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COTTON RESPONSE TO EARLY SEASON TERMINAL INJURY FROM INFESTATIONS OF TARNISHED PLANT BUG NYMPHS (*LYGUS LINEOLARIS* (PALISOT DE BEAUVOIS)) OF VARIOUS AGES

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Abstract

Cotton at the 2-leaf stage was manually infested with small (1^{st}-2^{nd} instar), medium (3^{rd} instar) and large (5^{th} instar) tarnished plant bug nymphs in a field study in Northeastern Arkansas. One lab reared nymph was released per plant on 23 May (15 DAP). Plants were monitored weekly through cutout using COTMAN™ with end of season final mapping conducted using COTMAP. At 18 days after treatment the medium and large bug treated plants had significantly fewer leaves and fewer actively growing terminals compared to the untreated check and small bug treatments. A significant reduction in no. of squaring nodes per plant prior to first flowers in the medium and large nymph treatments indicates that injury was more severe than that associated with the small nymphs. There were significant differences in yield during the 1^{st} and 2^{nd} harvest; however, no differences were observed during the 3rd and 4^{th} harvest. Results from mean maturity date calculations indicated a significant delay of 6 days associated with injury from large nymphs.

Introduction

Tarnished plant bug (TPB)(*Lygus lineolaris* (Palisot de Beauvois)) is a key pest in Midsouth cotton. In pre-squaring cotton, the terminal portions of plants are preferred feeding sites (Layton 1995). Injury from TPB feeding at this crop stage can cause a loss of apical dominance, which can result in multiple terminals per plant, a condition sometimes referred to as "crazy cotton"(Scales and Furr, 1968, Hanny et al. 1977). In studies with *Lygus hesperus* (Knight), Wene and Sheets (1964) found that pre-square injury by adults resulted in suppression of the growing point, prevented the development of true leaves, and produced plants with multiple main stems. When this feeding occurred during cool weather, the percent of plants producing multiple stems was almost double that from injury during warm weather. Strong (1970) reported that as little as 20 min. of feeding by *L. hesperus* destroyed the terminal of seedling cotton resulting in cessation of growth. With no further injury to the plant, re-growth of a new terminal occurred in about 10 days.

Terminal injury can delay development of squaring nodes and ultimately crop maturity (Wene and Sheets 1964, Tugwell et al. 1976, Hanny et al. 1977, Brook 1992). Given adequate time and resources, the crop can recover from terminal injury with no reduction of yield (Brook 1992); however, in northern cotton production areas with a limited growing season, time for compensation is limited, and crop delays can result in costly yield penalties.

Plant bugs and nymphs can move to pre-squaring cotton from proximate wild host plants when those plants senesce or are sprayed with herbicides. For example, in a reduced tillage production system, a delay in burndown of weeds until after crop emergence can result in movement of adult or immature plant bugs or other mirids from weed hosts onto seedling cotton (Luttrell et al. 2002). Adult insects may remain and feed on the cotton or fly to other areas; the immature insects would remain to feed on the crop. Wene and Sheets (1964) found that 3^{rd} - 5^{th} instar nymphs of *L. hesperus* were less injurious than adults when caged on cotton at the 1-2 leaf stage. Similar studies have not been conducted with TPB.

The objective of this experiment was to investigate crop injury and recovery following pre-square injury from TPB nymphs of various ages.

Materials and Methods

The variety Stoneville 4892 was planted at Wildy Farms in NE Arkansas near Manila (Mississippi County) on 8 May. No insecticides were applied at planting. The soil was sandy, an excessively drained part of the Routon-Dundee-Crevasse complex. Furrow irrigation began on 15 June and continued weekly until 3 September. One post emergence herbicide application of 0.66pt/acre of Caparol (prometryn) post direct and 1.5pt/acre of Direx (diuron) under a hood was made on 15 June.

There were 4 treatments: 1) Untreated Check, 2) one 1st –2nd instar TPB nymph released per plant (Sm Bug), 3) one 3rd instar nymph released per plant (Med Bug), 4) one 5th instar nymph released per plant (Lg Bug). TPB were released 15 days after planting (DAP) on 23 May, when the plants reached the 2-leaf stage. Nymphs of the appropriate size were aspirated into glass vials and placed in a small cooler containing ice for transfer to the field. Nymphs were allowed to walk out of the vials or were gently poured from the vial directly on true leaves. Care was taken to ensure that the bugs were clinging to the plant after release. TPB nymphs were obtained from a colony maintained on artificial diet at the USDA-ARS Biological Control and Mass Rearing Unit at Mississippi State, MS (Cohen 2000).

