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RESPONSE OF COTTON BH-121 TO SQUARE LOSS AT DIFFERENT GROWTH STAGES

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Abstract: Studies of the response of BH-121 variety of cotton to total square removal was conducted to determine the impact of bollworm damage on phenology and yield of cotton by total fruit loss when sown at different planting dates and growth stages at Khokhar Farm, Multan. The bollworm damage (100% square removal) was simulated by manually removing all squares for three weeks each of early, mid and late flowering stages at a three days interval. The vegetative growth (number of main-stem nodes and plant height) in 100% square removal treatments increased significantly than that of undamaged control treatments among all growth stages and crop sowing dates. In contrast, the reproductive growth (number of squares per plant and seed cotton yield) significantly decreased in 100% simulation treatments than that of undamaged control treatments at different growth stages of crop.

Keywords: BH-121 variety of cotton, compensation, crop phenology, simulated damage, yield.

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is an indeterminate perennial plant that is grown as an annual crop; vegetative growth continues after flower initiation and produces fruit as long as season persists. The growth pattern of cotton enables it to withstand the loss of many fruiting structures without significant reductions in yield. Thus cotton plant has the ability to compensate from damaged or abscised fruiting structures over time. The time for compensation can delay harvest operations and increase the risk of adverse weather effects. This shows that when plants are young, they have sufficient time to recover fully [Montez and Goodell 1994].

The cotton plant is extremely susceptible to pest attack. Among pests, the cotton bollworms [*Helicoverpa armigera* (Hübner), *Pectinophora gossypiella* (Saunders), *Earias insulana* (Boisduval) and *Earias vittella* (Fabricius)] cause 30-40% losses in seed cotton yield [Ahmad 1980]. However the cotton plant has the ability to reproduce fruiting parts and to certain extent is able to recover from the damage especially during the early growing season. Such damage can be simulated manually by the removal of appropriate plant structures. This approach can control precisely the amounts of damage and so explore the limits of the capacity of crop to compensate for damage. Furthermore, much smaller plots and greater replications can be used to increase the precision of experimentation [Brook *et al*. 1992]. The loss of reproductive structures can sometimes alter the physiological growth and development of the plant. Assimilates normally incorporated into these missing structures are redirected to other plant sinks, if available. With the determinate species, fruit loss that is induced by insect, disease, physiological damage, or unfavorable weather can have devasting effects on yields. Indeterminate plants, however, are able to withstand a limited exposure to fruit-abscising influences, since these plants flower over a longer period of time [Pettigrew *et al*. 1992].

Previous fruit removal studies on cotton have demonstrated that the removal of reproductive structures can increase vegetative growth [Phelps *et al*. 1997, Moss and Bednarz 1999, Bednarz and Roberts 2000]. Abaye *et al*. [2001] reported that higher square removal rate showed slow nodal development. Lentz [1990], Brook *et al*. [1992], Wilson and Sadras [1998], Gore *et al*. [2000] and Stewart *et al*. [2001] studied that heavy fruit loss significantly delayed crop maturity at the time of harvest. Wilson [1986] evaluated that fruit removal had no effect on crop maturity. Kennedy *et al*. [1991], Pettigrew *et al.* [1992], Montez and Goodell [1994], Holman *et al*. [1997], Phelps *et al*. [1997], Moss and Bednarz [1999], and Bednarz and Roberts [2000] determined that square removal resulted increased plant height. Goodell *et al*. [1990] stated that late season square removal did not affected the final plant height.

Turnipseed *et al*. [1995] reported that early-planted cotton plants produced significantly more squares than that of late planted crop plants. Brook *et al*. [1992], Montez and Goodell [1994], Brown *et al*. [2000], Gore *et al*. [2000], and Abaye *et al*. [2000] demonstrated that extremely heavy fruit damage (100% defruiting) greatly reduced the yield. Terry [1992], Mann *et al*. [1995], Turnipseed *et al*. [1995], Jones *et al*. [1996a, b], Gore *et al*. [1998], Wilson and Sadras [1998], Moss and Bednarz [1999] and Stewart *et al*. [2001] reported that even 100% early square removal produced only slightly lower yields than that of control treatments. Mid and late season square removal produced significantly lower yields than control plots, as compared to the early season square removal.

