2004 BELTWIDE COTTON CONFERENCES, SAN ANTONIO, TX – JANUARY 5-9

CONSEQUENCES OF SQUARE SHED FOLLOWING PRE-FLOWER INFESTATIONS OF TARNISHED PLANT BUG (*LYGUS LINNEOLARIS* PALISOT DE BEAUVOIS) IN ARKANSAS COTTON

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Abstract

Cotton crop response to varying levels of square loss resulting from tarnished plant bug (TPB) feeding was assessed using standardized COTMAN procedures in a 2-year study conducted in northeast Arkansas. Natural populations of plant bug were augmented with laboratory reared TPB nymphs. Each treatment received different numbers of TPB nymphs over the first 3 weeks of squaring or was untreated or was sprayed with insecticides. Plant bug feeding resulted in as much as 50% shed of 1st position squares by the time of 1st flowers compared to less than 6% shed in protected treatments. Highest levels of shed resulted in significant yield loss; however, square shed levels of 25% were found not to reduce final yield. No differences in numbers of pre-flower sympodia were noted in response to TPB feeding; however, terminal growth after first flowers, as reflected in NAWF measures, was higher where pre-flower shed rates were high, resulting in a delay of physiological cutout and crop maturity. Results from this and other past studies indicate that high yields do not require complete annihilation of all pest insects, and that low to moderate levels of square shed pre-flower are easily tolerated.

Introduction

Midsouth cotton producers sometimes apply insecticides against low population densities of tarnished plant bugs (TPB) and other mirids in order to maintain a near perfect square set in preflowering cotton. Such applications likely are unneeded, but decision-makers lack the confidence not to spray during this vulnerable time in the season. Growers and their crop advisors need updated decision guides for managing square retention prior to first flowers, and they need evidence – real time data – that their crop is doing well, even without protective sprays.

Research efforts in Arkansas have been focused on refinement of plant based decision guides for incorporation into the COTMAN™ crop monitoring system (Danforth and O'Leary 1998). We are working to refine existing plant based economic injury levels that could allow incorporation of new plant based action levels into the system. In earlier research conducted in Marianna, AR, Holman (1996), showed that TPB infestations 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 that sustained 19% square shed. Yields actually were numerically higher for treatments at the 19% square shed rate compared to treatments with lower shed rates. One day of delay was associated with each 4% shed of first position squares.

Similar levels of crop delay, measured as days to physiological cutout (number of days from planting until mean NAWF = 5), were observed in 2001 and 2000 TPB trials by Teague et al. (2001, 2002). In the 2000 study, in a normal date of planting, a 12 day delay was associated with 40 to 41% first position square shed. In the 2001 trial, physiological cutout was delayed by 8 days in treatments where pre-flower first position square shed rates from TPB injury ranged from 34 to 38%. In both years, the crop compensated for most early season square loss. Additional studies were needed to evaluate crop response to an array of square loss, to validate earlier research and to update decision guides. We conducted field studies in 2002 and 2003 with two objectives: 1) to compare crop response to varying levels of square loss resulting from plant bug feeding and 2) to assess plant responses with standardized COTMAN procedures.

Materials and Methods

The experiment was conducted at Wildy Farms, a commercial farm located in Northeast Arkansas near Leachville. The cultivar Stoneville 4892 was seeded on 29 April 2002 and 27 May 2003. The soil was a Routon-Dundee-Crevasse Complex (sand). Plots were 6 rows wide, 30 ft long. Plant population density was ca. 3 plants/ft of row. Two sections of row, each 15 ft long, were selected in the center of each plot for plant bug treatments. Plots were irrigated daily (as needed) using subsurface drip irrigation (1 drip line per bed). Standard grower practices for fertility, weed control, plant growth regulator application and defoliation were followed through the season; only insecticide inputs were varied for the experiment.

Different levels of pre-flower square loss were achieved by augmenting natural populations of plant bug with laboratory reared nymphs released three times at weekly intervals during the 1st three weeks of squaring. There were 5 treatments: 1) 1 bug/ft of row, 2) 3 bugs/ft, 3) 9 bugs/ft, 4) 0 bugs (natural population) and 5) 0 bugs and sprayed with insecticide. Bugs were released at weekly intervals during the first 3 weeks of squaring. Insecticide was applied in the sprayed treatment on comparable dates using a backpack sprayer and 4 row boom. Release dates in 2002 were 14, 21 and 29 June (46, 53 and 61 days after planting). Trimax (imidacloprid 0.047 lb ai/ac) was applied in sprayed plots on 11, 19, 26 June and 2 July. In 2003, bugs were released on 2, 9 and 16 July (36, 43 and 50 days after planting). Centric (thiamethoxam 0.047 lb ai/ac) was applied in sprayed plots on 25 June, 2, 11, July and imidacloprid (0.047 lb ai/ac) was applied 17 July. In both years, blanket applications of imidacloprid insecticide were made across the field at the time of first flowers (one week after the final bug release) to terminate insect feeding in all treatments. Imidacloprid also was applied through the drip irrigation system (Provado 8oz/ac) weekly from that point on until cutout.

