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RESPONSE TO MECHANICAL AND TARNISHED PLANT BUG *(LYGUS LINEOLARIS)* INJURY OF SEEDLING COTTON *(GOSSYPIUM HIRSUTUM)*

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Abstract

Comparison of plant response to mechanical injury and tarnished plant bug (*Lygus lineolaris)* feeding at two early stages of crop development were made in a field study in Northeast Arkansas in 2001. At either the 1st or 4th-leaf stage, plant terminals were mechanically removed using forceps or infested with one 3rd instar plant bug. Injury treatments along with an untreated check were monitored through cutout using COTMAN™. End of season plant mapping also was performed. Compared to the check, bug and manual injury treatments delayed squaring and days to 1st flower by one week, and also reduced the number of sympodial nodes at 1st flower. While plant response was similar at the 1-leaf stage, it was not at the 4-leaf stage. Plants injured mechanically at the 4-leaf stage had fewer sympodial nodes on all sample dates and produced a higher percent of their yield on monopodial branches compared to plants infested with one plant bug nymph. After 1st flower, differences in crop maturity were not apparent; this was probably due to soil variability in the experimental plots and fall weather conditions conducive to maturing a late crop. Terminal injury had no effect on final seed cotton yield. The results from this experiment indicate that the plant response to feeding injury caused by one 3rd instar plant bug during the 1-leaf stage were comparable to plants mechanically injured. When injury was delayed until the 4-leaf stage, plants did not respond equally to mechanical and plant bug injury.

Introduction

The tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois) (TPB) is a key pest in Mid-south cotton (Tugwell et al. 1976). Economic damage from TPB feeding can occur during the 4 to 6-leaf stage through early square production (Scales and Furr 1968). In seedling cotton, the apical meristem is the preferred feeding site, and feeding at this stage often results in necrotic or wilted leaves, reduced vegetative growth, and a loss of apical dominance (Layton 1995). This injury delays terminal growth, sympodia development and, ultimately, crop maturity (Wene and Sheets 1964, Tugwell et al. 1976, Hanny et al. 1977, Brook et al. 1992). The loss of apical dominance delays plant growth and results in an increased number of mainstem branches, a condition that is often referred to as "crazy cotton" (Scales and Furr, 1968, Tugwell et al. 1976, Hanny et al. 1977).

Given adequate time and resources, the crop can recover from terminal injury with no reduction of yield (Brook et al. 1992). However, in northern cotton production areas, weather conditions in early fall limit time for compensation, and crop delay can result in costly yield penalties. Coy et al. (2002) found that when one 5th instar TPB was released on seedling cotton, the ensuing injury to the terminal resulted in a 6-day delay, as measured by the mean maturity date, and reduced yield as much as 25 percent.

Many researchers have used adults and nymphs of various *Lygus sp.* or mechanical injury to examine the plant's response to feeding during the seedling and early square stages (Wene and Sheets 1964, Scales and Furr 1968, Evenson 1969, Tugwell et al.1976, Hanny et al. 1977, Brook et al. 1992, Ihrig et al. 1996 and Teague et al. 2002). In experiments where plant bugs were used to injure seedling cotton, crop delays and reductions in yield were often observed (Wene and Sheets 1964, Tugwell et al.1976, and Hanny et al. 1977). In those non-choice studies, bugs were caged on the plant. In simulated feeding studies, the terminal or apical meristem of the plant was removed or injured with forceps. This technique also resulted in crop delay; however, no reduction in yield was reported (Evenson 1969, Tugwell et al.1976, Brook et al. 1992, and Ihrig et al. 1996).