The objective of this study was to evaluate the impact of simulated bollworm damage at different growth stages on phenology and yield of cotton sown at different planting dates.

MATERIALS AND METHODS

The trials were conducted on a commercial variety of BH-121 at the Khokhar Farm, Shujabad Road, Multan during 2002-03 crop season. The crop was sown on beds (in rows) by dibbling method on four different sowing dates *viz*., 24th May 2002, 31st May 2002, 7th June 2002 and 14th June 2002. The total experimental area was 67.56 m x 86.48 m (5842.58 m^2), which was divided into 96 plots and size of plot was 4.50 m x 4.50 m (20.25 m^2). The distances between rows and plants were 75cm and 23cm respectively.

The treatments consisted of four sowing dates and two simulated bollworm damages. The treatments were arranged in split plot design with three replications. Main plot and sub plot treatments comprised of four levels of sowing dates and two levels of simulated bollworm damages (100% square removal, and 0% undamaged control). Thus there were eight treatments (4x2) in the study.
The experiments were carried out at three growth stages of cotton plants, for three weeks each *viz*., early flowering stage (40 days after sowing), mid flowering stage (60 days after sowing) and late flowering stage (80 days after sowing).
At early flowering stage, ten experimental cotton plants were selected randomly in each plot. The five plants were defruited 100%, by manual removal of the pin head squares, for three weeks at a three days interval, while other five plants were kept intact (0% defruiting). At mid and late flowering stages, similar procedure was followed.
All the treatments including control (0% defruiting) were observed for bollworms infestation and were kept free from bollworm population. To minimize the effects of sucking insect pests, suitable insecticide was sprayed. All the agronomic practices were carried out according to the normal recommendations of Central Cotton Research Institute, Multan [Anonymous 2002].
At the end of each experiment (comprising of three weeks), plant mapping was carried out in order to observe the number of squares and main-stem nodes formed per plant, and to measure plant height. The seed cotton yield per plant was also recorded at crop maturity.
The experiments were terminated on November 24, with a single picking. The seed cotton harvested from each plot was placed in paper bags for weighing on an electrical balance (Chyo Balance Corp MJ-500). The percent compensation was computed from the number of squares formed per plant, the number of main-stem nodes formed per plant, the average plant height and the data of yield per plant for each situation. The responses expressed by the plants as a result of the 100% simulated bollworm damages were calculated by using the following formula:

$$\% \text{ Compensation} = \frac{S - S_0}{S_0} \times 100$$

S = Simulated for 100% square loss, S_0 = Without square loss.

RESULTS AND DISCUSSION

EFFECT OF DEFRUITING ON NUMBER OF NODES

The mean number of nodes on main stem, per plant was significantly different for four sowing dates (F=9.60; df=3; P=0.01) at early flowering stage (10th July 2002 to 31st July 2002). The crop sown on D_1 (24th May) showed maximum number of nodes per plant following D_2 (31st May), D_3 (7th June) and D_4 (14th June). This was because of the fact that D_1 crop plants had passed more time for its vegetative growth than that of D_2, D_3, and D_4 crop plants, as compensation requires time. The mean number of nodes on main stem, formed per plant was significantly different (F=710.7795.94; df=1; P=0.00) for S (28.81) and S_0 (17.04) as given in Table 1. These data indicated that the mean number of nodes in square removal treatments increased than that of undamaged control treatments because of 100% removal of fruit. Phelps *et al*. [1997], Moss and Bednarz [1999], and Bednarz and Roberts [2000] reported that number of main-stem nodes increased by increasing the intensity of fruit removal. The vegetative response of cotton indicates a shift in the carbohydrate source/sink relationship in which the severe (100%) square loss treatments diverted excess carbohydrate to vegetative growth. In contrast, the control treatments with no square removal had sufficient demand from fruiting structures to handle the available resource [Montez and Goodell 1994]. Goodell *et al.* [1990] noted in their work that excessive vegetative growth is associated with early fruit loss in cotton plant.

Table 1: Mean number of nodes formed by cotton plants in response of sowing dates variation; and 100% simulated bollworm damage and undamaged control at early flowering stage (10th July 2002 to 31st July 2002).