All TPB nymphs in 2002 were obtained from a colony maintained on artificial diet (Cohen 2000) at the USDA-ARS Biological Control and Mass Rearing Research Unit at Mississippi State, MS. In 2003, nymphs were obtained from eggs laid by TPB adults collected from wild plant hosts in NE Arkansas and held on artificial diet. Bug infestation procedures were standardized similar to the method outlined by Tugwell et al. (1976). For release, TPB nymphs (2nd and 3rd instar) were aspirated from rearing containers into 1.5 inch long sections of opaque tubing (Dayco One Fuel Line Hose 5/16" I.D). Tubes were placed at the base of each plant's main stem (Fig 1), and bugs were allowed to crawl out of the tube and up the plant. The bugs were transferred to the field at daybreak.

Plants were monitored in each plot from the early squaring period through cutout using the COTMAN™ crop monitoring system (Danforth and O'Leary 1998). In all sampling activities, plant mappers touched the plants as little as possible to minimize thigmonastic effects. Five consecutive plants in 2 treatment rows were monitored weekly. Sampling included measurement of plant height, number of squaring nodes, and presence or absence of first position squares. Square shed data were divided into 2 categories of square size: total and small. Total squares were all first position squares. Small squares were 1st position squares located in the top 3 sympodial nodes. After first flowers, nodes above white flower (NAWF) also were monitored. Prior to 1st flowers, square shed most likely was due to insect injury. After the onset of flowering, loss of squares and bolls likely was due to a combination of factors including physiological stresses and residual insect related injury. Because of this range of stresses, descriptions of post-flower crop fruiting dynamics were categorized in terms of % retention rather than % shed.

Final plant mapping was performed following defoliation using COTMAP (Bourland and Watson 1990). Ten plants in one row per 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 and number 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 over 4 dates in 2002 (23 Sep, 2, 14 and 21 Oct) and 2003 (1, 20, 27 Oct and 3 Nov). Harvest aid chemicals for defoliation and boll opening were applied 1 Oct in 2002 and 15 Oct in 2003. Mean maturity date was calculated from yield measurements (Bourland et al 2000). All crop monitoring and yield data were analyzed using AOV with mean separation using LSD.

Results

2002 Season

Spring conditions were not conducive to early crop development in the 2002 study. Crop delay was quite apparent in COTMAN growth curves that show that 1st squares appeared nearly 10 days later than the target date, 35 days after planting (Fig 2). Native plant bug population densities were low, and 1st position square shed recorded in the first COTMAN sample at 45 days after planting (DAP) was less than 2% in all treatments (Table 1a). Following release of bugs at 46, 53 and 61 DAP, square retention began to decrease in plants infested with nymphs compared to untreated and sprayed plants. Significant treatment differences in total percent 1st position square shed among treatments were observed at 57 DAP and on every subsequent sample date. Following the 61 DAP plant bug release, total square shed averaged 44% in plots receiving 9 bugs/ft compared to 6% for the sprayed check and 11.8 % for untreated check. Plant bugs will feed on tiny squares in the plant terminal (Tugwell et al 1976), but high levels of small square shed were noted only in the 9 bug/ft treatment (Table 1a).

A reduction in mean number of sympodia per plant was observed in 9 bug/ft treatment compared to other treatments prior to flowers (Table 2a). A reduction in numbers of pre-flower sympodia have not been noted in our previous TPB studies (Teague et al. 2000, 2001), and may be related to terminal injury from bug feeding. Coy et al. (2002) reported reduced sympodial growth rates in response to TPB induced terminal injury in pre-squaring cotton.

Retention of fruiting forms after first flowers at 70 DAP was significantly higher in sprayed and natural treatments (96%) compared to where bugs had been released (from 50 to 79 %) (Table 4). By 85 DAP, however, shed of small bolls and squares increased in the natural and sprayed treatments resulting in retention rates comparable to that of 1bug/ft treatment. No insects were associated with these late season physiological sheds.

Sympodial development is depicted in COTMAN growth curves as squaring nodes plotted as nodes above 1st square (NAFS) and nodes above white flower (NAWF) (Fig. 2). No significant differences in mean days to cutout were observed in 2002 (Table 3). There was an extended period of cloudy weather during the first 2 weeks of flowering which may have affected fruiting dynamics – slope of NAWF curves show some lag in declining about 2 weeks after flowering when compared to the COTMAN target curve (Fig. 2).

Late season weather was conducive to crop development. From cutout until defoliation, heat unit accumulation ranged from 941 to 1114 DD60s for all treatments (Table 3). Mean maturity date did not differ among the 5 treatments and ranged from 154 to 158 days.

The only significant difference between treatments detected in final plant mapping was in percent early boll retention, defined as 1st plus 2nd position bolls on the five lowest sympodia. Early boll retention was significantly higher in the sprayed plants compared to plants that were unprotected or that had been infested with plant bugs. (Table 5a).