Varis (1972) examined sugar beet response to injury from *Lygus rugulipennis* Popp. and found that damage could be reproduced only by combining mechanical piercing of the plant with either removal of plant fluid or injection of pectinase into the meristem. Tingey and Pillemer (1977) concluded that efforts to simulate plant bug feeding by mechanical injury alone do not accurately represent the feeding process. Brook et al. (1992) stated that, while mechanical injury was not an exact duplication of plant bug injury in cotton, it was close enough to study plant response. Despite the contradicting evidence, researchers have continued using mechanical injury alone to evaluate plant response to plant bug feeding injury. A direct comparison of cotton plant response to mechanical injury and TPB feeding has not been done. The objective of this experiment was to investigate crop injury and recovery following pre-square injury from TPB nymphs compared to mechanically induced injury.

Materials and Methods

The cotton variety Stoneville 4892BR was planted on Wildy farms near Manila, Arkansas (Mississippi County) on 8 May 2001. No insecticides were applied at planting. The soil is a sandy, 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. 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. Aerial applications were made on 20 July (Orthene 90S (0.33 lb ai/acre)) and 1 and 11 Aug (Centric 40 WG (3 oz ai/acre)). Defoliant was applied on 1 Oct.

Plots were 4 rows wide and 30 feet long. A 10 ft section in the 2 center rows of each plot was thinned to a uniform stand density of 1.5 plants per ft. All treatments and data collection were made using these plants. There were 5 treatments: 1) an untreated check (Ck), 2) mechanical removal of the terminal at the 1-leaf stage (M1), 3) one 3rd instar TPB per plant at the 1-leaf stage (B1), 4) mechanical removal of the terminal at the 4-leaf stage (M4), and 5) one 3rd instar TPB per plant at the 4-leaf stage, (B4). The experiment was arranged in a randomized complete block design, and there were 4 replications

Treatments were applied on 20 May (1-leaf), and 5 June (4-leaf). Mechanical injury was accomplished by removing all plant tissue above the subtending leaf of the appropriate node (Ihrig et al.1996). Tarnished plant bug 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). Plants were infested with nymphs as described by Coy et al. (2002).

Plants were inspected 2 days after treatment (DAT) for the presence of nymphs. Care was taken not to disturb the nymphs during the inspection. At 10 DAT injury assessments were made, counts of number of damaged terminals and true leaves per plant were recorded. Plants with a necrotic, wilted or missing terminal or leaf were considered damaged. Percent of plants producing squares on 27 June (50 days after planting (DAP)) and mean number of sympodial nodes per plant at 1st flower were also recorded. Plants were monitored weekly from squaring through physiological cutout using COTMAN™ (Danforth and O'Leary 1998). Sampling measurements were the same as described by Coy et al. (2002). Crop delay was measured using Nodes above White Flower (NAWF) counts and calculating days from planting to physiological cutout (NAWF=5) (Bourland et al. 2001).

Final plant mapping was made 19 Oct using COTMAP procedures (Bourland and Watson 1990). One row from each plot was hand harvested on 12, 17, 26 Sept. and 9, 17 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). To calculate percent yield from monopodial branches, a single harvest of the 2nd row was made on 24 Oct with bolls from mainstem sympodial branches harvested separately from monopodial branches (Coy et al. 2002). All data were analyzed using the ANOVA procedure with means separated using LSD.

Results and Discussion

Weather conditions during crop emergence were not conducive to early plant growth, and a combination of low nighttime temperatures, wind, and blowing sand caused some seedling injury. Thrips numbers were low, and no other early season pests were present. All plants were inspected for the presence of plant bugs 2 DAT to determine the number of nymphs present. No plant bugs were found on any plants in the check or mechanically injured plots. Only 3 nymphs could be located on plants infested at the 1-leaf stage. A total of 34 nymphs were located on plants infested at the 4-leaf stage.

