement of boll weevil into the study area until late in the season when entire field sprays of ULV malathion began for the first year of boll weevil eradication.

Environmental conditions at time of emergence for the 3 dates of planting varied with each date (warmer, drier etc). There were significant differences (pr>F 0.005; LSD05=0.25) in plant stand density between the 16 May, 1 June and 12 June planting dates measured at 3.56, 3.90, and 3.35 plants/ft of row, respectively. Subsequent differences in crop vigor and size at the time of first squares when each injury treatment was to be administered resulted in significant interactions with treatments and dates of planting on most crop measures. To simplify interpretation of data, dates of planting were separated. Crop injury, development and yield data were analyzed separately.

Square Shed

Bug and Crush treatments were initiated at approximately the same time period for each date of planting – 35 to 37 days after planting. The 1st plant monitoring data came approximately 4 days later (Table 1). In all 3 dates of planting, square shed differed significantly between treatments on most sample dates.

In the 1st date of planting, total percent shed of 1st position squares was remarkably similar for Crush and Bug – 53% and 43% shed at 56 days after planting compared to 7.3% in the Protected treatment (Table 1). Shed of large and small squares was different between the Crush and Bug treatments. Large square shed was significantly higher in Crush compared to Bug treatments in the 2nd and 3rd sampling dates. Conversely, small shed was higher for Bug compared to Crush treatments during the same sampling period. Although large square shed was lower in the Bug injury treatment, squares may have been sufficiently large that plant bug feeding would not result in abscission. Squares were not dissected to determine injury (Williams et al. 1987).

Unlike the 1st date of planting, the later planting dates received the Bug or Crush treatments on just 2 occasions rather than 3. Square shed from Bug treatments in the 3rd date of planting was comparable to that observed in the May planting, but shed associated with plant bugs was lower in the 2nd date. Insecticide drift from a neighboring field on the experiment station during the experiment was thought to have occurred affecting 2 of 3 Bug treatment plots. The low level of injury for those Bug treatment plots (< 10%) for that date of planting is attributed to mortality from the insecticide (Table 1).

Squaring Nodes

There were no differences in mean no. of squaring nodes per plant until after 1st flowers (Table 2). Mean no. squaring nodes for each date of planting at the time of injury treatments ranged from 2.8 to 5.8 (Table 2). These data are plotted as nodes above 1st square and nodes above white flower in COTMAN growth curves in Fig. 2. When compared to the COTMAN target development curve, it is apparent the rate of squaring node accumulation was lower than expected in the 1st date of planting in the days leading to first flowers (Fig. 2a). This was probably due to heat and water stress (irrigation was initiated simultaneously across all dates of planting so the early date of planting was exposed to dry conditions for a longer period than other dates). Growth curves were slightly above target in the latest date of planting indicating rapid growth in the warmer conditions of mid-June (Fig. 2b&c). Growth curves are not continuous for Bug and Crush treatments in the 1st and 3rd dates of planting because samplers took only NAWF readings on those dates, and because of injury treatments, no flowers were present in those plots. In the 2nd date of planting the sample data were taken before flowers therefore nodes above 1st square were counted.

Numbers of squaring nodes per plant for the 1st date of planting were not affected by injury treatments until after first flowers (Table 2). Boll loading is a major strain producing factor so a decline in NAWF is expected after flowering (Fig. 1). If it does not occur, one must be alert for problems with boll retention and/or boll filling. Differences in NAWF in the Protected compared to Bug and Crush injury treatments in the May 16 and June 12 plantings indicate reduced strain associated with lower square retention (Table 1). COTMAN growth curves for the 1st date of planting clearly show differences in NAWF between treatments and reflect crop delay in the Bug treatment (Fig. 2). Days to cutout (no. of days from planting until mean NAWF = 5) were significantly higher -10 to 11 days - for the Bug treatment compared to either Crush or Protected (Table 3).

There was a significant difference in the 2nd date of planting between injury treatments in squaring nodes at day 57 just before flowers (Table 2). After that, NAWF values were very similar. For this date of planting, there was insufficient injury from Bug treatments to result in delay of cutout (Table 3).

For the 3rd date of planting significant differences in squaring nodes were apparent at 73 days after planting (Table 2). Days to cutout were significantly higher for Bug compared to Protected treatments. There was no difference in days to cutout between the treatment plots with manual square removal as compared to the sprayed plots (Table 3).