Plant bug feeding in the 9 bug/ft treatment significantly reduced yields compared to other treatments (Table 6a). In the early harvests, the sprayed treatment had highest yields, but by the final harvest, highest yields were associated with the unprotected check. Yield from the sprayed treatment was no different than that produced in plants that had been exposed to 1 and 3 bugs/ft.

2003 Season

Wet, cold weather reduced stand of the original April planting and forced replanting the experiment on May 27 – a very late date of planting for Northeast Arkansas. COTMAN growth curves show that 1st squares appeared for all treatments prior to the target date of 35 days after planting (Fig 3). Native plant bug population densities were low, and 1st position square shed recorded in the first COTMAN sample at 35 DAP was less than 4% in all treatments (Table 1b). Following release of bugs at 36, 43 and 50 DAP, square retention began to decrease in plants infested with nymphs compared to untreated and sprayed plants. Significant treatment differences in total percent 1st position square shed were observed at every post-infestation sample date up to 1st flowers. Total 1st position square shed after three weeks of plant bug releases averaged 53% in plots receiving 9 bugs/ft compared to 0.3% for the sprayed check and 1 % for untreated check. Small square shed rates of 10% or more were noted only in the treatments where TPB were released (Table 1b).

Retention of fruiting forms after first flowers at 69 DAP was significantly higher in sprayed and natural treatments (>90%) compared to where bugs had been released (from 53 to 86 %) (Table 4). By 83 DAP, physiological shed of small bolls and squares resulted in reduced retention in all treatments except for the 9 bug/ft treatment where retention rates actually increased. As in 2002, no insects appeared to be responsible for the late season square and boll sheds.

No differences in mean number of sympodia per plant were observed among treatments through first flowers (Table 2b), but COTMAN growth curves (Fig 3) show that decline in NAWF values was delayed where shed rates were highest (3 and 9 bugs/ft). Where 9 bugs/ft were released for 3 weeks and the resulting square shed rates exceeded 50%, plants failed to reach physiological cutout by 1 Sept. Plants exposed to 3 bugs/ft for 3 weeks, where mean square shed at first flowers was 26%, reached cutout 12 days later than plants protected with insecticide sprays. Values for mean maturity dates also indicated significant crop delays for plants with high square shed rates (Table 3). Mean maturity dates ranged from 148 to 155 days. Heat unit accumulation after cutout was limited in 2003 because of the late date of planting and cool September temperatures. Because of insect induced crop delay, the last effective boll populations of 3 and 9 bugs/ft treatments received fewer than 400 DD60s from anthesis until application of defoliant on 15 Oct.

Results from final plant mapping indicated that no. of effective sympodia, no. of sympodia with 2nd position bolls, % bolls in outer positions, % early boll retention, % bolls on extra axillary position and % early boll retention were all significantly affected by plant bug induced square shed. No. of effective sympodia was significantly higher for plants in the 9 bugs/ft treatment where square shed rates at first flowers exceeded 50%.

Overall yields in 2003 were surprisingly high considering the late date of planting (Table 6b). Lowest lint production was associated with the 9 bug/ft treatment; however, compensation from early damage was apparent in that treatment by the final harvest. As was the case in 2002, yield from the sprayed treatment was no different than that produced in plants that had been exposed to 1 and 3 bugs/ft. Highest yield was associated with the untreated control. HVI measures have not yet been made to examine fiber quality differences among treatments.

Discussion

In studies conducted in both 2002 and 2003, augmenting natural field populations of plant bug with lab reared nymphs allowed us to examine crop response to an array of square injury and loss resulting from plant bug feeding. First position square shed levels after 3 weeks of infestation ranged from a high of 44 and 53% to lows of 6 and 0.3%. Using standardized COTMAN procedures, we were able to document changes in square shed in a systematic manner through the season and determine the effects of preflower square shed on crop delay and yield.

In the 2002 experiment, plant injury by bugs delayed crop maturity compared to protected plants, but trends were not comparable to Holman's (1996) observations of 1 day delay for every 4% shed. We do not know why. Perhaps the excessively cloudy weather that occurred during the 1st two weeks of flowering or the influence of other environmental factors affected crop response. Plant bug induced injury did result in significant crop delay in 2003. One penalty for crop delay in northern cotton productions regions is limited heat unit production if there are cool fall temperatures. Seasonal cutout dates for NE Arkansas are 31 July (85% probability of attaining 850 DD60s from that date forward in the season based on local historical weather records) and 8 Aug (50% probability of attaining 850 DD60s). Plants in 2003 treatment plots all reached NAWF=5 after those dates. Heat unit accumulation in 2003 at the Leachville site from the latest possible cutout dates of 31 July and 8 Aug until defoliation on 15 Oct were 898 and 778 DD60s, respectively. The last effective boll populations of the 3 and 9 bug/ft treatments in 2003 received fewer than 400 DD60s before application of defoliants. COTMAN decision guides suggest that the last effective boll population should receive 850 DD60s in the period from anthesis to defoliation to ensure quality fiber production (Danforth and O'Leary 1998).

