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Response of Cotton NIAB-Krishma to Square Loss at Different Growth Stages

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Abstract.- Studies of the response of NIAB-Krishma variety of cotton to total square removal were 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) signif1cantly decreased in 100% simulation treatments than that of undamaged control treatments at different growth stages of crop.

Key words: NIAB-Krishma variety of Cotton, simulated damage, compensation, crop phenology.

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) has a capacity to partially compensate for the loss of floral buds (squares). The cotton plant is extremely susceptible to pest attack. Among pests is, the cotton bollworms [*Helicoverpa armigera* (Hubner), *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 recover from the damage especially during early growing season rather than that of mid and late growing seasons. 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.

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 devastating 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).

Cotton 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 (Brown *et al.,* 2001). The indeterminate growth pattern of cotton enables it to withstand the loss of many fruiting structures without significant reductions in yield. However compensation requires time which 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 objective of this study was to evaluate the impact of bollworm damage on phenology and yield of cotton by total fruit loss when sown at different planting dates and growth stages.

MATERIALS AND METHODS

The trials were conducted on a commercial variety of NIAB-Krishma 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. The total experimental area was 67.56×86.48 m (5842.58 m^2), which was divided into 96 plots and size of plot was 4.50×4.50 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

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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 by square removal as mentioned below. Thus there were eight treatments (4x2) in the study.

Main plot treatment		**Sub plot treatment (square removal or simulated bollworms damage)**	
Plot	**Date of survey**	**Plot**	**Treatment**
D_1	24th May 2002	S	100% square removal
D_2	31st May 2002	S_0	No square removal (cotton)
D_3	7th June 2002		
D_4	14th June 2002		

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). Likewise at mid and late flowering stages, ten experimental cotton plants were selected randomly in each plot. The five plants were defruited 100%, by manual removal of the pin head squares and bolls as well, for three weeks at a three days interval, while keeping other five plants intact (0% defruiting).

The damage inflicted was thus probably more severe than real insect pest attack. Although removal of squares and bolls did not exactly mimic the effect of insect damage; it was nonetheless sufficiently similar to pest damage to extrapolate from these experiments to the real world of pest management (Wilson and Bishop, 1982).

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, 2002, 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 under study. The responses expressed by the plants as a result of the 100% simulated bollworm damages were calculated by using the following formula:

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

Data for each experiment were analyzed independently by using the analysis of variance (ANOVA) in MSTAT-C (a computer based statistics programme).

RESULTS AND DISCUSSION

Across all experiments, the damage imposed (100% fruit loss) had striking visual effects among all sowing dates and different growth stages of crop in the field.

Effect of defruiting on number of nodes

The mean number of nodes on main stem, formed per plant was significantly different among the interaction between four sowing dates and simulated bollworm damage (F=10.55; df=3; P=0.00) when investigating at early flowering stage (10th July 2002 to 31st July 2002). The maximum number of nodes formed per plant (27.03) was recorded in 02S and the minimum number of nodes formed per plant (14.97) was recorded in 03S0 (Table I). These data indicated that the mean number of nodes for 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.* (l990) noted in their work that excessive vegetative growth is associated with early fruit loss in cotton plant.

Table I.- Mean number of nodes formed by 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	No. of nodes per plant	Treatment	No. of nodes per plant
D_1S	21.90c	D_1S_0	15.00c
D_2S	27.03a	D_2S_0	17.80d
D_3S	25.40b	D_3S_0	14.97e
D_4S	23.07c	D_4S_0	16.80d

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

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=10.34; df=3: P=0.00). The maximum number of nodes formed per plant (24.73) was observed in 02S and the minimum number of nodes formed per plant (12.87) was observed in D_3S_0 (Table II). Number of nodes in 100% square removal treatments was increased than that of undamaged control treatments. These results are in conformity of Lei (2001) who stated that the loss of fruit can lead to an increase in vegetative and reproductive growth depending upon the number of fruit remaining on the plant. The vegetative growth is inversely proportional to the number of fruit remaining on the plant.

The mean number of nodes on main stem, formed per plant was significantly different only for simulated bollworm damage (F=8.31; df=l; P=0.02) when demonstrated at late flowering stage (22nd August 2002 to 13th September 2002). The number of nodes formed by the undamaged plants was higher at the later growth stage (Table III). The results were supported by Goodell *et al.* (1990) who stated that late season square removal did not affect the number of main-stem nodes.

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

Treatments	No. of nodes per plant	Treatment	No. of nodes per plant
D_1S	24.67a	D_1S_0	21.07b
D_2S	24.73a	D_2S_0	23.07ab
D_3S	18.80c	D_3S_0	12.87c
D_4S	24.60a	D_4S_0	15.87d

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

Table III.- Mean number of nodes formed by cotton plants sown at different dates in response of 100% simulated bollworm damage and undamaged control at early flowering stage (22nd August 2002 to 13th September 2002).

Treatments	No. of nodes per plant
S	25.108b
S_0	26.600a

The mean percent compensation in number of main-stem nodes formed per plant was significantly different for four sowing dates when investigating at early flowering stage (10th July 2002 to 31st July 2002). The D_1 (24th May) and D_4 (14th June) had statistically more or less similar percent compensation in number of nodes but significantly different from D_3 (7th June) and D_2 (31st May) as displayed in Table IV. It was because of the fact that if there is a significant number of fruit remaining, then substitution of lost fruit can maintain the carbon demand by fruit without resuming vegetative growth. If few fruit remain, then the surplus carbon will be used for vegetative growth until fruit numbers build up again.

