MANUALLY APPLIED INFESTATIONS OF TARNISHED PLANT BUG NYMPHS IN LATE SEASON COTTON TO IDENTIFY THE FINAL STAGE OF CROP SUSCEPTIBILITY

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Abstract

Research to refine and validate end-of-season crop management guides for defining the final stage of crop susceptibility for tarnished plant bug (*Lygus lineolaris* (Palisot de Beauvois)) was continued in 2007 in Northeast Arkansas. The insect control termination guide in COTMAN that has been in use for heliothine caterpillars and boll weevils (NAWF=5 +350 DD60s) has been validated in small and large plot trials in Arkansas and has been shown to be is a very conservative recommendation --- *more* than sufficient for late season plant bug management. For natural infestations that include season long pressure, termination of insect control before cutout +250 has resulted in yield penalties. Field research in 2007 supports previous research findings showing increased crop tolerance to plant bug as the crop matures. In the 2007 field trial on the Judd Hill Research Farm Station in Trumann, manual infestations of >10 nymphs/ft were made weekly beginning the week prior to physiological cutout (mean Nodes Above White Flower (NAWF) =5) and extended until 600 DD60s after cutout. No reductions in yield were observed compared to untreated cotton or cotton protected with insecticides. These data plus our previous results from 2000-2007, indicate reduced susceptibility to plant bug in cotton around the time of physiological cutout. We suggest that decision makers consider earlier termination timing for plant bug control in cotton. Termination at NAWF=5+250 DD60s appears to be adequate in fields of uniform maturity particularly in production areas with low levels of early season plant bug pest pressure.

Introduction

When is a cotton crop safe from new infestations of cotton insect pests? Decision makers using the COTMAN™ crop monitoring system (Danforth and O'Leary 1998) designate physiological cutout -- the flowering date of the last effective boll population, as when the average NAWF in the field = 5 (Bourland et al 1992). When that boll population has accumulated 350 DD60s (heat units) the crop has been shown to be safe from new infestations of the most significant boll feeding insect pests, boll weevil (*Anthonomus grandis* Boheman), tobacco budworm (*Heliothis virescens* (Fab.)) and bollworm (*Helicoverpa zea* (Boddie)) (reviews by O'Leary et al 1996, Cochran et al 1999, and Danforth et al 2004). For plant bug, the research to determine the final stage of crop susceptibility has been ongoing in Arkansas since 2001.

In Northeast Arkansas, where pest pressure generally is lower that some other Midsouth production areas, manual infestation techniques have been used to simulate late season hatch of plant bug nymphs. Field collected or lab reared plant bug nymphs were released in cotton at different times in late season. These trials were open field, not caged, tests where plant bugs move freely about the plant feeding on plant structures and fruiting forms of their *free choice*. Yield and quality from those treatment plots were compared to untreated cotton and cotton receiving protective insecticide sprays. In the 2001 and 2002 trials in Mississippi County, 3 to 5 nymphs (2^{nd} and 3^{rd} instar) were released per plant (9 to 20/ft) starting at about 1 week after physiological cutout (NAWF=5 + 80 to 150 DD60s). Additional infestations were made in subsequent weeks such that plants were infested at cutout + 1, 2 and 3 wks, cutout + 2 and 3 wks and cutout + 3 wks. Plant monitoring results indicated significant feeding injury to upper canopy bolls, but there was no significant yield penalty associated with plant bug feeding compared to untreated or protected controls in either year. Mean yields ranged from 1180 to 1250 lbs/acre in 2001 and 1034 and 1150 lbs/acre in 2002 (Teague et al 2002 and Teague 2003, unpublished). When a similar trial was repeated in 2004, a drip irrigated, high yielding (3.5 bale cotton) crop was damaged when manual infestations were made the week of physiological cutout; field collected plant bug nymphs released at 1 or 3 bugs/plant (plant densities of 3-4 per ft of row) significantly reduced yield. In 2005, infestations were made ca 150 DD60s after cutout, and no yield reductions were measured. Manual infestation timing at NAWF=5+350 in 2006 resulted in no reductions in yield (Teague et al 2007). Our findings indicate that very high yielding crops remain susceptible to new outbreaks of plant bug that occur at the time of cutout, but the crop becomes increasingly tolerant as it matures.

In 2007 research, manual infestation timing was expanded over several weeks ranging from pre-cutout cotton until first open boll. The objective was to validate the COTMAN 350 rule, and determine if there were yield or quality penalties for earlier termination of insect control.

Materials and Methods

The 2007 trial was located at the University Research Farm on the Judd Hill Plantation in Poinsett County near Trumann AR. Cultivar DPL 444 was planted 11 May in a Dundee silt loam soil. Plots were furrow irrigated. The experiment was arranged in a randomized complete block with 3 replications. Plots for each test were 50 ft long, 10 rows wide and separated by 10 ft alleys.