Plots were 4 rows wide and 30 feet long. After plant emergence, 10 ft of row that contained 15 healthy plants were marked off within the 2 center rows of each plot. All treatments and data collection were made on these plants. Treatments were replicated 4 times in a randomized complete block design.

Plants were visually inspected for the presence of nymphs at 2 and 7 days after treatment (DAT) (release of bugs). Nine and 18 DAT, plant injury and crop growth was assessed. Total no. of plants with terminal damage (withered, flagged or aborted), no. of plants with active terminal growth (new unfurled growth of a leaf), and no. of true leaves per plant were recorded. As the crop began to square, plants were monitored weekly through cutout using the COTMAN™ system (Danforth and O'Leary 1998). Prior to first flower, sampling included measurements of plant height, no. of squaring nodes, and retention of first position squares. Five consecutive plants in each row were monitored weekly until 83 days after planting. Nodes above white flower (NAWF) were monitored after first flowers until cutout (NAWF=5). Plant mappers were careful to avoid excessive handling of plants during sampling.

Weekly insecticide applications of Provado 1.6F (imidacloprid) (0.047 lb (AI)/acre) were made with a backpack sprayer and 4 row boom on 11, 19, 26 June and 2 July. Applications by air were made on 20 July (Orthene 90S (1/3 lb/ac)) and 1 and 11 Aug (Centric 40 WG (3 oz/ac)). Defoliant was applied on 1 Oct.

Final plant mapping was done on 23 Oct using the COTMAP system (Bourland and Watson 1990). Eight plants per plot were sampled for node number of first (lowest) sympodial branch on the main axis. Total number of monopodia, and number of monopodia with fruit, number of bolls on the monopodial branches, and bolls located on the main stem sympodia (1st and 2nd position) were recorded along with bolls located on outer positions (>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. Because most plants in the infested plots had loss of apical dominance, criteria for main axis (main stem) had to be established. The main axis was determined to be the branch which had the lowest sympodia with two or more fruiting positions. All other branches were categorized as monopodial branches.

One row from each plot was hand harvested on 17, 28 Sept, and 17, 29 Oct. The cumulative weight per plot of each harvest was used to calculate the mean maturity date for each treatment (Richmond and Ray 1966, Bourland et al. 2001). The mean maturity date is equal to the sum of each sequential harvest weight times the no. of days after planting for each harvest date, that number is then divided by the sum total weight of harvest.

On 5 Nov, the 2nd row was harvested; the bolls from monopodial branches were harvested separately from those on main stem branches. These data were used to calculate percent yield from monopodial branches. NAWF counts were also used to measure maturity of the crop (Bourland et al. 2001). Days to physiological cutout (NAWF=5), and DD60 accumulation from cutout until final harvest were calculated. All data were analyzed using the ANOVA procedure with means separated using Tukey's family error rate of 0.05.

Results and Discussion

Weather conditions during crop emergence were less than optimal; a combination of low nighttime temperatures, wind, and blowing sand caused seedling injury. Thrips numbers were low, and no other early season pests were present.

All plants were inspected for nymphs 2 DAT. Samplers were careful not to touch the plants or disturb the bugs; therefore, inspections were not rigorous. Only 6-8 bugs out of 30 per plot were observed. Due to their size, small nymphs were difficult to locate, but could be found in the terminal or under the leaves. The medium nymphs were mostly observed in the terminal area of the plant; their feeding activity did not always "kill" the terminal. The large nymphs caused the most severe injury, feeding on both the terminal and true leaves of the plant. They fed on the terminal, usually killing it, and then often began feeding on the petioles resulting in the death of the leaf. They were not usually found on the plant if the terminal had been destroyed. At 7DAT plants were carefully inspected, and no nymphs were observed.