Because of the poor growing conditions, some plant terminal damage was apparent in all plots at 10 DAT, 19% of plants in the Ck plots had necrotic, wilted or missing terminals (Table 1). In B1 and M1 treatment plots, 52% and 65% of plant terminals were damaged, respectively. Mean number of true leafs per plant were also reduced in M1 and B1 treatments compared to the Ck. Assessments made 10 days after the 4-leaf stage treatments indicated that plants in the Ck plots had recovered from early injury and only 5% of the terminals were damaged. In the M4 and B4 treatment plots, 12% and 11% of terminals were damaged, respectively. There were significantly more true leafs associated with B4 and Ck plants than with M4 plants.

Mean number of sympodial nodes per plant in the Ck plots was 2.82 by 41 DAP (Table 2). Bug and manually injured plots contained too few squaring plants to make comparable measures in those treatments. Bug and manually induced terminal injury resulted in a one-week delay of squaring compared to the Ck. By 50 DAP significantly fewer plants in the M1, B1 and M4 treatments were squaring compared to the Ck and B4 treatments (Table 3). There were no differences in the number of sympodia between the M1 and B1 treatments, both treatments were observed to have fewer sympodia than the Ck except for measures made on 26 June (Table 2). Injury at the 4-leaf stage also delayed and reduced the number of sympodia. On the 26 June and 7 July sample dates, there were no differences between the Ck and B4 treatments; both were observed to have a greater number of sympodia than the M4 treatment. On 26 June, 2, 9 and 16 July, the M4 treatment contained fewer sympodia than all other treatments including the B4. Flowers were observed in Ck treatment plots 9 July (62DAP); no flowers were observed in bug and manually injured until 16 July (69DAP) (Table 2).

Squaring delay and reductions in the number of nodes above first square (NAFS) per plant per week for bug and manual injury compared to the check were readily apparent in COTMAN growth curves (Fig. 1 & 2). A sandy area extending through the experimental plots resulted in unexpected plant variability after the onset of flowering. Continued plant growth as measured by NAWF was reduced in these sandy areas. Consequently, NAWF values did not indicate a maturity delay when measured in days to physiological cutout (Table 4). There was a 2-3 day delay in mean maturity date of injured plants; however, it was not significant (Table 4).

Hand harvesting was initiated on 12 Sept. There were no differences in lint yield between treatments at first harvest (Table 5), but by the 2nd and 3rd harvests, on 17 and 26 Sept., yield from the Ck was significantly higher than other treatments indicating a delay in crop maturity associated with terminal injury. The crop was defoliated on 1 Oct., and by 17 Oct there were no differences in cumulative yield among treatments. The contribution of yield from monopodial branches was measured from a once-over harvest made on 24 Oct. The total number of monopodial branches and percentage of total yield from monopodial branches was significantly higher in the M4 treatment compared to all other treatments (Table 6).

Final plant mapping results indicated that the distribution of yield on the plant was significantly affected only by mechanical injury at the 4-leaf stage. Plants injured mechanically at the 4-leaf stage had fewer numbers of effective sympodia, sympodia with bolls on 1st and 2nd positions, and percent total bolls in outer positions compared to other treatments. Plant mapping data indicated that there were no differences in the mean number of total monopodial bolls per plant between treatments; however the M4 treatment resulted in a increased production in monopodial branches and a greater percentage of bolls on those branches than all other treatments (Table 7).

Conclusions

All bug and manually induced injury treatments increased the number of days to 1st squares, days to 1st flowers and reduced the total number of sympodia at 1st flower compared to the uninjured check. Such early season delays may lengthen the time required to mature the crop, and in northern production areas limit yield. This was not the case in this study, however. By the end of the season, plants had compensated for injury, and there were no differences between treatments in seed cotton yield. Soil variability in combination with weather conditions conducive to maturing a late crop resulted in no differences in days to cutout or mean maturity date for any treatments. No treatment reached NAWF=5 prior to 9 Aug. The latest possible cutout date for the study area is 9 Aug. Based on historical weather data contained in the COTMAN expert system, a flower on this date has a 50% probability of accumulating the necessary heat units (850 DD60's) required for boll maturation.