Plant bug infestation treatments (Table 1) included untreated and insecticide sprayed treatments (Table 2). Plant bug nymphs were obtained from the USDA-ARS SIRU plant bug colony maintained on artificial diet (Cohen 2000) at Starkville, MS. Nymphs were pre-conditioned on field collected cotton squares overnight prior to release. Manual infestations of 15 to 30 bugs/ft were made by allowing nymphs to crawl from strips of confetti-sized strips of white copy paper (0.25 inch wide and 11 inches long) laid across the tops of plants. The paper strips are used to line the bottom of TPB rearing containers. Bugs were released during the cool period of the morning just after dew had dried. Both rows in the entire 50 ft section received bugs. Insecticides were applied in the sprayed plots (Treatment 7) using a JD high clearance sprayer with 8 row boom.

Plant bug numbers were monitored using weekly drop cloth sampling. Three ft of row per plot were sampled by beating plants over a drop cloth positioned between rows 3 and 4 of each plot – 1.5 ft from each row. After manual infestations were initiated, (in rows 5 and 6), sampling for the infested plot was moved to row 6, and only 1.5 ft of row was sampled. Sampling was done 24 hrs after manual infestations and repeated at 2 or 3 day intervals. A different section of the 50 ft row was sampled each period. Through the season, care was taken not to disturb plants in row 5 of any plot. Row 5 was used for harvest and fiber quality determinations.

Plants were monitored in each plot from the early squaring period through cutout using the Squaremap procedure in the COTMAN system (Danforth and O'Leary 1998). Five consecutive plants in treatment rows 3 and 4 were monitored weekly. After manual infestations, sampling was located in row 6 in areas not subjected to drop cloth sampling. Squaremap sampling included measurement of plant height from soil to plant apex, number of sympodia on the main plant axis, and retention of first position fruiting forms on those branches (Bourland et al 1992).

Plant bug feeding injury was evaluated using boll and flower injury assessments. Small and large boll damage was evaluated in samples taken 21 Aug. Twenty small (<0.75 inch) and 20 large bolls were collected from the upper canopy of row 6. External feeding injury was noted, and then bolls were sliced to determine internal injury. For both assessments, injury was rated 0, 1 or 2 with 0 recorded for no injury, 1 for minor injury (1 lock internal) and 2 (moderate to severe external injury or >1 lock internal). White flower anther injury was rated over 4 dates with injury rated 0 (no injury) or 1 (anther injury). Irrigation was terminated after final irrigation on 9 Aug, cutout+300 DD60s. Harvest aid defoliant and boll openers were applied 4 Sept at cutout + 940 DD60s. Final plant mapping was performed after defoliation using COTMAP (Bourland and Watson 1990). Ten plants in row 5 of each plot were examined for node number of first (lowest) sympodial branch on the main axis, number of monopodia, and number 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 was also noted. Plant height was measured as distance from soil to apex. For fiber quality assessments, fifty boll samples were taken on 18 Sept from consecutive plants on consecutive fruiting positions in the center portion of row 5. Fiber samples were ginned on a laboratory gin and sent to the International Textile Center at Texas Tech University for HVI analysis. Machine harvest was done 21 Sept with a modified 2-4row JD cotton picker set up for single row weight measures for small plots. Seed cotton yields were converted to lint yields based on uniform 38% turn-out. All crop monitoring and yield data were analyzed using AOV with mean separation using LSD.

Table 1. Treatment list and timing for 2007 tarnished plant bug termination trial.

Treatment number	Timing of plant bug release: Crop maturity status at time of plant bug release	Calendar date	Days after planting
1	NAWF=6.5	19-Jul	69
2	NAWF=5 (cutout)	28-Jul	78
3	Cutout + 200 DD60s	05-Aug	86
4	Cutout + 400 DD60s	12-Aug	93
5	Cutout + 600 DD60s	20-Aug	101
6	Untreated[1]		
7	Sprayed late season	15, 23, 31-Jul, 8-Aug	66, 73, 81, 87

[1]Acephate 90S (0.40 lb/ac) was applied to all plots 29 May; thereafter only Treatment 7 was sprayed.

Table 2. Application timing and products for insecticide in treatment 7.

Application Date	Days after planting	Product (rate/acre)
16-Jul	76	Acephate 90S (0.5 lb/ac) + Diamond (10 oz/ac)
23-Jul	85	Diamond (10 oz/ac)
31-Jul	92	Bidrin 8EC (3 oz)/ac
06-Aug	99	Bidrin 8EC (3 oz)/ac

Results

Crop growth: Conditions were conducive for early season plant growth. Temperatures in May through early July were moderate, but high day time temperatures and limited rainfall followed in late July and early August (Figs 1, 2). No pretreatment differences among plants were noted for nodal development or fruit retention using COTMAN Squaremap procedures pre and post flowers. Pace of squaring node development and cutout dates were similar across the treatments so these data were pooled to calculate a single crop growth curve (Fig 3). The crop reached physiological cutout (NAWF=5) on 27 July, 77 days after planting.

Unusually high daytime temperatures affected late season terminal plant growth and retention of fruiting forms. By cutout, treatment effects from insect feeding on squares were confounded with physiological square shed. Late season retention was similar across treatments and did not provide a good indication of insect activity (data not shown). By the time of the last manual infestation (cutout +600 DD60s), there were open bolls; plant terminal growth had ceased and few squares were available for bugs.