Treatments	No. of nodes per plant
D_1 = 24th May	24.30 a
D_2 = 31st May	23.02 b
D_3 = 7 th June	22.53 bc
D_4 = 14th June	21.87 c
S = Simulated for 100% square loss	28.81 a
S_0 = Without square loss	17.04 b

Means followed by the same letters are non-significantly different (LSD; P = 0.05).

Table 2: Mean number of nodes formed by cotton plants sown at different dates in response of 100% simulated bollworm damage and undamaged control at mid flowering stage (1st August 2002 to 21st August 2002).

Treatments	No. of nodes per plant	Treatments	No. of nodes per plant
D_1 S	32.07 a	D_1 S_0	25.23 cd
D_2 S	25.40 c	D_2 S_0	22.07 d
D_3 S	28.67 b	D_3 S_0	16.20 e
D_4 S	26.20 bc	D_4 S_0	14.87 e

Means followed by the same letters are non-significantly different (LSD; P = 0.0,
D1S = Simulated for 100% square loss on 24th May, D1S_0 = Without square loss on 24th May,
D2S = Simulated for 100% square loss on 31st May, D1S_0 = Without square loss on 31st May,
D1S = Simulated for 100% square loss on 7th June, D1S_0 = Without square loss on 7th June,
D1S = Simulated for 100% square loss on 14th June, D1S_0 = Without square loss on 14th June.

At mid flowering stage (1st August 2002 to 21st August 2002), the average number of nodes on main stem, formed per plant was also significantly different in the interaction between sowing dates and simulated bollworm damage (F=9.03; df=3; P=0.00). The maximum number of nodes formed per plant (32.07) was observed in D_1S and the minimum number of nodes formed per plant (14.87) was observed in D_4S_0 (Table 2). These data indicated that the number of nodes in square removal treatments increased than that of undamaged control treatments because of 100% removal of fruit.

At late flowering stage (22nd August 2002 to 13th September 2002), the average number of nodes on main stem, formed per plant was significantly different (Table 3) for four sowing dates ($F=20.21$; $df=3$; $P=0.00$). The crop sown on 24th May (D_1) showed maximum number of nodes per plant following D_3 (7th June), D_2 (31st May) and D_4 (14th June). This was because of the fact that D_1 crop plants had passed more time for its vegetative growth than that of D_2, D_3, and D_4 crop plants, as compensation requires time.

Percent compensation in number of main-stem nodes formed per plant was significantly different ($F=8.03$; $df=3$; $P=0.01$) for four sowing dates when investigating at mid flowering stage (1st August 2002 to 21st August 2002). The D_3 (7th June) and D_4 (14th June) were found to have statistically more or less similar % compensation number of nodes formed per plant but significantly different from D_1 (24th May) and D_2 (31st May) as displayed in Table 4. In literature no reports for % compensation in number of nodes in response of mid growth stages of crop were available; therefore comparison could not be possible.

Table 3: Mean number of nodes formed by cotton plants sown at different dates in response of 100% simulated bollworm damage at late flowering stage (22nd August 2002 to 13th September 2002).

Treatments	No. of nodes per plant
D_1 = 24th May	33.63 a
D_2 = 31st May	26.88 bc
D_3 = 7 th June	28.53 b
D_4 = 14th June	24.33 c

Means followed by the same letters are non-significantly different (LSD; P = 0.05).

Table 4: Mean % compensation in number of nodes formed by cotton plants sown at different dates in response of 100% simulated bollworm damage increased than that of undamaged control treatments at mid flowering stage (1st August 2002 to 21st August 2002).

Treatments	% compensation
D_1 = 24th May	28.53 b
D_2 = 31st May	15.14 b
D_3 = 7 th June	80.32 a
D_4 = 14th June	76.31 a

Means followed by the same letters are non-significantly different (LSD; P = 0.05).

The mean percent compensation in number of main-stem nodes formed per plant was non-significantly different among the four sowing dates when demonstrated at early and late flowering stages.