Final Plant Mapping

Significant differences in plant structure were observed between injury treatments for all dates of planting as measured in final plant mapping (Tables 4, 5, 6). As with the COTMAN shed and squaring node data, differences were most obvious in the 1st and 3rd dates of planting; however, for all 3 dates, significant differences in boll distribution were observed. Percentage of total bolls associated with 1st sympodial position was significantly higher in Protected plants compared to plants with insect and manually induced square shed. Percent early boll retention, defined as 1st plus 2nd position bolls on the 5 lowest sympodia, was also higher in Protected plants. Number of aborted terminals was negligible in any treatments.

For the 1st and 3rd dates of planting where insect feeding effects were most apparent, there were significant differences between the Bug and Protected treatments in several measures of plant structure including the no. of fruiting sites and no. of fruiting forms including: total nodes, total no. of sympodia, total outer bolls (bolls on sympodial positions > 2), highest sympodia with 2 nodal positions, and no. of effective sympodia. Plant height of the Crush treatment was greater than the Protected plants in the 1st date of planting; however, the Bug treatment was significantly greater than both.

Yield and Quality

Significantly lower yields in the 1st harvest of the earliest date of planting were associated with the Bug injury treatment compared to Protected plots (Table 7). Crush treatment yields were intermediate. By the 2nd harvest, compensation appeared complete in both Bug and Crush treatments, and there were no differences in final yield. No delay or reduction in yield was observed in the 2nd date of planting, but delay, and loss of yield to Crush and Bug treatments were observed in June 12 planting date. There was insufficient time for time-dependent compensatory response in this very late planted cotton, and yields from the Protected treatment were significantly higher than either Bug or Crush treatments.

Injury treatments had no significant effect on fiber quality. Micronaire values were very low in the final harvest in the June 12 planting (Table 8). A change in experimental protocol would be necessary to evaluate injury treatments on lint quality with timing of crop termination (defoliation) dependent on cutout date. In this study, defoliant was applied on 3 October, and DD60s (heat units) from cutout varied from 543 to 1206 between the different treatments (Table 3). COTMAN assumes maturity of last effective boll population is at 850 DD60s (Wells 1991).

Concluding Remarks

A major concern with pest effects of tarnished plant bug in cotton has been with crop delay as well as with yield loss. Holman (1996) infested squaring cotton with tarnished plant bug nymphs, and showed that bugs reduced cotton yield at increasing rates when square shed (1st position squares measured at time of first flower) exceeded 26%. On the other hand, lint yields of treatments that sustained 1 to 7% shed rates were not significantly different from those which sustained 19% square shed. In fact, yields were numerically higher for treatments at the 19% square shed rate. Compensation at these levels of square shed required additional time; there was one day of delay associated with each 4 % of first position square shed. Tugwell et al. (1976) observed a 60% reduction in yield when they released plant bug nymphs on squaring plants. Yields in that study overall were very low (490 lbs lint/ac in undamaged cotton).

Hearn and Room (1979) listed 2 types of time-dependent compensatory responses to loss of fruiting structures in cotton: 1) ***time dependent tolerance*** - when fruiting structures that would have shed physiologically replace those previously damaged or 2) ***time-dependent compensation*** **–** when loss of fruiting structures delays metabolic stress therefore lengthening the time of squaring and allowing some of the additional squares to set bolls. They included 2 additional forms of compensatory response that were independent of time: 3) ***instantaneous tolerance*** **–** when the damage occurs to fruiting forms that would have shed physiologically anyway or 4) ***instantaneous compensation*** **–** when resources that would have been directed to damaged bolls are directed to the remaining undamaged bolls making them bigger.

In our study we found direct evidence of the first 3 of these compensatory responses. Our research protocol did not include measurement of individual boll weights to determine instantaneous compensation; however, some preliminary observations made in the 2nd harvest showed trends toward larger bolls in the Crush and Bug treatments. More detailed evaluation of this response is needed in the future. As far as time-dependent compensatory responses are concerned, we observed significant crop delay measured as days to physiological cutout when square retention was significantly reduced by tarnished plant bug feeding in the first 3 weeks of squaring. Such delay was not observed when squares were manually removed. Possible explanations for lack of delay include effects of additional handling of plants with manual removal. Another is that plant bug induced damage was more severe, extensive or otherwise *different* than the manual removal. For manual square removal, all injury came on day 1 The injury from plant bug feeding likely would have been spread over the period from release to time of plant monitoring - at least 4 days and even afterward if the nymphs were not dislodged from plants during inspection. Monitoring of square shed did not indicate great differences in square abscission between Crush and Bug treatments. Crop effects were not apparent in-season until NAWF measurements were available.