In both years of this experiment, plants with lowest square retention at 1st flower produced lowest yield, but plants with highest retention at first flower did not necessarily produce highest yields. The connection between square retention and subsequent boll retention and boll loading involves complex nutritional and hormonal influences and is poorly understood (reviewed by Sadras 1995). It is known that if retention is high when first flowers appear, the cotton plant's natural feed-back mechanisms can cause small bolls and tiny squares to shed during boll filling (Mauney 1979, Guinn 1979, Hearn and Room 1979 and others). Preflower square shed resulting from plant bug feeding will lead to modification of the boll load sink and boll loading stress after first flowers, affecting both final boll retention and boll filling. Results from our work and many other past studies indicate that high yields do not require 100% retention of squares (Montez and Goodell 1994, Ungar et al. 1987, Lentz 1990, Herbert and Abaye 1999, Brook et al 1992, Mann et al 1997, Doederlein et al 2003). Our research results in Northeast Arkansas and in Central Eastern Arkansas validate earlier work by Holman (1996) who found that plants can tolerate shed rates as high as 19% without suffering yield reductions. Regression of shed rates and yield from the current experiment show similar trends (Fig 4).

Pre-flower plant monitoring using COTMAN allows decision-makers to monitor and document shed rates in a systematic and repeatable manner. Determining presence or absence and relative abundance of plant bugs in the field is a challenging and difficult sampling chore. By adding systematically collected, crop monitoring information to the decision-making process, crop advisors and growers will be more confident in deciding whether to spray or not to spray costly insecticides. If Midsouth cotton producers are to reap the full benefit of boll weevil eradication and the availability of caterpillar resistant transgenic varieties, unnecessary and uneconomical insecticide applications must be eliminated.

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Acknowledgements

This project was funded in part through Cotton Incorporated Core Funds and the Arkansas State Support Committee. Special thanks to David Wildy, Justin Wildy, Dale Wells and the staff at Wildy Farms along with Joe Stewart, USDA-ARS for their support and assistance.

Table 1a. Total and small square shed (% of first position floral buds) as influenced by treatments (2002)[1].

Square Size[2]	Time of infestation (DAP)[3]	Sample time (DAP)	Mean no. shed squares (%) in each treatment: 9 Bugs[4]	3 Bugs[4]	1 Bug[4]	Natural	Sprayed[5]	*Pr>F*	*LSD₀₅*
Total		45	0.9	1.7	0.9	2.0	0.0	*0.32*	
	46	50	4.9	5.2	3.9	1.8	0.6	*0.12*	
	53	57	39.4	34.7	8.2	4.2	5.0	*0.001*	*10.33*
	61	63	51.4	37.9	24.2	7.3	4.4	*0.001*	*12.48*
		65	44.0	28.4	16.0	11.8	6.0	*0.001*	*14.97*
Small		45	0.0	0.0	0.0	4.0	0.0	*0.35*	
	46	50	3.4	0.0	0.0	0.0	3.3	*0.79*	
	53	57	26.7	10.0	0.0	0.0	0.0	*0.05*	*8.5*
	61	63	33.3	0.0	0.0	0.0	0.0	*0.003*	*9.2*
		65	20.0	6.7	0.0	0.0	0.0	*0.008*	*7.0*

[1]Square shed percentages were determined from 10 plants/plot using standard COTMAN Squaremap procedures.
[2]Small squares were 1st position squares in the top 3 sympodia; total squares were all 1st position squares.
[3]Days after planting (DAP).
[4]No. of nymphs, 2nd to 3rd instar, released per plant per application. Bugs were released 3 times at weekly intervals during the first 3 weeks of squaring on 14, 21 and 29 June (46, 53 and 61 days after planting).
[5]Imidacloprid (0.047 lb ai/ac) was applied on 11, 19, 26 June and 2 July.

Table 1b. Total and small square shed (% of first position floral buds) as influenced by treatments (2003)[1].

Square Size[2]	Time of infestation (DAP)[3]	Sample time (DAP)	Mean no. shed squares (%) in each treatment: 9 Bugs[4]	3 Bugs[4]	1 Bug[4]	Natural	Sprayed[5]	*Pr>F*	*LSD₀₅*
Total		35	2.4	1.6	2.4	3.1	3.9	*0.55*	
	36	41	33.9	12.4	3.6	4.7	3.6	*0.001*	*7.78*
	43	48	40.8	17.8	6.4	1.8	0.7	*0.001*	*8.24*
	50	55	55.1	23.5	8.7	0.4	0.3	*0.001*	*11.5*
		62	53.2	26.4	10.8	1.0	0.3	*0.001*	*11.14*
Small		36	1.7	0.0	1.7	3.3	2.5	*0.28*	
	36	41	24.2	7.5	2.6	3.3	1.7	*0.001*	*6.75*
	43	48	27.5	12.7	2.5	0.0	0.0	*0.0003*	*10.2*
	50	55	38.3	17.5	5.8	0.0	0.0	*0.0001*	*12.1*
		62	30.0	15.0	10.0	0.8	0.0	*0.01*	*16.37*

[1]Square shed percentages were determined from 10 plants/plot using standard COTMAN Squaremap procedures.
[2]Small squares were 1st position squares in the top 3 sympodia; total squares were all 1st position squares.
[3]Days after planting (DAP).
[4]No. of nymphs, 2nd to 3rd instar, released per plant per application. Bugs were released 3 times at weekly intervals during the first 3 weeks of squaring on 2, 9 and 16 July (36, 43 and 50 days after planting).
[5] Thiamethoxam (0.047 lb ai/ac) applied 25 June, 2, 11, July and imidacloprid (0.047 lb ai/ac) applied 17 July.