Results from plant terminal damage assessments made 9 DAT, indicated that injury associated with Med Bug and Lg Bug treatments was more severe than for Sm Bug or the check. A significantly (P>F= 0.001 AOV) greater no. of plants were observed having damaged terminals in Med Bug (78%) and Lg Bug treatments (69%) compared to Sm Bug (43%) and Check (30%) treatments. At 18 DAT, plants in Check and Sm Bug treatments had significantly greater no. of plants with actively growing terminals compared to Lg Bug and Med Bug treatments (Table 1). At 9 DAT there was no difference between the total numbers of true leaves per plant between treatments; however, at 18 DAT, significant differences were observed between Lg and Med Bug treatments and the Check and Sm Bug treatments, indicating a developmental delay in Med Bug and Lg Bug injured plants.

On 15 June, at the time of post direct application of herbicide, the average plant height in the Check plots was 6.75 inches. Bug infested plants were 2-3 inches shorter because of reduced growth following injury. Selectivity of post emergence herbicide applications was reduced because of those plant height differences. Shorter plants suffered greater herbicide injury, and some plants in the Med Bug and Lg Bug treatments did not survive the combination of bug and herbicide injury. Plant stand density counts on 16 July indicated Check and Sm Bug plots had significantly more plants than the Lg Bug plots (Table 5).

On 18 June (41 DAP), plants in the Check plots averaged 2.5 squaring nodes; in plots where TPB nymphs had been released, there were fewer than 5 plants/row with squares present. By 50 DAP, the percent of plants producing squares in the Check plots was significantly higher compared to Med Bug or Lg Bug treatment plots (Table 2). On all sampling dates, differences between treatments were observed for plant height, sympodial nodes, and squaring nodes (Tables 3, 4). Mean no. of squaring nodes for each treatment are plotted as nodes above 1st square and nodes above white flower in COTMAN growth curves in Fig 1. When compared to the COTMAN target development curve (tdc), it is apparent that square initiation in all plots was delayed. This common delay was probably related to the cool weather immediately after planting. Once squaring began, however, a significant delay was noted between treatmtents. The Med Bug and Lg Bug treatments had fewer squaring nodes than the Check or Sm Bug plots on each sample date during the entire season (Fig 1). No plots reached physiological cutout (NAWF=5) prior to 9 Aug (93 DAP). This is the latest possible cutout date for the study area. Based on historical weather data, a flower on this date has a 50% probability of accumulating the necessary heat units (850 DD60's) required for boll maturation.

Final plant mapping results indicate that mean no. of total nodes and effective sympodia were significantly greater in the Check and Sm Bug treatments compared to Med Bug and Lg Bug treatments (Table 10). There were no differences in the mean no. of monopodia per plant; however, the percent of yield from monopodial branches in the Med Bug infested plots was greater than that from other treatments (Table 6). There were no differences between treatments in days to cutout (NAWF=5) (Table 7); however, the mean maturity date shows a significant delay of 6-days between the Check and Lg Bug treatments (Table 8). Yields were significantly lower in the Lg Bug treatments compared to other treatments in the first two harvests, on 17 and 28 Sept; however, by 17 and 26 Oct there were no differences between treatments (Table 9).

Conclusions

Differences in terminal damage between untreated plants and plants injured by TPB were not as great as in Hanny's cage study (1977), where he reported 98% terminal damage from one adult TPB/plant. In this study injury from Lg Bug feeding was sufficient to result in a significant crop delay as measured by mean maturity date. Early season observations indicated that injury resulting from Sm Bug treatments was not as severe as that observed in Med Bug and Lg Bug treatments. Due to low survival of all nymphs, most of the injury occurred within the first two days after release. During this time the small nymphs apparently were not able to injure the plants as severely as the medium and large nymphs, and plants in Sm Bug treatment plots were able to compensate for the injury. Plants were not able to compensate from the increased amount and severity of feeding injury caused by the 3rd and 5th instar nymphs. Strong (1970), Tugwell et al. (1976), and Hanny et al. (1977) observed reduced growth following terminal injury in pre-square cotton, and they reported that a significant yield reduction could result if optimal growing conditions did not allow for compensatory growth following injury.

The results of this study show that the size of plant bug nymphs infesting plants affects severity of injury. Feeding by 5th instar plant bug nymphs resulted in a 6-day maturity delay. In Northern production areas of the U S Cotton Belt, where the growing season is shorter, and time for compensation is limited, crop delays can result in reduced lint quality, which results in costly yield penalties for the producer.