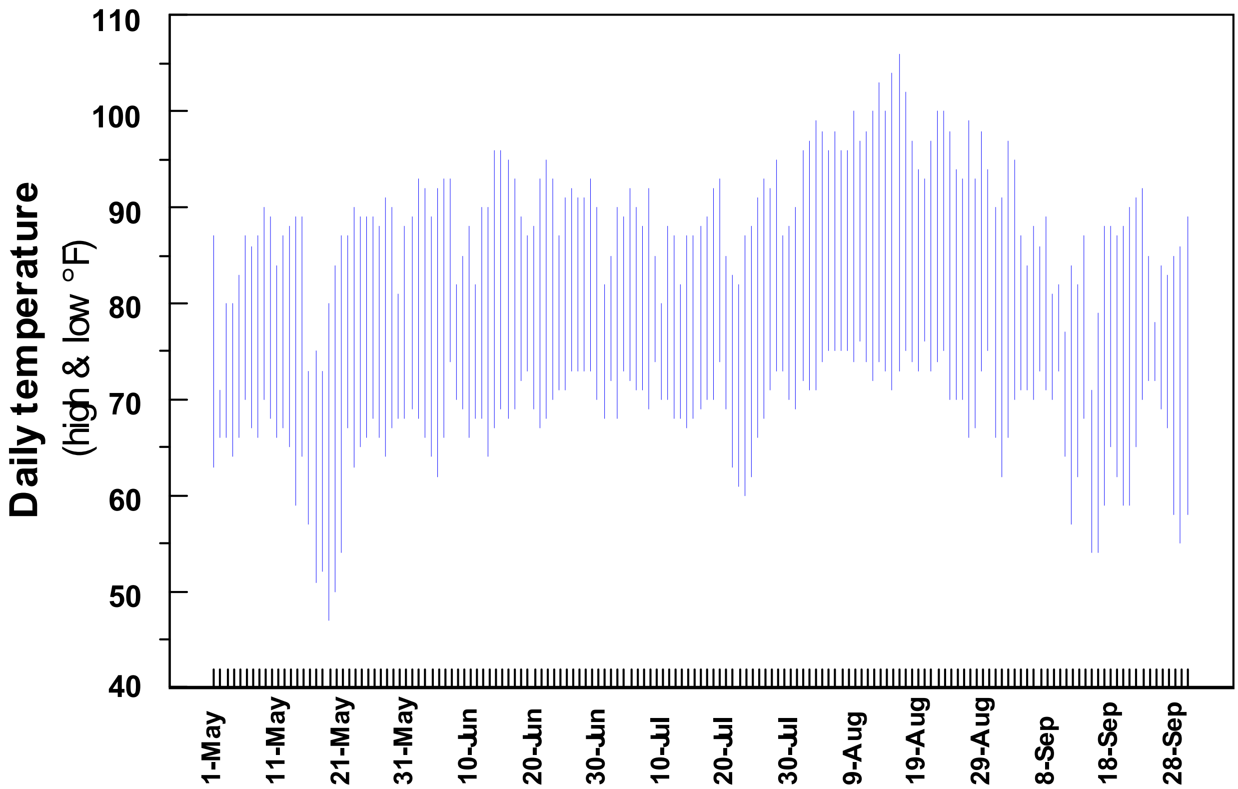

Figure 1. Daily high and low temperatures recorded at the Judd Hill Research Farm from May through September 2007.