Incorporating Compensation into a Crop Management Strategy

Sadras (1995) suggested that poor compensatory growth could be expected at both "high" and "very low" yield levels; he used the range of <892 lbs/ac as a low and 1500 to 1600 lbs/ac as a high yield. He concludes that "...a thoughtful account of growing conditions is essential to understand compensation".

One way for crop managers to dictate their own luck with compensation is to make management choices that do not decrease the crop's compensation capacity. Appropriate choices for dates of planting with suitable temperatures for a selected cultivar, type of seed bed, plant stand density, timely and adequate irrigation and fertilizer applications, correct use of plant growth regulators, and proper pest control all affect *time* available for compensation. These management choices also affect *extent* of compensation.

To adequately investigate the complexities of compensatory response of cotton, researchers must use an integrated approach that considers multiple factors including water, nitrogen, carbon and arthropod herbivory (Sadras 1995). The research reported here represents initiation of a series of strain – stress experiments that will be expanded in 2001. The overall goal is development of decision aids that allow a grower to economically exploit the upper levels of the crop's carrying capacity -- when compensation is not needed or to any extent possible.

Acknowledgements

The authors thank the Mr. Claude Kennedy, Director of the Cotton Branch Experiment Station and his staff for their assistance in the study. We also acknowledge support from USDA-ARS research entomologist, Dr. Bill McGovern, and we thank Ms. Gay McCain, USDA-ARS, Mississippi State, MS for providing the tarnished plant bugs.

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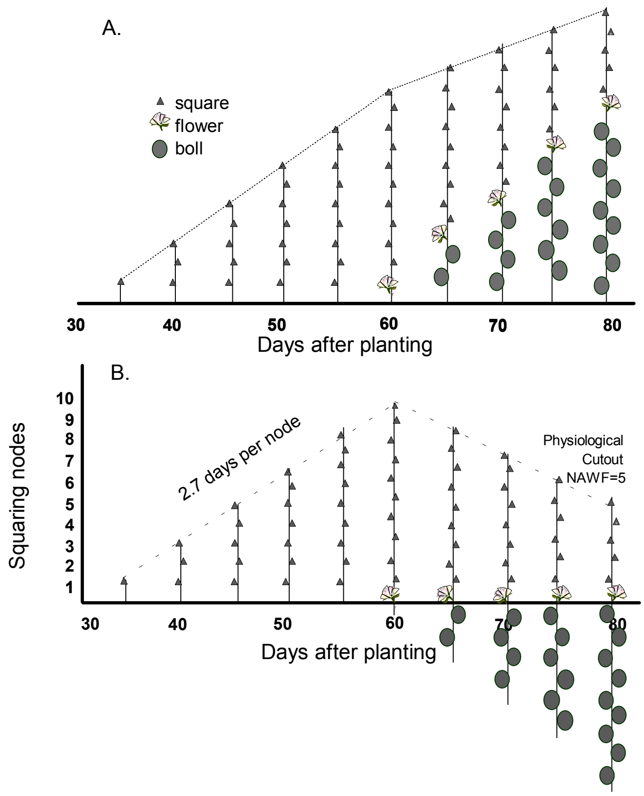

Figure 1. As cotton plants begin squaring, the initial increase in number of squaring nodes (fruiting branches that have not yet flowered) is exponential; at first flower the increase becomes linear and eventually stops. The abrupt downturn at first flower is associated with strain from boll loading (A) that occurs with good growing conditions and in the absence of pests. When squaring nodes are plotted against days after planting, the resulting reference curve is the COTMAN Target Development Curve (B).

Table 1. Total, large and small square shed (% of first position floral buds) as influenced by square injury treatments for 3 dates of planting[1].