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Literature Cited

Bourland, F. M., C. E. Watson, Jr. 1990. COTMAP, a technique evaluating structure and yield of cotton. Crop Sci. 39: 224-226

Bourland, F. M., N. R. Benson, E. D. Vories, N. P. Tugwell, and D. M. Danforth. 2001. Measuring maturity of cotton using nodes above white flower. J. Cotton Sci. 5:21-28

Brook, K.D., A. B. Hearn & C.F. Kelly. 1992b. Response of cotton, *Gossypium hirsutum* L., to damage by insect pest in Australia: Manual simulation of damage. J. Econ. Entomology. 85:1368-1377

Cohen, A. C. 2000. New Oligidic Production Diet for *Lygus hesperus* Knight and *L. lineolaris* (Palisot de Beauvois). J. Entomol. Sci. 35: 301-310

Danforth, D. M. and P. F. O'Leary (ed.) 1998. COTMAN expert system 5.0. User's Manual. U. of Ark Agric. Exp. Sta., Fayetteville, AR.

Hanny, B. W., T. C. Cleveland, and W. R. Meredith, Jr. 1977. Effects of Tarnished Plant Bug (*Lygus lineolaris*), Infestation on Presquaring Cotton (*Gossypium hirsutum*). Enviro. Ento. 6:460-462.

Layton, M. B. 1995. Tarnished Plant Bug: Biology, Thresholds, Sampling, and Status of Resistance. In Proc. Beltwide Cotton Prod. Res. Conf., 1995. Natl. Cotton Counc. Am. Memphis, TN.

Luttrell, R. G. T. G. Teague, N. P. Tugwell, D. Wells, S.Coy, S. Wingard, C. Yates 2002. Observations of the Cotton Fleahopper in Arkansas. Beltwide Cotton Prod. Res. Conf., 2002. Natl. (In Press)

Richmond, T. R. and L. L. Ray. 1966. Product-quantity measures of crop maturity in cotton. Crop Sci. 6: 235-239

Scales, A. L., and R. E. Furr. 1968. Relationship Between the Tarnished Plant Bug and Deformed Cotton Plants. J. Econ. Entomol. 61: 114-118

Strong, F. E. 1970. Physiology of Injury Caused by *Lygus hesperus.* J. Econ. Entomol. 63: 808-814

Tugwell, N. P., S.C. Young, JR., B. A. Dumas, & J. R. Phillips. 1976. Plant bugs in cotton: importance of infestation time, types of cotton injury, and significance of wild host near cotton. Ark. Agric. Exp. Stn. Rpt. Series 227. 24pp.

Wene, G. P., and L.W. Sheets. 1964. Lygus bug injury to pre-squaring cotton. Ariz. Agric. Exp. Stn. Tech. Bull. 166. 28 pp.

Table 1. Percent of plants with actively growing terminals and mean no. of true leaves per plant determined at 9 and 18 days after release of 1 TPB nymph per plant onto cotton at 2-leaf stage[1].

	% Plants with Actively Growing Terminals		**Mean no. True Leaves/Plant**	
Treatment	**9 DAT[2]**	**18 DAT**	**9 DAT**	**18 DAT**
Check	67.3	85.8	1.8	3.7
Sm Bug	56.3	76.5	1.7	3.1
Med Bug	34.2	39.8	1.5	1.5
Lg Bug	20.5	32.5	1.5	1.7
P > F	0.002	0.002	0.11	0.01
$MSD_{.05}$	27.3	34.0		1.8

[1]Bugs were released 15 days after planting.
[2] Days after treatment.

Table 2. Plant response to injury following release of TPB nymphs on 2-leaf stage cotton -- mean % of plants producing squares 50 DAP[1].

Treatment	% Plants Squaring
Check	84
Sm Bug	82
Med Bug	54
Lg Bug	58
P > F	0.001
MSD .05	17.3

[1]Days after planting.

Table 3. Mean number of sympodia per plant observed for each terminal injury treatment over 7 sample dates.