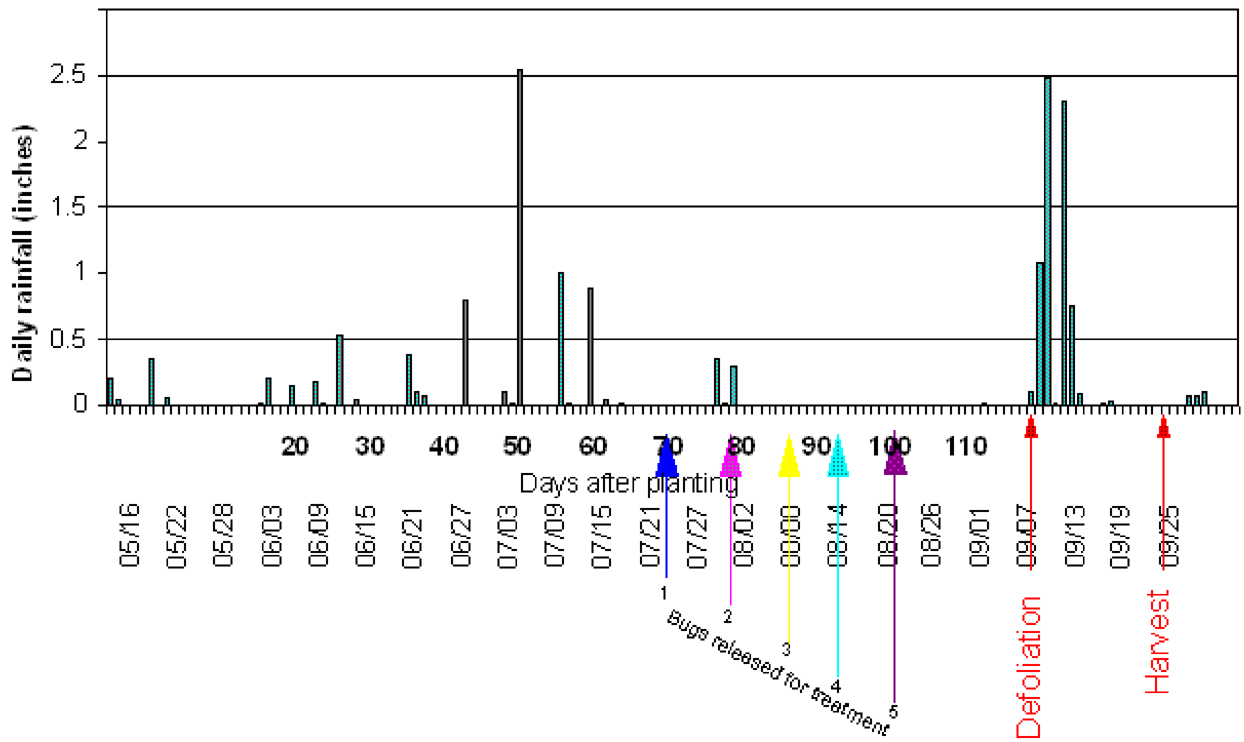

Figure 2. Rainfall and irrigation schedule for 2007 control termination trial. Timing for bug releases is indicated with colored arrows below the x-axis.

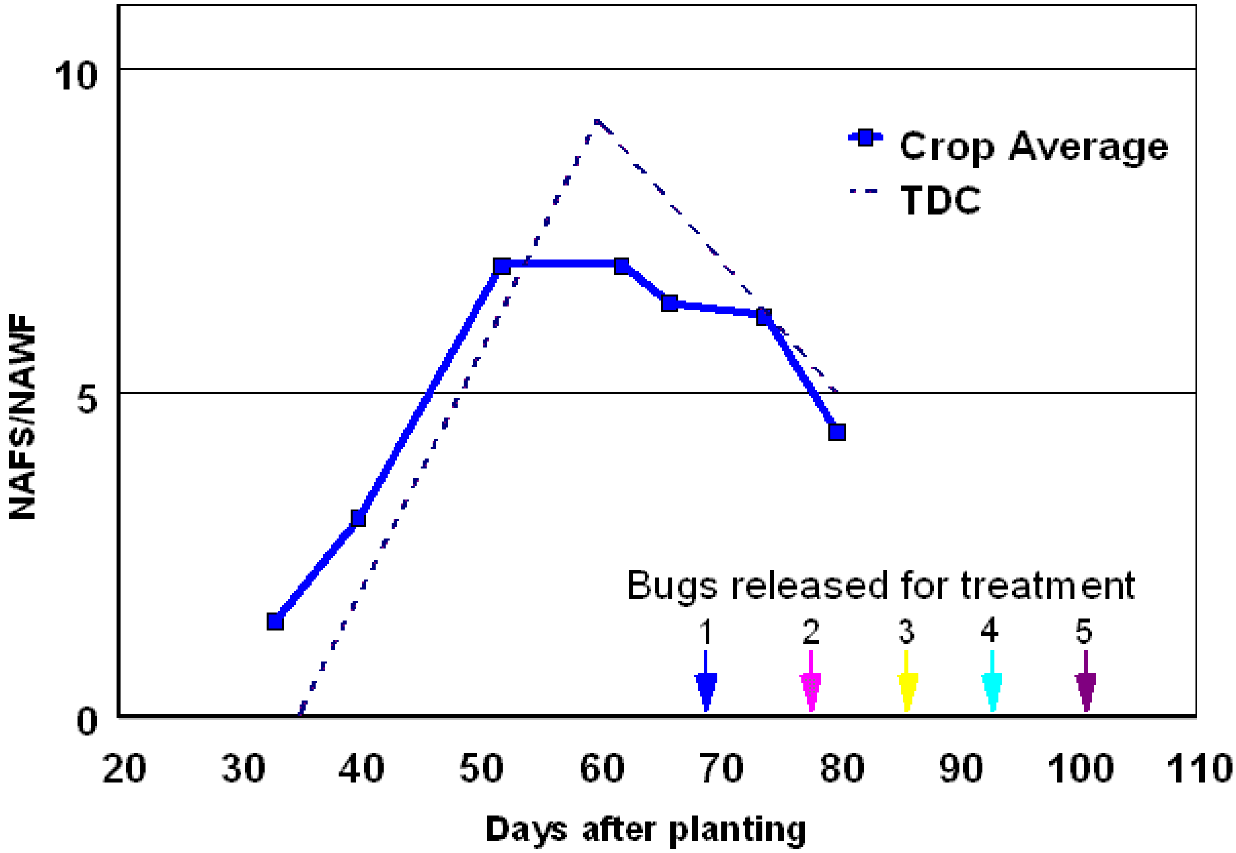

Figure 3. COTMAN growth curves for 2007 plant bug termination trial depicting mean number of main stem squaring nodes (Nodes above first square/Nodes above white flower) observed for the study field compared to the COTMAN standard curve. Growth curves and cutout dates were similar across the treatments; mean values for all treatments are shown. The crop reached physiological cutout (NAWF=5) on 27 July, 77 days after planting. Plant bug nymphs were released over 5 different dates shown on the x-axis.