Even though the delays did not affect the yield in this study, feeding by nymphs can reduce yield by 25% and delay maturity of the crop up to 6-days (Coy et al. 2002). Strong (1970), Tugwell et al. (1976), Hanny et al. (1977), and Brook et al. (1992) reported that terminal injury to pre-squaring cotton could reduce yield potential and delay crop maturity, eventually reducing yields if optimal growing conditions do not allow for compensatory growth. During most years in Northeast Arkansas, these early season delays would force the crop to mature when insect pest pressure is high and weather conditions unfavorable.

In this study plant bugs were released onto uncaged plants. Only 2.5% of plant bugs survived for 2 days on 1-leaf cotton. Even with this low survival rate, at 10 DAT damaged terminals were observed on more than 50% of plants infested with one 3rd instar plant bug. This level of damage indicates that under the field conditions in this study, just one plant bug nymph can injure the terminal of seedling cotton. When plants were infested at the 4-leaf stage the survivorship of plant bugs increased to 28%. Feeding by nymphs at this stage was not concentrated in the terminal and did not typically injure the terminal severely enough to destroy it.

The results from this experiment indicate that plant response to injury at the 1-leaf stage by the feeding of one 3rd instar plant bug was comparable to plants in which the terminal was mechanically removed. When injury was delayed until the 4-leaf stage, plants did not respond similarly to mechanical and plant bug injury. Injury at the 1-leaf stage resulted in plants with comparable numbers of sympodia, monopodia and percentage of yield produced on those branches. Results from end of season plant mapping indicated no differences between mechanical or bug injury at the 1-leaf stage. At the 4-leaf stage, however, plant growth following feeding of 3rd instar nymphs was no different from the untreated check when comparing number of sympodia, number of monopodia, or percentage of yield produced on those branches. Plants injured mechanically at this stage had fewer sympodia on all sample dates, produced more monopodial branches and higher yield from those branches. One possible reason for reduced injury by bugs at the later plant stage is the larger and older plant may simply have more feeding sites compared to 1-leaf plants. It is possible that feeding by nymphs was not as concentrated in the terminal area of the plant, and terminals were not destroyed.

Literature Cited

Bourland, F. M., C. E. Watson, Jr. 1990. COTMAP, a technique evaluating structure and yield of cotton. Crop Sci. 39: 224-26.

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. 1992. Response of cotton, *Gossypium hirsutum* L., to damage by insect pests in Australia: Manual simulation of damage. J. Econ. Entomology. 85:1368-77

Cohen, A. C. 2000. New oligidic production diet for *Lygus hesperus* Knight and *L. lineolaris* (Palisot de Beauvois). J. Entomol. Sci. 35: 301-10.

Coy, S., T. G. Teague, N. P. Tugwell, E. J. Villavaso, & S. Wingard. 2002. Cotton response to early season terminal injury from infestations of tarnished plant bug nymphs (*Lygus lineolaris* (Palisot De Beauvois)) of various ages. Proc. Beltwide Cotton Prod. Res. Conf., 2002. Natl. Cotton Counc. Am. Memphis, TN.

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.

Evenson, J.P. 1969. Effects of floral and terminal bud removal on the yield and structure of the cotton plant in the Ord Valley, North Western Australia. Cotton Grower Rewiew 46: 37-44.

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. 6:460-62.

Ihrig, R. A., Bradley, J. R. Jr., and J. V. Duyn. 1996. The effects of early season terminal bud and square removal on cotton yields in North Carolina. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis TN. pp. 941-945

Layton, M. B. 1995. Tarnished plant bug: Biology, thresholds, sampling, and status of resistance. Proc. Beltwide Cotton Prod. Res. Conf., 1995. Natl. Cotton Counc. Am. Memphis, TN.