EFFECT OF DEFRUITING ON PLANT HEIGHT

The plant height (cm) was significantly different among the interaction between four sowing dates and simulated bollworm damage ($F=11.96$; $df=3$; $P=0.00$) when investigating at early flowering stage (10th July 2002 to 31st July 2002). D_1S and D_2S_0 expressed maximum and minimum plant height, respectively (Table 5). These results indicated that mean plant height increased in all 100% simulation treatments than that of undamaged control treatments. Kennedy *et al*. [1991], Pettigrew *et al.* [1992], Montez and Goodell [1994], Holman *et al*. [1997], Phelps *et al*. [1997], Moss and Bednarz [1999], and Bednarz and Roberts [2000] who reported that square removal resulted increased plant height. On contrary, Delaney *et al.* [1998] investigated that plant height was not affected by terminal removal. Severe fruit loss diverted excess carbohydrate to vegetative growth whereas control treatments had sufficient demand from fruiting structures to handle the available resource [Montez and Goodell 1994].

Table 5: Mean plant height of cotton plants sown at different dates in response of 100% simulated bollworm damage and undamaged control at early flowering stage (10th July 2002 to 31st July 2002).

Treatments	Plant height (cm)	Treatments	Plant height (cm)
D_1 S= 24th May	113.3 a	D_1 S_O= 24th May	99.40 b
D_2 S= 31st May	91.13 cd	D_2 S_O = 31st May	80.60 e
D_3 S= 7 th June	108.2 a	D_3 S_O= 7 th June	91.73 cd
D_4 S= 14th June	96.57 bc	D_4 S_O= 14th June	87.10 d

Means followed by the same letters are non-significantly different (LSD; P = 0.05).

Table 6: Mean plant height of cotton plants in response of sowing dates variation; and 100% simulated bollworm damage and undamaged control at mid flowering stage (1st August 2002 to 21st August 2002).

Treatments	Plant height (cm)
D_1 = 24th May	137.4 a
D_2 = 31st May	122.1 b
D_3 = 7 th June	104.1 c
D_4 = 14th June	83.65 d
S = Simulated for 100% square loss	117.20 a
S_0 = Without square loss	106.38 b

Means followed by the same letters are non-significantly different (LSD; P = 0.05).

The plant height (cm) was significantly different for four sowing dates (F=33.14; df=3; P=0.00) when investigating at mid flowering stage (1st August 2002 to 21st August 2002). The crop sown on 24th May 2002 (D_1) showed maximum plant height following D_2 (31st May), D_3 (7th June) and D_4 (14th June) as displayed in Table 6. This was because of the fact that D_1 crop plants had passed more time for its vegetative growth than that of D_2, D_3, and D_4 crop plants, as compensation requires time. The mean plant height was significantly different (F=218.01; df=1; P=0.00) for S (117.2) and S_0 (106.38) as given in Table 6. Montez and Goodell [1994] stated that plant height was significantly increased in case of severe square removal.

The average percent compensation in plant height was significantly different for four sowing dates (F=8.62; df=3; P=0.01) when investigating at early flowering stage (10th July 2002 to 31st July 2002). The treatments D_1 (24th May), D_2 (31st May) and D_4 (14th June) were found to have statistically more or less similar % compensation in plant height but significantly different from D_3 (7th June) as displayed in Table 7.

Table 7: Mean % compensation in plant height of cotton plants sown at different dates in response of 100% simulated bollworm damage increased than that of undamaged control treatments at early flowering stage (10^{th} July 2002 to 31^{st} July 2002).

Treatments	% compensation
D_1 = 24th May	14.05 b
D_2 = 31st May	13.07 b
D_3 = 7 th June	17.95 a
D_4 = 14th June	10.86 b

Means followed by the same letters are non-significantly different (LSD; P = 0.05).

The plant height (cm) for four sowing dates at late flowering stage and the mean % compensation in plant height for four sowing dates at mid and late flowering stages were found to be non-significantly different.

EFFECT OF DEFRUITING ON NUMBER OF SQUARES

The mean number of squares formed per plant was significantly different among the interaction between sowing dates and simulated bollworm damage (F=6.55; df=3; P=0.01) when investigating at early flowering stage (10^{th} July 2002 to 31^{st} July 2002). The treatments D_1S_0 and D_3S expressed maximum and minimum plant height, respectively (Table 8). These results revealed that number of squares decreased in almost all 100% simulation treatments than that of undamaged control treatments. Turnipseed *et al.* [1995] and Pitman *et al.* [2000] also reported that late planted crop plots produced significantly lower yields following 100% removal for four weeks than control plots.

Table 8: Mean number of squares formed by cotton plants at different dates in response of 100% simulated bollworm damage and undamaged control at early flowering stage (10^{th} July 2002 to 31^{st} July 2002).