Plant bug survival: The natural field population of plant bugs was at low density season long, providing an ideal setting for manual infestations. In the plant bug samples taken after each release date, high bug numbers were observed in that treatment plot with numbers in non-release plots remaining at low levels (Fig 4). As many as 30 bugs per ft were observed in drop cloth samples taken 24 hrs after initial release. Survival of manually infested bugs was greatest in the first infestation period; nymph densities were sustained at higher levels and for a longer period of time in that pre-cutout treatment, compared to subsequent timings (Fig 4). Plant terminals, squares and small bolls at this point in the season likely provided better food than post-cutout plants. Plant bug mortality likely was associated with abiotic factors (high temperatures and low humidity). Natural enemies, including spiders and ants, were observed feeding on nymphs; natural biological control likely contributed to rapid decline of nymphs. As nymphs completed development, movement of adults from infested plots to adjacent plots was not apparent in sample data. Sprayed and unsprayed checks each had comparability low numbers of plant bugs through the season.

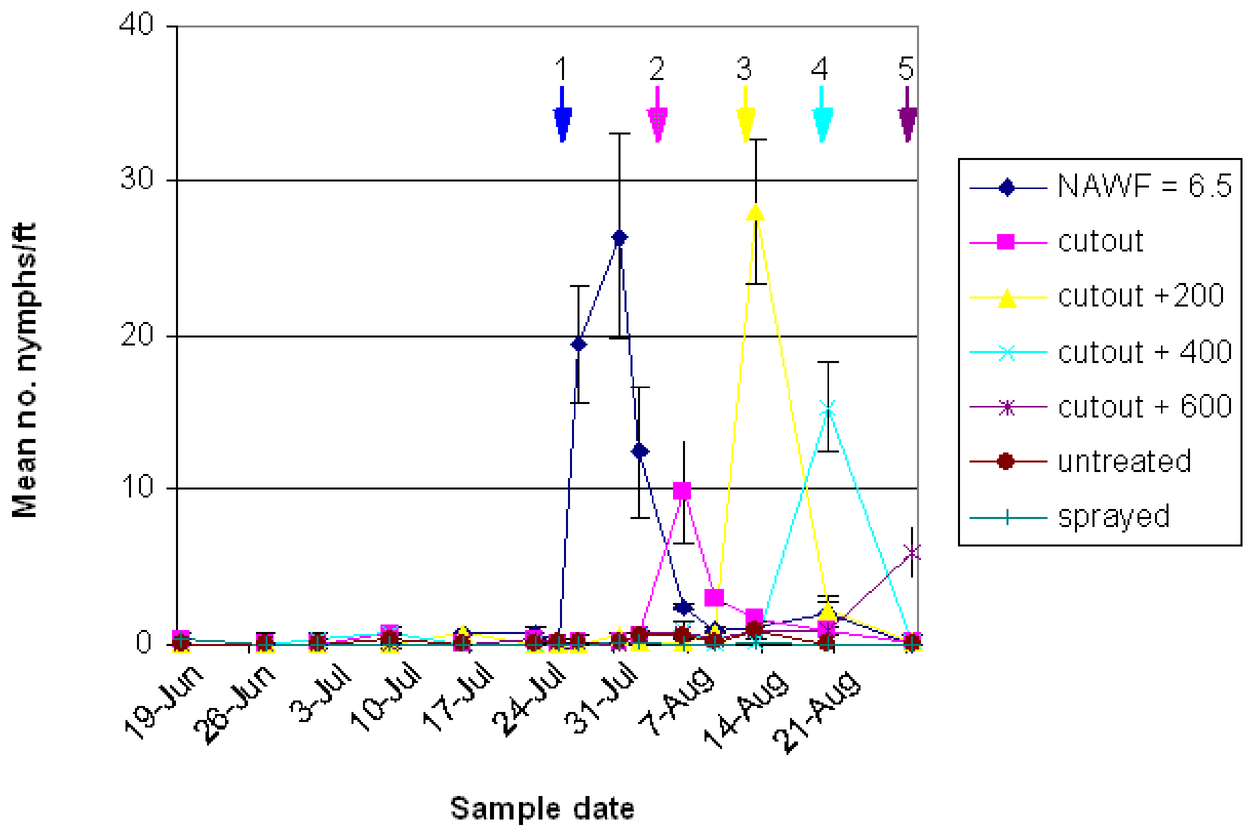

Figure 4. Mean number of plant bugs observed per ft of row, season-long, in plant bug termination trial. Timing of manual infestations for each treatment are indicated by arrows at the top of the chart.

Damage assessments: Insect feeding following manual infestations was evident in boll and white flower injury assessments (Figs 5, 6). External boll injury for large bolls appeared to overestimate damage compared to internal boll damage. Small boll damage and white flower anther injury reflected insect feeding activity after manual infestations. End-of-season plant mapping results indicate significant differences in early boll retention, total nodes and height between the pre-cutout infested treatment and other plant bug treatments (Table 3).

Yield: No differences in yield were observed among treatments in 2007 (Fig 7). No differences in fiber quality or yield components associated with plant bug treatments were observed with the exception of fiber strength *(p*=0.04; LSD_{05}=0.1) (Table 4).