Table 2a. Mean number of sympodia per plant as influenced by treatment (2002). [1]

Sample Date (DAP)[2]	Mean no. sympodia for each treatment: 9 Bugs[4]	3 Bugs[4]	1 Bug[4]	Natural	Sprayed[5]	*Pr>F*	*LSD₀₅*
13 June (45)	2.6	2.8	2.5	2.7	2.4	*0.38*	
18 June (50)	3.6	3.9	3.7	4.2	4.2	*0.05*	*0.48*
25 June (57)	5.9	6.1	5.9	6.2	6.6	*0.19*	
01 July (63)	7.4	8.0	7.6	7.8	7.5	*0.63*	
03 July (65)	7.2	8.2	8.1	8.4	8.2	*0.01*	*0.61*
08 July (70)	9.0	9.4	9.1	9.4	9.6	*0.62*	
12 July (74)	9.7	9.9	10.3	10.4	10.3	*0.21*	
16 July (78)	9.7	10.8	10.2	11.0	10.7	*0.21*	
19 July (81)	11.1	11.8	11.9	11.6	11.7	*0.21*	
23 July (85)	12.4	12.1	11.6	12.2	12.2	*0.22*	

[1]Sympodia were counted on 10 plants per plot using standard COTMAN Squaremap procedures.
[2]Days after planting (DAP).

Table 2b. Mean number of sympodia per plant as influenced by treatment (2003). [1]

Sample Date (DAP) [2]	Mean no. sympodia for each treatment: 9 Bugs[4]	3 Bugs[4]	1 Bug[4]	Natural	Sprayed[5]	*Pr>F*	*LSD_{05}*
07/02 (36)	2.5	2.5	2.5	2.5	2.7	*0.77*	
07/07 (41)	3.7	3.4	3.3	3.9	3.7	*0.25*	
07/14 (48)	4.5	4.3	4.7	4.7	4.5	*0.80*	
07/21 (55)	6.3	5.8	6.2	6.0	6.4	*0.74*	
07/28 (62)	7.9	7.7	7.6	7.8	7.3	*0.47*	
08/04 (69)	9.2	9.2	9.2	8.7	9.2	*0.73*	
08/11 (76)	10.4	10.7	10.5	10.1	10.0	*0.39*	
08/18 (83)	12.0	12.0	12.1	11.2	11.5	*0.23*	

[1]Sympodia were counted on 10 plants per plot (4 replications) using standard COTMAN Squaremap procedures.
[2]Days after planting (DAP).

Table 3. Effect of treatments on no. of days to physiological cutout, and mean no. of heat units (DD60s) accumulated from date of physiological cutout until application of defoliants for both 2002 and 2003 studies.

Year	Treatment	Mean date of physiological cutout1	Mean no. days to cutout	DD60s from cutout date to defoliation 2	Mean maturity Date (DAP)3
2002	9 Bugs	29 July	92	1047	2 Oct (157)
	3 Bugs	02 Aug	96	965	3 Oct (158)
	1 Bug	31 July	93	1029	1 Oct (156)
	Natural	04 Aug	97	941	2 Oct (157)
	Sprayed	27 July	89	1114	29 Sep (154)
2003	9 Bugs	----[4]	----	----	29 Oct (155)
	3 Bugs	30 Aug	95	341	27 Oct (153)
	1 Bug	20 Aug	85	548	24 Oct (151)
	Natural	13 Aug	78	704	22 Oct (148)
	Sprayed	18 Aug	83	595	24 Oct (151)

[1]Date at which treatments reached mean NAWF = 5.
[2]Defoliation occurred 1 Oct 2002 and 15 Oct 2003.
[3]Mean maturity dates were significantly different in 2003 (Pr>F = 0.002; LSD=2.2 days).
[4]Plants did not reach NAWF=5 by 1 Sept.

Table 4. Total retention of all fruiting forms (% of first position squares and bolls) as influenced by treatments for both 2002 and 2003[1] studies.