Date of planting	Square Size[2]	Time of injury (DAP)[3]	Sample time (DAP)	Mean no. shed squares (%)				
				Bug[4]	**Crush**	**Protected**	***Pr>F***	***LSD_{05}***
May 16	Total	37	41	32.9	26.8	4.5	*0.04*	*20.0*
		44	50	42.6	41.0	6.7	*0.001*	*10.6*
		52	56	53.3	43.3	7.3	*0.008*	*20.9*
	Large	37	41	59.1	86.7	8.4	*0.02*	*43.0*
		44	50	71.1	35.0	13.8	*0.001*	*17.8*
		52	56	75.6	42.0	12.8	*0.003*	*23.9*
	Small	37	41	25.5	10.6	3.4	*0.09*	*20.3*
		44	50	16.7	4.5	0.6	*0.009*	*7.7*
		52	56	25.5	6.7	1.1	*0.03*	*15.8*
June 1	Total	36	40	9.1	8.3	0.0	*0.08*	
		43	47	25.8	71.7	0.3	*0.006*	*28.9*
	Large	36	40	11.1	61.1	0.0	*0.03*	*39.8*
		43	47	39.2	100.0	0.0	*0.005*	*37.9*
	Small	36	40	8.7	4.2	0.0	*0.07*	
		43	47	17.8	56.1	0.6	*0.007*	*23.5*
June 12	Total	35	42	34.9	25.3	3.7	*0.03*	*20.9*
		42	46	47.7	53.7	8.1	*0.001*	*3.9*
	Large	35	42	58.8	50.3	7.0	*0.04*	*39.6*
		42	46	69.2	92.0	9.3	*0.001*	*9.6*
	Small	35	42	16.6	2.2	1.7	*0.002*	*5.0*
		42	46	23.3	5.6	6.7	*0.01*	*9.1*

[1]Data are means of 3 replications. Square shed percentages were determined from 10 plants per plot using standard COTMAN procedures.
[2]Small squares were 1st position squares in the top 3 sympodia; large squares were all squares from the 4th sympodia down the plant; total were all 1st position squares.
[3]Days after planting (DAP).
[4]Insecticide drift for the June 1 date of planting affect Bug injury.

Table 2. Squaring node number as influenced by square injury treatment for 3 dates of painting. [1]

Date of planting	Sample date (DAP) [2]	Mean no. squaring nodes				
		Bug	**Crush**	**Protected**	***Pr>F***	***LSD_{05}***
May 16	06/26 (41)	3.9	3.7	3.5	*0.42*	
	07/05 (50)	5.8	5.6	5.7	*0.19*	
	07/11 (56)	6.9	6.6	6.6	*0.61*	
	08/1 (77)	5.7	5.1	4.8	*0.007*	*0.37*
	08/11 (87)	5.3	4.9	4.4	*0.21*	
	08/17 (93)	4.9	4.4	3.9	*0.03*	*0.67*
	07/24 (100)	3.4	3.0	2.5	*0.57*	
June 1	07/11 (40)	3.0	3.0	2.8	*0.62*	
	07/18 (47)	4.9	4.7	5.1	*0.65*	
	07/28 (57)	7.4	7.0	6.9	*0.02*	*0.28*
	08/11 (71)	6.6	6.4	6.1	*0.16*	
	08/17 (77)	5.2	5.5	5.4	*0.71*	
	08/24 (84)	3.6	3.9	3.9	*0.63*	
June 12	07/24 (42)	5.3	5.8	4.9	*0.04*	*0.61*
	07/28 (46)	6.4	6.8	6.3	*0.05*	*0.35*
	08/17 (66)	7.8	7.6	7.5	*0.29*	
	08/24 (73)	6.3	6.2	5.5	*0.02*	*0.49*

[1]Data are means of 3 replications. Squaring nodes were counted on 10 plants per plot using standard COTMAN procedures.
[2]Days after planting (DAP).