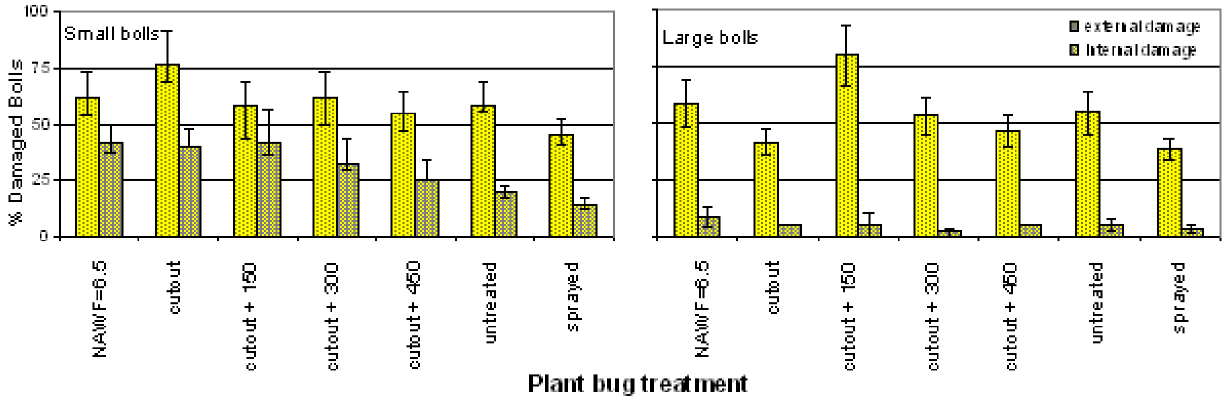

Figure 5. Significant differences in external symptoms of boll damage (p=0.05) were observed among treatments on 21 Aug small (LSD_{05}=17.3) and large ((LSD_{05}=24.7)) boll damage survey. No differences were observed among treatments for internal injury for either small (p=0.43) or large bolls (p=0.80). Twenty large and twenty small bolls were inspected in each plot. Damage ratings were converted to % damage, and mean percent damage (±SEM) are shown.

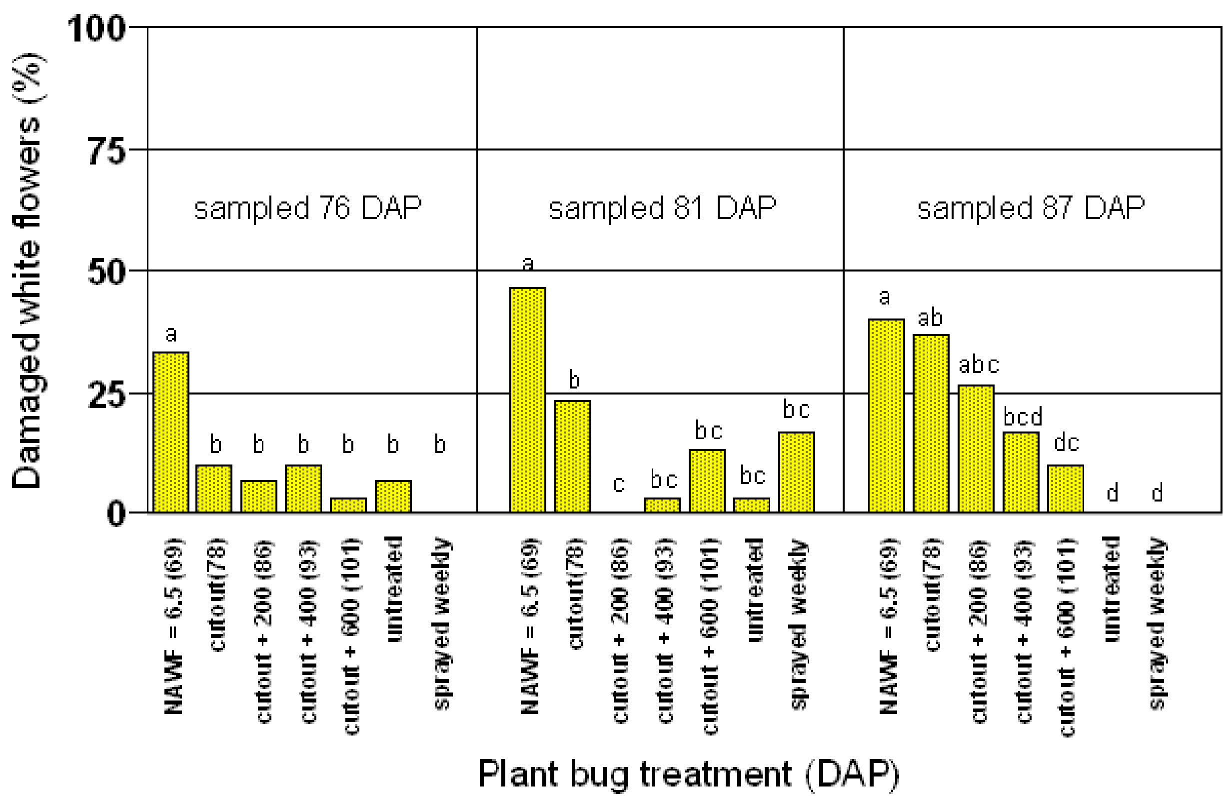

Figure 6 White flowers observed with anther injury symptoms on the 76 DAP sample (26 July), 81 DAP (31 July) and 86 DAP (8 Aug) samples. Ten flowers were inspected per plot and rated as undamaged or damaged. After 86 DAP insufficient numbers of flowers were available to continue sampling. Significant differences among treatments were observed on each date; treatments with the same letter did not differ.