Year	Sample time (DAP)	Mean no. retained squares and bolls (%) in each treatment: 9 Bugs[2]	3 Bugs[2]	1 Bug[2]	Natural	Sprayed[3]	*Pr>F*	*LSD_{05}*
2002	70	50.8	69.2	79.6	95.9	96.2	*0.01*	*7.8*
	78	79.6	87.3	85.0	92.6	93.2	*0.006*	*10.2*
	85	64.9	76.7	86.8	86.3	87.1	*0.001*	*9.7*
2003	69	53.5	75.7	85.8	94.6	91.6	*0.0001*	*9.3*
	76	58.5	71.9	78.5	89.6	89.0	*0.0001*	*9.4*
	83	65.2	69.7	74.1	83.0	81.1	*0.02*	*11.1*

[1]Retention was determined from 10 plants per plot using COTMAN Squaremap procedures.
[2]No. of nymphs, 2nd to 3rd instar, released per plant per application. Bugs were released 3 times at weekly intervals during the first 3 weeks of squaring.
[3]Plants were sprayed with labeled rates of either imidacloprid or thiomethoxam (0.047 lb ai/ac) 4 times during the pre-flower squaring period; all plots received insecticide after 1st flowers.

Table 5a. Results from final end-of-season plant mapping following defoliation using COTMAP (2002)[1].

Category	Mean per plant for each treatment					Pr>F
	9 Bugs	3 Bugs	1 Bug	Natural	Sprayed	
1st Sympodial Node	5.9	5.6	5.8	5.6	5.9	0.27
No. Monopodia	1.1	1.1	1.4	0.9	0.9	0.29
Highest Sympodia with 2 nodes	13.8	14.3	13.9	12.7	14.3	0.57
Plant Height (inches)	38.3	38.0	38.1	36.9	35.4	0.12
No. Effective Sympodia	12.5	11.8	12.1	12.0	11.5	0.29
No. Sympodia	17.8	18.0	18.2	17.8	17.7	0.96
No. Sympodia with 1st Position Bolls	4.0	4.6	4.8	4.4	4.1	0.44
No. Sympodia with 2nd Position Bolls	1.5	1.4	1.2	1.7	1.5	0.65
No. Sympodia with 1st & 2nd Bolls	1.4	1.1	1.4	1.6	1.3	0.63
Total Bolls/Plant	11.1	11.1	12.1	12.0	10.4	0.41
% Total Bolls in 1st Position	49.1	51.6	51.1	49.6	51.8	0.92
% Total Bolls in 2nd Position	26.3	22.5	21.3	27.2	26.6	0.41
% Total Bolls in Outer Position	16.0	18.3	20.0	15.3	15.5	0.31
% Total Bolls on Monopodia	7.5	7.2	7.2	7.2	5.7	0.97
% Total Bolls on Extra – Axillary	1.0	0.4	0.4	0.7	0.4	0.58
% Boll Retention - 1st Position	30.3	32.0	34.3	33.4	30.5	0.69
% Boll Retention - 2nd Position	21.1	17.5	18.6	25.9	19.5	0.26
% Early Boll Retention	15.4	26.7	28.8	33.3	25.0	0.03
Total Nodes/Plant	22.8	22.6	22.9	22.5	22.6	0.93
Internode Length (inches)	1.7	1.7	1.7	1.6	1.6	0.23

[1] means of 8 plants per plot.

Table 5b. Results from final end-of-season plant mapping following defoliation using COTMAP (2003)[1].

Category	Mean per plant for each treatment					Pr>F
	9 Bugs	3 Bugs	1 Bug	Natural	Sprayed	
1st Sympodial Node	7.1	7.1	7.1	7.0	6.4	0.10
No. Monopodia	1.8	1.9	2.0	2.3	1.8	0.67
Highest Sympodia with 2 nodes	10.7	10.1	9.2	8.7	9.3	0.19
Plant Height (inches)	40.6	40.8	39.0	37.4	38.9	0.74
No. Effective Sympodia	11.1	10.2	9.9	9.3	9.4	0.06
No. Sympodia	15.2	14.8	14.0	13.5	14.3	0.16
No. Sympodia with 1st Position Bolls	3.5	4.6	4.6	4.5	4.4	0.22
No. Sympodia with 2nd Position Bolls	1.5	2.4	1.6	1.9	2.0	0.04
No. Sympodia with 1st & 2nd Bolls	1.0	0.8	1.0	1.1	1.1	0.82
Total Bolls/Plant	10.6	11.4	10.7	11.2	10.5	0.82
% Total Bolls in 1st Position	42.6	47.5	52.1	50.0	52.3	0.37
% Total Bolls in 2nd Position	23.8	27.8	24.0	26.8	29.1	0.42
% Total Bolls in Outer Position	11.1	9.0	4.9	2.1	3.6	0.01
% Total Bolls on Monopodia	19.2	15.4	17.9	19.3	13.5	0.74
% Total Bolls on Extra – Axillary	3.4	0.2	1.1	1.8	1.5	0.03
% Boll Retention - 1st Position	29.7	36.2	39.7	41.2	38.0	0.05
% Boll Retention - 2nd Position	23.7	31.5	27.6	34.9	33.6	0.17
% Early Boll Retention	16.3	36.0	45.3	50.3	51.3	0.001
Total Nodes/Plant	21.2	20.9	20.1	19.6	19.8	0.73
Internode Length (inches)	1.9	2.0	1.9	1.9	2.0	0.95

[1] means of 10 plants per plot.