Richmond, T. R. and L. L. Ray. 1966. Product-quantity measures of crop maturity in cotton. Crop Sci. 6: 235-39

Scales, A. L., and R. E. Furr. 1968. Relationship between the tarnished plant bug and deformed cotton plants. J. Econ. Entomol. 61: 114-18

Strong, F. 1970. Physiology of injury caused by *Lygus hesperus*. J. Econ. Entomol. 63: 808-814

Teague, T.G., N. P. Tugwell, E.J. Villavaso, and S. Coy. 2002. Comparison of cotton plant response to square loss following manual removal or tarnished plant bug feeding – Results from field trials in 2001. Proc. Beltwide Cotton Prod. Res. Conf., 2002. Natl. Cotton Counc. Memphis, TN.

Tingy, W. M., and E. A. Pillemer. 1977. Lygus Bugs: Crop resistance and physiological nature of feeding injury. Entomo. Soc. of America Bulletin 23: 277-287.

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.

Varis. A.L. 1972. The biology of *Lygus rugulipennis* Popp. (Het., Miridae) and the damage caused by this species to sugar beet. Ann. Agric. Fenn. 11: 1-56.

Wene, G. P., and L.W. Sheets. 1964. Lygus bug injury to pre-squaring cotton. Ariz. Agric. Exp. Stn. Tech. Bull. 166. 25 pp.

Table 1. Percentage of plants with damaged terminals and mean no. of true leaves per plant determined at 10 days after injury treatments.

	% Plants with damaged Terminals at 10 DAT		**Mean no. True Leaves/Plant at 10 DAT**	
Treatment[†]	**30 May**	**15 June**	**30 May**	**15 June**
Ck	19	5	4.17	6.88
M1	65		1.36	
B1	52		1.53	
M4		12		5.00
B4		11		6.88
Pr > F	*<0.0001*	*0.33*	*<0.0001*	*<0.0001*
LSD .05	*2*		*0.42*	*0.65*

[†]Bug (B) or Mechanical (M) injury treatments were imposed at 1st or 4th true leaf stages (12 or 28 days after planting).

Table 2. Mean[1] number of sympodial nodes per plant observed for each terminal injury treatment up to appearance of 1st flowers.

Date of sample	**Days after planting**	**Terminal Injury Treatment**						
		Ck	**M1**	**B1**	**M4**	**B4**	**Pr > F**	**LSD .05**
18 June	41	2.82	0	0	0	0	0.0001	0.30
26 June	49	4.78	4.03	3.75	2.28	4.08	0.0015	0.95
2 July	55	6.93	5.50	4.95	3.33	6.15	<0.0001	0.84
9 July[2]	62	9.23	7.48	6.83	5.55	7.78	<0.0001	0.93
16 July[3]	69	9.35	8.15	8.18	7.28	8.68	<0.0001	0.57

[1]Means of 5 consecutive plants per row on 2 rows per plot.
[2]1st flowers observed in Ck plots.
[3] 1st flowers observed in M and B injury treatment plots

Table 3. Mean % of plants producing squares 27 June (50 DAP[†]) following manual or bug induced injury at the 1st or 4th true leaf stage.

Treatment	**% Plants Squaring**
Ck	86
M1	63
B1	53
M4	41
B4	82
Pr > F	*<0.0001*
LSD .05	*13*

[†]Days after planting

Table 4. Mean maturity date and days to physiological cut-out (NAWF=5) associated with injury treatments from one tarnished plant bug nymph or by mechanical injury to the terminal of cotton at the 1 or 4-leaf stage of growth.

Treatment	Mean Maturity Date†	Days to Physiological Cutout
Ck	145	99
M1	147	100
B1	148	100
M4	148	97
B4	148	99
Pr>F	*0.75*	*0.70*

† The mean maturity date is expressed as days after planting and is equal to the sum of each sequential harvest weight times the number of days after planting for each harvest date, that number is then divided by the sum total weight of harvest.

Table 5. Mean lint yield observed following terminal injury treatments at 1 or 4-leaf stages by tarnished plant bug nymphs or mechanical injury†.