Table 3. Results from final end-of-season plant mapping following defoliation using COTMAP for plant bug infestation timing in relation to physiological cutout (NAWF=5)[1].

Category	Mean per plant for each plant bug infestation timing treatment								
	NAWF=6.5	cutout	cutout + 200	cutout + 400	cutout + 600	untreated	sprayed	*P>F*	*LSD_{05}*
1st Sympodial Node	5.4	5.5	5.4	5.4	5.6	5.3	5.6	*0.60*	*0.50*
No. of Monopodia	1.4	1.8	1.3	1.2	1.5	1.6	1.8	*0.45*	*0.69*
Highest Sympodia with 2 nodes	12.6	11.2	11.6	11.2	11.0	11.9	10.8	*0.03*	*1.00*
Plant Height (inches)	49.3	46.0	46.0	45.3	45.9	46.6	42.4	*0.06*	*2.66*
No. of Effective Sympodia	9.3	7.6	7.8	7.8	7.4	8.1	7.8	*0.11*	*1.27*
No. of Sympodia	14.6	13.3	13.5	13.2	13.1	13.9	12.8	*0.01*	*0.91*
No. of Sympodia with 1st Position Bolls	4.5	4.0	3.7	4.2	4.3	4.7	4.6	*0.16*	*0.81*
No. of Sympodia with 2nd Position Bolls	1.0	0.8	0.7	0.7	0.7	1.0	0.9	*0.77*	*0.59*
No. of Sympodia with 1st & 2nd Bolls	1.5	2.0	2.6	2.0	1.9	1.6	1.4	*0.12*	*0.83*
Total Bolls/Plant	9.1	9.3	9.9	9.2	9.2	9.0	8.7	*0.91*	*1.98*
% Total Bolls in 1st Position	67.0	64.6	63.2	67.3	68.4	69.8	69.6	*0.58*	*8.47*
% Total Bolls in 2nd Position	26.4	30.1	33.0	29.1	28.2	28.3	26.3	*0.29*	*6.02*
% Total Bolls in Outer Position	5.3	0.7	1.8	1.4	1.4	1.5	0.4	*0.03*	*2.70*
% Total Bolls on Monopodia	0.9	4.6	2.0	2.2	2.1	0.4	3.3	*0.74*	*5.72*
% Total Bolls on Extra – Axillary	0.4	0.0	0.0	0.0	0.0	0.0	0.4	*0.61*	*0.61*
% Boll Retention - 1st Position	41.2	45.2	46.4	46.7	47.8	44.9	47.4	*0.61*	*7.87*
% Boll Retention - 2nd Position	19.4	24.9	28.2	23.8	23.7	21.6	21.3	*0.33*	*7.74*
% Early Boll Retention	47.3	61.7	66.0	60.0	63.7	59.7	57.7	*0.01*	*8.53*
Total Nodes/Plant	18.8	18.1	17.9	17.6	17.9	18.2	17.4	*0.05*	*0.83*
Internode Length (inches)	2.6	2.5	2.6	2.6	2.6	2.6	2.4	*0.21*	*0.13*