Table 6a. Cumulative mean lint yield over 4 harvest dates taken for each treatment (2002).

	Mean lb lint/ac picked on each harvest date [1,2]							
Treatment	**09/23**		**10/02**		**10/14**		**10/21**	
9 bugs/ft	418	bc	599	b	781	c	858	c
3 bugs/ft	386	c	626	b	996	bc	1064	b
1bug/ft	613	ab	799	ab	1135	ab	1187	ab
Natural	558	ab	806	ab	1266	a	1332	a
Sprayed	704	a	860	a	1033	ab	1092	b
LSD(05)	*223*		*207*		*241*		*200*	
Pr>F	*0.05*		*0.05*		*0.01*		*0.01*	

[1]Means followed by similar letters within columns are not different.
[2]Lint percent calculated based on 33% turnout.

Table 6b. Cumulative mean lint yield over 4 harvest dates taken for each treatment (2003).

	Mean lb lint/ac picked on each harvest date [1,2]							
Treatment	**10/01**		**10/20**		**10/27**		**11/03**	
9 bugs/ft	16	b	94	c	550	c	1023	b
3 bugs/ft	42	b	264	bc	817	b	1204	ab
1bug/ft	53	b	493	b	1048	ab	1280	ab
Natural	165	a	757	a	1208	a	1412	a
Sprayed	71	ab	504	ab	974	ab	1195	ab
LSD(05)	*96*		*262*		*245*		*254*	
Pr>F	*0.04*		*0.001*		*0.009*		*0.05*	

[1]Means followed by similar letters within columns are not different.
[2]Lint percent calculated based on 33% turnout.

Figure 1. Tubes used for releasing plant bug nymphs at the base of plants.

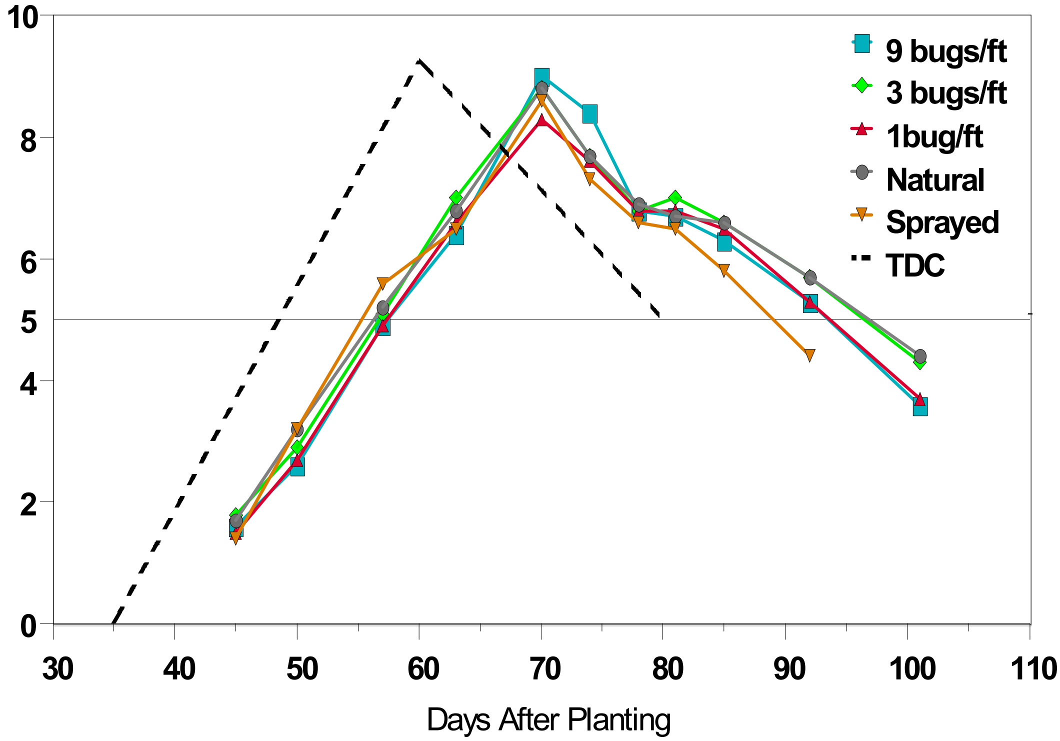

Figure 2. COTMAN target development curve (TDC) and crop growth curves of plants exposed to 9, 3 or 1 tarnished plant bug nymph/wk for 3 weeks, untreated plants (natural infestations) or plants protected with insecticide in 2002 trial.