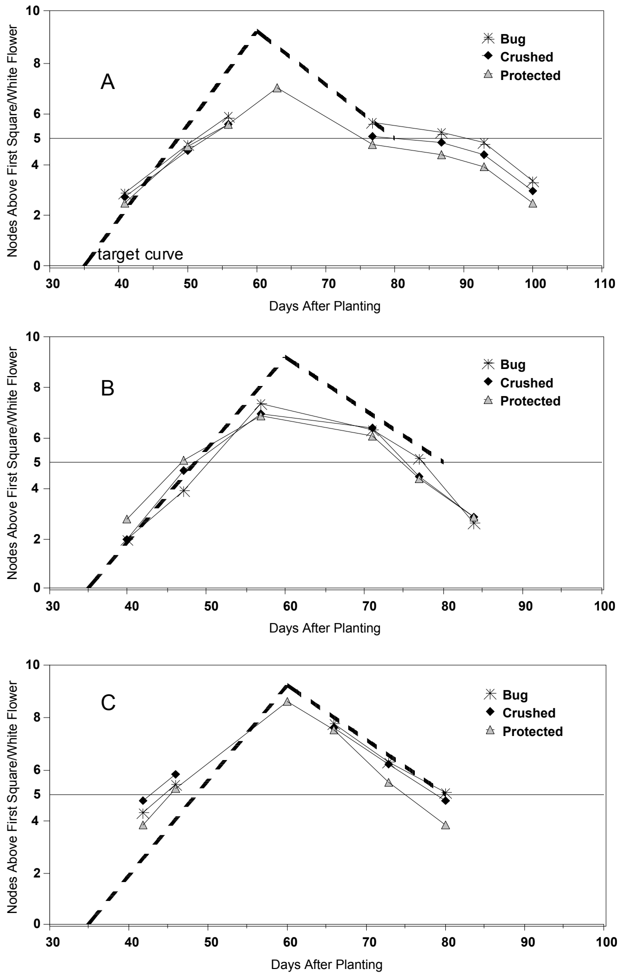

Figure 2. COTMAN growth curves for 3 dates of planting: A) May16, B) June 1, and C) June 12. Curves depict growth of plants exposed to tarnished plant bug nymphs, plants with manually removed squares or plants protected with insecticide.

Table 3. Effect of injury treatments on no. of days to cutout for the 3 dates of planting, and the heat unit accumulation from date of cutout until application of defoliant on Oct 3.

DOP	Injury treatment	Mean date of physiological cutout[1]	Mean no. days to cutout	DD60s from cutout to defoliation on Oct 3
May 16	Bug	14 Aug	90.3	923
	Crush	03 Aug	79.7	1166
	Protected	02 Aug	78.0	1206
	pr>F		*0.02*	*0.03*
	LSD_{05}		*8.06*	*187.5*
June 1	Bug	18 Aug	78.0	835
	Crush	20 Aug	79.7	794
	Protected	19 Aug	79.0	811
	pr>F		*0.70*	*0.58*
	LSD_{05}			
June 12	Bug	31 Aug	80.3	543
	Crush	29 Aug	78.7	577
	Protected	26 Aug	75.7	637
	pr>F		*0.04*	*0.44*
	LSD_{05}		*3.42*	

[1]Date at which the mean no. of squaring nodes above white flower = 5 (NAWF = 5).

Table 4. Plant response to injury treatments in May 16 date of planting - results from final plant mapping following defoliation[1].

Category	Bug	Crush	Protected	*LSD_{05}*
1st Sympodial Node	5.9	5.9	6.1	
No. of Monopodia	1.7	1.4	1.5	
Highest Sympodia with 2 nodes	13.4	10.9	9.7	*1.5*
Plant Height (inches)	49.1	43.5	39.8	*3.4*
No. of Effective Sympodiaz	12.5	10.4	9.6	*0.9*
No. of Sympodia	16.6	14.5	13.4	*1.2*
No. of Sympodia with 1st Position Bolls	3.7	3.3	5.1	*0.7*
No. of Sympodia with 2nd Position Bolls	2.1	2.5	1.4	
No. of Sympodia with 1st & 2nd Bolls	0.8	0.7	1.6	*0.4*
Total Bolls/Plant	11.4	10.3	11.6	
% Total Bolls in 1st Position	39.4	39.0	58.1	*4.5*
% Total Bolls in 2nd Position	25.7	31.2	26.4	
% Total Bolls in Outer Position	15.4	15.8	5.1	*8.9*
% Total Bolls on Monopodia	15.4	13.5	10.4	
% Boll Retention - 1st Position	27.1	27.0	50.4	*4.8*
% Boll Retention - 2nd Position	21.9	30.0	31.9	
% Total Bolls on Extra -Auxillary	4.1	1.5	0.0	
% Early Boll Retention	15.3	29.3	60.7	*11.2*
Total Nodes/Plant	21.5	19.4	18.5	*1.3*
Internode Length (inches)	2.3	2.2	2.2	

[1]means of 10 plants per plot

Table 5. Plant response to injury treatments in June 1 date of planting - results from final plant mapping following defoliation[1].

Category	Bug	Crush	Protected	*LSD_{05}*
1st Sympodial Node	7.7	7.4	7.3	
No. of Monopodia	2.7	2.4	2.3	
Highest Sympodia with 2 nodes	9.3	9.1	8.9	
Plant Height (inches)	48.0	47.8	45.6	
No. of Effective Sympodia	8.5	7.7	8.1	*0.5*
No. of Sympodia	12.5	12.4	12.0	
No. of Sympodia with 1st Position Bolls	4.3	3.1	4.8	
No. of Sympodia with 2nd Position Bolls	1.3	2.3	0.8	*0.7*
No. of Sympodia with 1st & 2nd Bolls	0.7	0.5	1.5	*0.3*
Total Bolls/Plant	9.6	8.6	10.2	
% Total Bolls in 1st Position	53.1	42.8	61.5	
% Total Bolls in 2nd Position	20.5	32.5	22.5	*8.1*
% Total Bolls in Outer Position	7.0	7.4	2.5	
% Total Bolls on Monopodia	16.3	15.7	13.0	
% Boll Retention - 1st Position	39.5	29.5	52.1	*10.1*
% Boll Retention - 2nd Position	20.9	30.7	25.8	*7.3*
% Total Bolls on Extra-Axillary	3.2	1.6	0.3	
% Early Boll Retention	36.7	36.0	60.0	*7.6*
Total Nodes/Plant	19.2	18.9	18.4	
Internode Length (inches)	2.5	2.5	2.5	