[1] means of 10 plants per plot

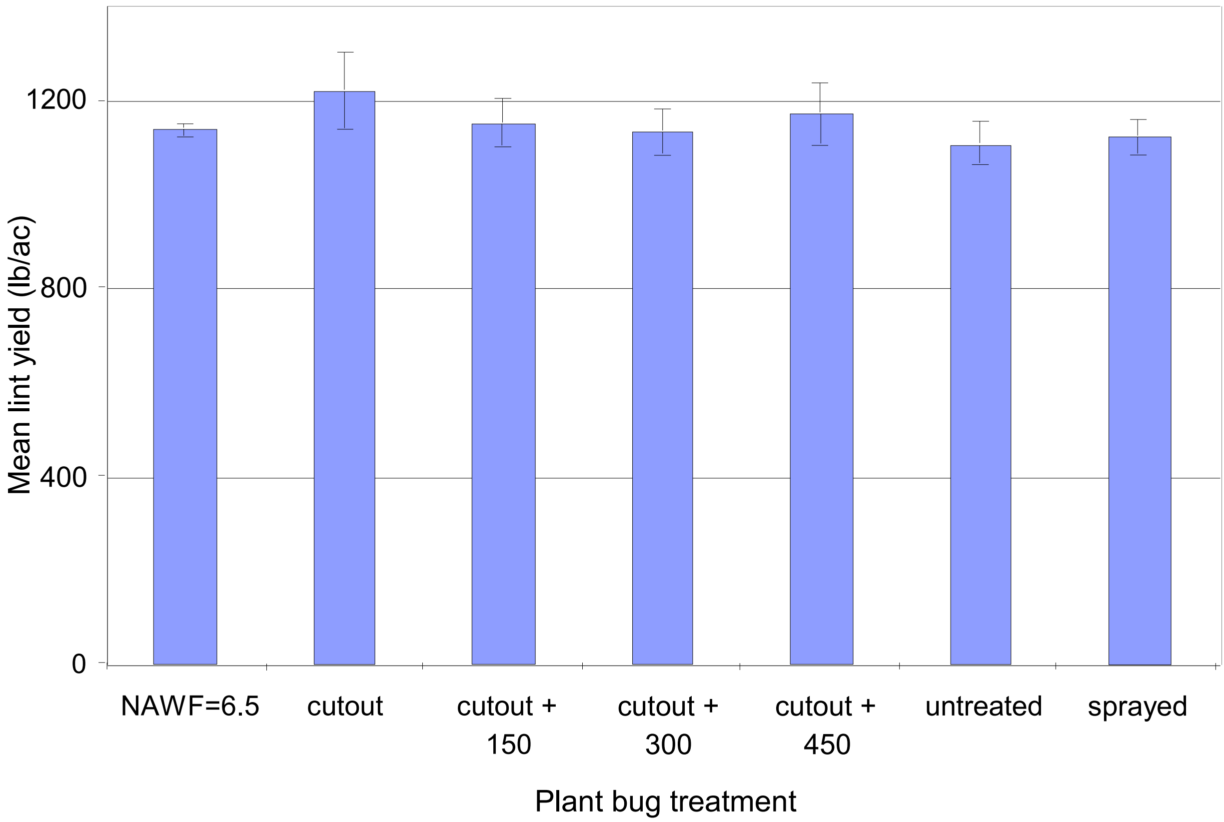

Figure 7. Mean lint yield for plant bug infestation treatments; no significant treatment effects were observed (*P*=0.60).

Table 4. Means for HVI classing data and yield component information for 50 boll samples collected in hand-harvested plots throughout consecutive plants for tarnished plant bug infestation trial, Judd Hill 2007[1].

Plant bug treatment	Lint %	Boll weight	Micronaire	Length	Uniformity	Strength	Elongation	Leaf	Fibers per seed	Fiber density
NAWF=6.5	42.43	4.78	3.63	1.16	84.97	29.90	4.60	2.33	20292	34.72
cutout	42.81	4.90	3.70	1.15	83.73	29.57	4.60	1.00	20222	35.89
cutout + 200	42.33	4.77	3.80	1.14	82.60	29.03	4.20	2.33	19679	35.12
cutout + 400	43.00	4.92	3.60	1.14	83.20	29.30	4.33	1.67	21334	37.30
cutout + 600	42.46	4.47	3.33	1.15	83.40	30.60	4.90	2.33	21308	39.30
untreated	42.66	4.54	3.27	1.14	83.13	29.20	4.40	1.00	21590	40.86
sprayed	43.45	4.74	3.83	1.15	84.17	30.37	4.30	2.33	19604	35.49
P>F	*0.79*	*0.54*	*0.08*	*0.86*	*0.49*	*0. 04*	*0.44*	*0.14*	*0.58*	*0.26*

1 Determinations made at International Textile Center, Texas Tech University, Lubbock.

Discussion

Plant bugs were sufficient in number to cause visible boll and flower injury. Despite differences in numbers of insects and differences in boll and flower injury, NO differences in yield were observed among treatments in 2007. Fruiting forms damaged by plant bug feeding did not make significant contributions to economic yield. Similar findings were observed in manual infestation trials in Mississippi County in 2001, 2002, and 2005 when infestations were made after cutout. Infestations made at cutout in 2004 in high yielding cotton significantly reduced yields. In the 2004 study, drip irrigated cotton produced over 1500 lbs lint/acre, and upper canopy bolls including outer bolls significantly contributed to that high yield. Plant bug infestation at cutout damaged the population of last effective bolls, and that damage resulted in a significant yield penalty. Similar yield losses would likely have occurred in 2007 if the crop capacity had been the higher range for this study site.

Plant bugs used in this study were from a laboratory colony and were reared on artificial diet. Numbers of lab bugs per sample and feeding damage from those bugs should not be compared with numbers of a naturally occurring population of bugs. Never-the-less, the lab bugs were at extremely high numbers, and their feeding activity resulted in obvious plant injury. In plant bug control termination trials conducted with natural populations further south in Marianna, termination timing before cutout significantly reduced yields in 2 of 3 years during 2004 through 2006 (Teague et al. 2005, 2006, Monge et al 2007). In years with season-long plant bug pressure, 2004 and 2006, yields were significantly decreased if tarnished plant bug control was terminated before NAWF = 5+240 DD60s. Continuing control beyond 280 DD60s did not significantly increase yields. Lower numbers of plant bugs were observed in 2005 however, numbers in late season were above current economic thresholds. No yield reduction was associated with insect damage from those infestations.

These data plus our previous results from 2000-2007, indicate reduced susceptibility to plant bug in cotton around the time of physiological cutout. We suggest that decision makers consider earlier termination timing for plant bug in cotton. Termination at NAWF=5+250 DD60s appears to be adequate in fields of uniform maturity particularly in production areas with low levels of early season plant bug pest pressure. The COTMAN 350 guide should be followed in fields with variable cutout dates (> 1 week difference across vigor classifications in a large highly variable field). This is a very conservative recommendation and is sufficient for late season plant bug management.

Acknowledgements

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