Date of sample	Days after planting	Terminal Injury Treatment					
		Check	Sm Bug	Med Bug	Lg Bug	*P > F*	*MSD .05*
18 June	41	2.5	---[2]	---	---		
26 June	49	4.6	4.4	3.2	3.1	0.015	1.4
2 July	55	6.1	5.9	4.4	4.2	0.005	1.5
9 July	62	8.7	8.0	6.3	6.6	< .0001	1.0
16 July	69	10.4	10.2	8.3	8.7	0.01	1.7
23 July	76	12.9	12.5	10.2	10.7	0.01	2.2
30 July	83	14.5	14.2	12.3	12.4	0.005	1.7

[1]Means of 5 consecutive plants per row on 2 rows per plot.
[2] No counts were made because fewer than 5 plants with squares were present.

Table 4. Effects of terminal injury treatments from TPB nymphs feeding on 2-leaf cotton on plant height measured in inches[1].

Date of sample	Days after planting	Terminal Injury Treatment					
		Check	Sm Bug	Med Bug	Lg Bug	P > F	MSD .05
26 June	49	11.5	10.6	8.5	8.8	0.002	1.9
2 July	55	16.3	15.9	12.8	12.1	0.006	3.2
9 July	62	25.4	24.9	20.3	19.5	0.017	5.6
16 July	69	32.5	32.6	26.5	27.0	0.007	5.5
23 July	76	39.9	39.0	32.8	33.8	0.006	5.6
30 July	83	46.1	45.5	39.4	41.6	0.009	5.3

[1]Means of 5 consecutive plants per row on 2 rows per plot.

Table 5. Plant stand density at 1st flower (16 July) following injury from TPB feeding and post direct herbicide application.

Treatment	Mean no. plants / 10 ft of row
Check	14.5
Sm Bug	14.4
Med Bug	13.1
Lg Bug	12.1
P > F	0.001
MSD .05	1.8

Table 6. Mean no. of monopodia per plant at harvest and % of total yield associated with monopodial branches for each terminal injury treatment.

Treatment	Mean no. of monopodia/plant[1]	% Yield from monopodial branches
Check	1.5	19.6
Sm Bug	1.5	20.8
Med Bug	1.8	35.7
Lg Bug	1.7	26.0
$P > F$	.52	0.01
$MSD_{.05}$		12.3

[1] The stem that contained the lowest sympodial branch with 2 or more fruiting positions was designated the main stem; all others were monopodial branches.

Table 7. Effect of terminal injury treatments on plant maturity as measured by nodes above white flower (NAWF) over 7 sample dates.

Date of sample	Days after planting	Terminal Injury Treatment					
		Check	Sm Bug	Med Bug	Lg Bug	$P > F$	$MSD_{.05}$
16 July	69	9.3	9.2	9.1	9.2	0.93	
23 July	76	8.7	8.4	8.0	8.2	0.20	
31 July	84	7.3	7.5	7.1	7.4	0.47	
6 Aug	90	6.3	6.7	5.9	6.8	0.01	0.43
13 Aug	97	5.8	6.2	5.8	6.0	0.32	
20 Aug	104	5.1	5.3	5.2	5.7	0.61	
27 Aug	111	3.9	4.3	4.1	5.0	0.14	

Table 8. Crop delay associated with terminal injury treatments as measured by mean no. of days from planting to physiological cutout (NAWF=5) and mean maturity date.

Treatment	Days to Physiological Cutout[1]	Mean Maturity Date[2,3]
Check	102	151
Sm Bug	103	155
Med Bug	101	154
Lg Bug	107	157
$P > F$	0.10	0.02
$MSD_{.05}$		4.74

[1]Nodes Above White flower =5.

[2] The mean maturity date is equal to the sum of each sequential harvest weight times the no. of days after planting for each harvest date, that number is then divided by the sum total weight of harvest.

[3]Expressed as days after planting.

Table 9. Yield response to terminal injury treatments following release of TPB nymphs on 2-leaf stage cotton[1].

Treatment	Mean lint yield (lbs/ac) for each date of harvest			
	17 Sep	28 Sep	17 Oct	29 Oct
Check	379	588	1130	1264
Sm Bug	297	472	1053	1287
Med Bug	286	486	992	1171
Lg Bug	188	313	763	951
$P > F$	0.02	0.02	0.13	0.12
$MSD_{.05}$	152	210		

[1] Lint yield was calculated as 33% of seedcotton weight.

Table 10. Plant response to injury following release of TPB nymphs on 2-leaf stage cotton --results from final plant mapping made on 23 Oct following defoliation[1].