	Mean lint yield (lbs/ac) for each date of harvest				
Treatment	12-Sep	17-Sep	26-Sep	9-Oct	17-Oct
Ck	311	456	690	956	1033
Ml	245	375	506	763	1058
B1	141	254	359	688	1071
M4	143	241	422	803	1139
B4	200	315	438	727	1288
Pr > F	*0.11*	*0.03*	*0.01*	*0.27*	*0.61*
$LSD_{.05}$		*142*	*155*		

†Lint yield was calculated as 33% of seedcotton weight.

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

Treatment	Mean no. of Monopodial branches/plant†	% Yield from monopodial branches
Ck	1.4	16
M1	1.4	19
B1	1.3	26
M4	2.1	42
B4	1.3	18
Pr>F	*0.0024*	*<0.0001*
$LSD_{.05}$	*0.36*	*7.94*

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

Table 7. Final end-of-season plant mapping observations made for each terminal injury treatment[†].

Category	Ck	M1	B1	M4	B4	$LSD_{.05}$
Plant Height (inches)	50.7	49.5	47.8	50.5	53.0	ns
1st Sympodial Node	7.2	7.2	6.8	7.3	7.6	ns
Highest Sympodia with 2 nodes	13.9	12.5	13.7	11.0	13.6	ns
No. of Effective Sympodia	13.3	11.9	13.1	10.2	12.7	2.16
No. of Sympodia with 1st Position Bolls	5.6	5.4	5.7	5.0	5.2	ns
No. of Sympodia with 2nd Position Bolls	2.2	1.8	2.2	1.5	1.9	ns
No. of Sympodia with 1st and 2nd Position Bolls	3.5	2.2	3.1	1.8	3.3	1.17
No. of Monopodia	1.7	1.8	1.7	2.5	1.8	0.57
Total Bolls/Plant	26.0	20.1	24.1	19.3	21.1	ns
Total Monopodial Bolls/Plant	5.7	5.0	6.4	8.2	4.9	ns
% Total Bolls in 1st Position	36.0	37.9	36.6	35.7	42.9	ns
% Total Bolls in 2nd Position	22.5	19.8	21.7	17.3	26.1	ns
% Total Bolls in Outer Position	18.6	16.0	15.9	3.6	14.3	8.73
% Total Bolls on Monopodia	22.5	24.6	25.7	43.1	24.9	12.44
% Boll Retention -1st Position	49.1	43.7	47.9	43.9	45.8	ns
% Boll Retention -2nd Position	41.1	32.0	38.7	31.8	39.1	ns
% Total Bolls on Extra-Axillary	0.40	1.8	0.1	0.3	0.2	ns
% Early Boll Retention	55.6	46.3	49.1	46.9	57.2	ns
Total Nodes/Plant	24.7	23.7	24.2	21.8	25.2	ns
Internode Length (inches)	2.1	2.1	2.0	2.3	2.1	ns

[†]means of 8 plants per plot.