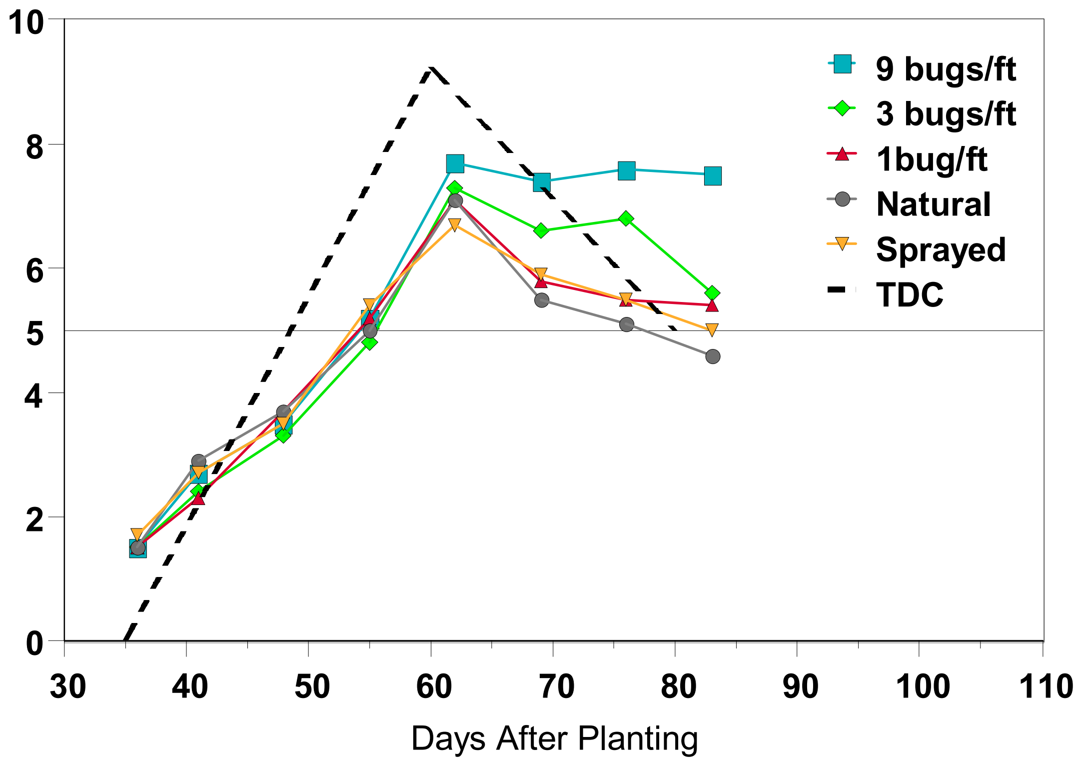

Figure 3. COTMAN target development curve (TDC) and crop growth curves of plants exposed to 9, 3 or 1 tarnished plant bug nymph/wk for 3 weeks, untreated plants (natural infestations) or plants protected with insecticide in 2003 trial.

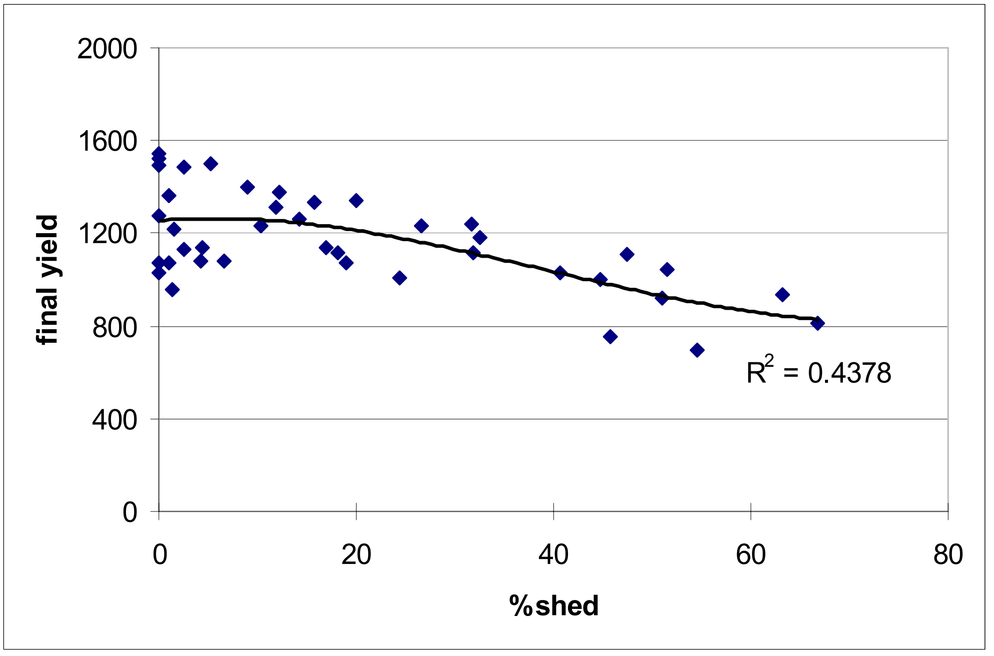

Figure 4. Final yield of treatments regressed on % shed of squares at the time of 1st flowers (y = 0.0029x3 - 0.3431x2 + 3.5438x + 1254.8).