Treatments	No. of squares per plant	Treatments	No. of squares per plant
$D_1 S$	25.00 b	$D_1 S_0$	61.47 a
$D_2 S$	16.40 bc	$D_2 S_0$	50.80 a
$D_3 S$	7.80 c	$D_3 S_0$	24.53 b
$D_4 S$	8.13 c	$D_4 S_0$	12.40 bc

Means followed by the same letters are non-significantly different (LSD; P = 0.05).
D1S = Simulated for 100% square loss on 24^{th} May, $D1S_0$ = Without square loss on 24^{th} May,
D2S = Simulated for 100% square loss on 31^{st} May, $D1S_0$ = Without square loss on 31^{st} May,
D1S = Simulated for 100% square loss on 7^{th} June, $D1S_0$ = Without square loss on 7^{th} June,
D1S = Simulated for 100% square loss on 14^{th} June, $D1S_0$ = Without square loss on 14^{th} June

The mean number of squares formed per plant was significantly different (F=9.66; df=3; P=0.01) for four sowing dates when investigating at mid flowering stage (1^{st} August 2002 to 21^{st} August 2002). The crop plants in D_1 (24^{th} May 2002) showed maximum number of squares following D_2 (31^{st} May), D_4 (14^{th} June) and D_3 (7^{th} June). This was because of the fact that D_1 crop plants had passed more time for its vegetative growth than that of D_2, D_3, and D_4 crop plants as compensation requires time (Table 9).

The mean number of squares formed per plant was significantly different (F=44.55; df=1; P=0.00) for simulated bollworm damage (F=43.97; df=3; P=0.00) when investigating at late flowering stage (22^{nd} August 2002 to 13^{th} September 2002). These results revealed that number of squares decreased significantly in simulation treatments than that of undamaged control treatments (Table 10). The findings are also in accordance with those of Brook *et al*. [1992], Montez and Goodell [1994], Brown *et al*. [2000], Gore *et al*. [2000], and Abaye *et al*. [2000] who reported that extremely heavy fruit damage (100% defruiting) greatly reduced yield.

Table 9: Mean number of squares formed by cotton plants sown at different dates in response of 100% simulated bollworm damage at mid flowering stage (1st August 2002 to 21st August 2002).

Treatments	No. of squares per plant
D_1 = 24th May	105.0 a
D_2 = 31st May	92.77 ab
D_3 = 7 th June	66.30 c
D_4 = 14th June	77.93 bc

Means followed by the same letters are non-significantly different (LSD; P = 0.05).

Table 10: Mean number of squares formed by cotton plants sown at different dates in response of 100% simulated in response of 100% simulated bollworm damage and undamaged control at mid and late flowering stages.

Treatments	No. of squares per plant
S= Simulated at 100% square loss	65.71 b
S_0 = Without square loss	104.77 a

The mean % compensation in number of squares formed per plant was non-significantly different for four sowing dates when investigating at early, mid and late flowering stages.

EFFECT OF DEFRUITING ON SEED COTTON YIELD

Based on the mean seed cotton yield (gm plant^{-1}), the simulated bollworm damages (F=55.73; df=1; P=0.00), (F=51.82; df=1; P=0.00) and (F=115.07; df=1; P=0.00) were found significantly different when demonstrating at early, mid and late flowering stages, respectively (Table 11). These results agree with those of Dunnam *et al*. [1943], Brook *et al*. [1992], Montez and Goodell [1994], Phelps *et al*. [1998], Brown *et al*. [2000], Gore *et al*. [2000], Abaye *et al*. [2000] and Brown *et al*. [2001] who reported that 100% defruiting definitely resulted in significant yield loss.

The mean % compensation in seed cotton yield was non-significantly different for four sowing dates when investigating at early, mid and late flowering stages.

Table 11: Mean values of seed cotton yield harvested in response of 100% simulated bollworm damage and undamaged control at early, mid and late flowering stages.

Treatments	Early Yield (gm plant^{-1})	Mid Yield (gm plant^{-1})	Late Yield (gm plant^{-1})
S= Simulated at 100% square loss	82.29 b	62.20 b	26.12 b
S_0 = Without square loss	90.40 a	88.33 a	90.14 a

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