Category	Check	Sm Bug	Med Bug	Lg Bug	$MSD_{.05}$
1st Sympodial Node	7.1	7.2	6.3	7.0	
No. of Monopodia	1.8	1.8	2.5	2.1	
No. of Fruiting Monopodia	1.3	1.3	2.0	1.6	
Highest Sympodia with 2 nodes	15.8	16.6	13.4	15.6	2.89
Plant Height (inches)	56.4	62.5	51.1	58.8	
No. of Effective Sympodia	14.3	15.0	11.8	12.9	2.59
No. of Sympodia with 1st Position Bolls	6.6	6.3	5.5	5.5	
No. of Sympodia with 2nd Position Bolls	2.2	2.5	1.8	1.8	
No. of Sympodia with 1st and 2nd Position Bolls	2.7	3.1	1.9	2.6	
Total Bolls/Plant	21.0	23.7	21.4	21.0	
% Total Bolls in 1st Position	44.2	39.8	35.2	40.0	
% Total Bolls in 2nd Position	23.0	23.8	17.3	21.0	
% Total Bolls in Outer Position	12.5	15.6	7.7	13.2	
% Total Bolls on Monopodia	19.7	20.8	39.2	25.5	
% Boll Retention -1st Position	47.6	45.8	41.6	41.9	
% Boll Retention -2nd Position	30.9	34.1	28.2	28.6	
% Total Bolls on Extra-Axillary	0.6	0.0	0.6	0.3	
% Early Boll Retention	51.3	45.3	44.8	42.7	
Total Nodes/Plant	25.8	26.8	23.1	25.6	2.97
Internode Length (inches)	2.2	2.3	2.2	2.3	

[1]means of 8 plants per plot.

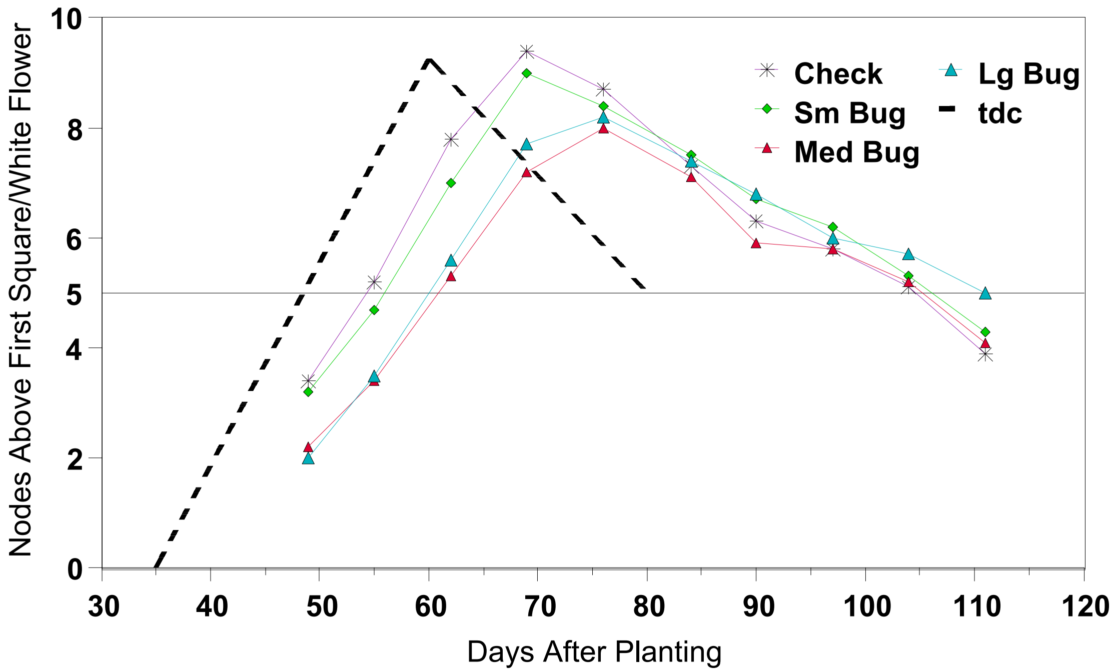

Figure 1. COTMAN target development curve (tdc) and crop growth curves for untreated check plants and plants on which small, medium and large TPB nymphs were released at the 2-leaf stage. The latest possible cutout date for the production region was 9 Aug. 93 days after planting.