[1] means of 10 plants per plot

Table 6. Plant response to injury treatments in June 12 date of planting - results from final plant mapping following defoliation[1].

Category	Bug	Crush	Protected	*LSD_{05}*
1st Sympodial Node	7.0	6.6	6.4	
No. of Monopodia	2.8	2.5	2.2	
Highest Sympodia with 2 nodes	11.5	10.8	9.9	*0.9*
Plant Height (inches)	51.0	49.2	45.8	*2.2*
No. of Effective Sympodia	9.5	9.2	8.3	*0.9*
No. of Sympodia	14.5	13.7	13.2	
No. of Sympodia with 1st Position Bolls	3.5	3.1	4.1	
No. of Sympodia with 2nd Position Bolls	1.3	2.3	0.9	
No. of Sympodia with 1st & 2nd Bolls	0.4	0.4	1.2	*0.5*
Total Bolls/Plant	8.5	8.7	8.8	
% Total Bolls in 1st Position	47.3	39.4	60.3	*14.9*
% Total Bolls in 2nd Position	20.8	30.8	24.1	
% Total Bolls in Outer Position	10.8	8.0	1.9	*6.1*
% Total Bolls on Monopodia	16.4	20.1	12.5	
% Boll Retention - 1st Position	27.4	25.2	40.4	*10.5*
% Boll Retention - 2nd Position	15.3	24.7	21.5	
% Total Bolls on Extra - Axillary	4.7	1.6	1.1	
% Early Boll Retention	20.3	28.0	51.3	*12.0*
Total Nodes/Plant	20.6	19.3	18.6	*1.4*
Internode Length (inches)	2.5	2.6	2.5	

[1]means of 10 plants per plot

Table 7. Cumulative mean lint yield over 3 harvest dates taken for each injury treatment for the 3 dates of planting.

		Cumulative lint yield (lb/ac) at each date of hand harvest[1]		
DOP	Injury treatment	Oct 10	Oct 20	Oct 27
May 16	Bug	1164.1 b	1206.8 a	
	Crush	1144.5 ab	1210.0 a	
	Protected	1212.6 a	1247.0 a	
	pr>F	*0.019*	*0.34*	
	LSD_{05}	*81.8*		
June 1	Bug	766.6 a	1072.6 a	1109.0 a
	Crush	730.2 a	1012.0 a	1035.6 a
	Protected	808.9 a	974.1 a	998.4 a
	pr>F	*0.76*	*0.76*	*0.70*
	LSD_{05}			
June 12	Bug	92.8 b	369.1 b	554.6 b
	Crush	72.2 b	493.5 b	624.1 b
	Protected	272.9 a	712.2 a	783.7 a
	pr>F	*0.003*	*0.003*	*0.01*
	LSD_{05}	*77.57*	*121.5*	*112.2*

[1]Means with a column for each date of planting and harvest date followed by a similar letter are not statistically different.

Table 8. Micronaire values of lint samples taken for 3 harvest dates for each injury treatment for the 3 dates of planting.

		Mean micronaire value at each harvest date		
DOP	Injury treatment	Oct 10	Oct 20	Oct 27[1]
16 May	Bug	5.40	4.23	
	Crush	5.40	4.36	
	Protected	5.27	4.23	
	pr>F	*0.51*	*0.65*	
1 June	Bug	4.96	4.40	
	Crush	5.03	4.30	
	Protected	4.87	4.03	
	pr>F	*0.62*	*0.36*	
12 June	Bug	4.70	3.57	2.23
	Crush	4.10	3.90	2.37
	Protected	4.60	3.63	2.33
	pr>F	*0.08*	*0.11*	*0.36*

[1]For Oct 27 samples there was insufficient lint for quality analysis for June 1 date of planting; all cotton in May 16 date of planting had been harvested by Oct 20.