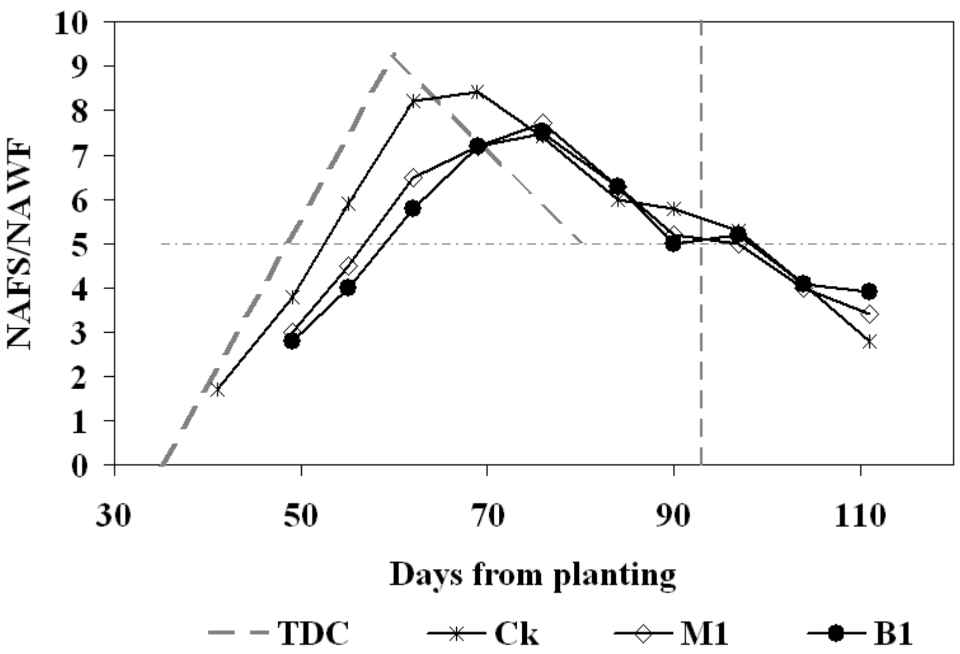

Figure 1. COTMAN™ target development curve (tdc) and crop growth curves for untreated check plants and plants injured mechanically or infested with one 3rd instar tarnished plant bug. Treatments were made at the 1-leaf stage. The latest possible cutout date for the region was 9 Aug. 93 days after planting.

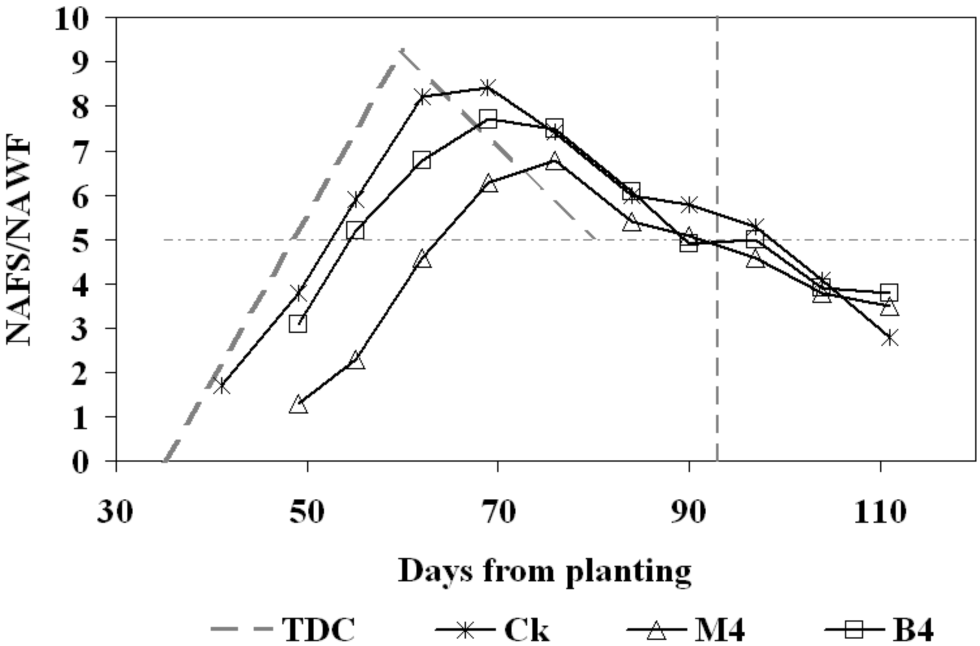

Figure 2. COTMAN™ target development curve (tdc) and crop growth curves for untreated check plants and plants injured mechanically or infested with one 3rd instar tarnished plant bug. Treatments were made at the 4-leaf stage. The latest possible cutout date for the region was 9 Aug. 93 days after planting.