Table IV.- Mean % compensation in number of nodes formed per plant sown at different dates in response of 100% simulated bollworm damage increased than that of undamaged control treatment at early (10th July 2002 to 31st July 2002) and mid (1st August 2002 to 21st August 2002) flowering stages.

Treatments	% compensation at early flowering	% compensation at mid flowering
D_1	46.72bc	17.28b
D_2	51.90b	12.65b
D_3	69.85a	47.87a
D_4	37.19c	55.12a

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

At mid flowering stage (1st August 2002 to 21st August 2002), the percent compensation in number of main-stem nodes formed per plant was also significantly different for four sowing dates (F=9.45; df=3; P=0.01). The crop sown on 7th June 2002 (D_3) and 14th June 2002 (D_4) had more percent compensation in number of main-stem nodes than that of 24th May 2002 (D_1) and 31st May 2002 (D_2) because in July when there was no fruiting body on plant after defruiting, the plant expressed the more % compensation in number of nodes (Table IV). The number of nodes was less when the squares were removed in the mid season of flowering (1st August to 21st August).

The mean percent compensation in number of main-stem nodes formed per plant was non-significantly different among the four sowing dates (F=0.39; df=3; P>0.05) when demonstrated at late flowering stage (22nd August 2002 to 13th September 2002).

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=14.90;df=3; P=0.00) when investigating at early flowering stage (l0th July 2002 to 31st July 2002). D_1S and D_2S_0 expressed maximum and minimum plant height, respectively (Table V). 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) 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 V.- 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)	Treatment	Plant height (cm)
D_1S	87.47a	D_1S_0	81.73b
D_2S	75.20c	D_2S_0	63.87e
D_3S	83.13b	D_3S_0	69.93d
D_4S	81.63b	D_4S_0	76.27c

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

The four sowing dates (F=170.53; df=3; P=0.00) were significantly different 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 VI. 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. In literature no reports for % compensation in plant height in response of mid growth stages of crop were available; therefore comparison could not be possible. The mean plant height was significantly different (F=95.94; df=1; P=0.00) for S_0 (94.90) and S_0 (86.05) as given in Table VI. Montez and Goodell (1994) stated that plant height was significantly increased in case of severe square removal.

Likewise at late flowering stage (22nd August 2002 to 13th September 2002), the sowing dates (F=6.75; df=3; P=0.02) were significantly different. The crop plants shown on D_1, D_4 and D_2 were found to have statistically more or less similar plant height but significantly different from D_3 (Table VI). The crop sown on D_3 and D_4 showed more plant height because there was no fruiting body on plant after defruiting at mid June and July and therefore plant expressed the more % compensation in plant height. The plant height was also significantly different (F=7.24; df=l; P=0.02) for simulated bollworm damage (Table VI).

Table VI.- 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) and late flowering stage (22nd August 2002 to 13th September 2002).

Treatments	Plant height at mid flowering stage	Plant height at late flowering stage
D_1	111.1a	113.9ab
D_2	101.3b	106.2b
D_3	82.23c	123.3a
D_4	67.37d	108.2b
S	94.90a	112.483b
S_0	86.05b	113.317a

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

The mean % compensation in plant height was significantly different for four sowing dates (F=23.23; df=3; P=0.00) at early flowering stage and sowing dates (F=8.94; df=3; P=0.01) at mid flowering stage. The crop sown on D_3 and D_4 also showed more plant height (Table VII). The % compensation in plant height was non-significantly different for four sowing dates (F=23.23; df=3; P=0.00) when investigating at late flowering stage (22nd August 2002 to 13th September 2002).

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=8.25; df=3: P=0.00) when investigating at early flowering stage (10th July) 2002 to 31st July 2002). The maximum number of squares formed per plant (123.4) was found in D_1S_0, The minimum number of squares formed per plant (10.20) was found in D_4S (Table VIII). 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 VII.- Mean % compensation in plant height (cm) sown at different dates in response of 100% simulated bollworm damage increased than that of undamaged control treatments at early (10th July 2002 to 31st July 2002) and mid (1st August 2002 to 21st August 2002) flowering stages.

Treatments	Plant height at mid flowering stage	Plant height at late flowering stage
D_1	7.07b	8.98b
D_2	17.75a	9.36b
D_3	18.87a	7.01b
D_4	7.04b	18.26a

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

Table VIII.- Mean number of squares formed by 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	No. of squares per plant	Treatment	No. of squares per plant
D_1S	43.33b	D_1S_0	123.4a
D_2S	34.67bc	D_2S_0	98.53a
D_3S	14.40c	D_3S_0	45.07b
D_4S	10.20c	D_4S_0	21.13bc

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

The average number of squares formed per plant were significantly different for simulated bollworm damage (F=151.55; df=l; P=0.00) at mid flowering stage and simulated bollworm damage (F=51.96; df=l; P=0.00) at late flowering stage. These results indicated that number of squares decreased in simulation treatments than that or undamaged control treatments because of the total square loss (Table IX). 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 IX.- Mean number of squares formed by cotton plants in response of 100% simulated bollworm damage and undamaged cotton at mid flowering stage (1st August 2002 to 21st August 2002) and late flowering stage (22nd August 2002 to 13th September 2002).

Treatments	Squares % at mid flowering stage	Squares at late flowering stage
S	77.68b	60.46b
S_1	155.78a	107.80a

The mean percent 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), the sowing dates (F=12.50: df=3; P=0.00), (F=9.23: df=3; P=0.00) and (F=13.49: df=3; P=0.00) were found significantly different when demonstrating at early, mid and late flowering stages respectively. At all growth stages, D_4 (14th June) and D_1 (24th May) had maximum and minimum seed cotton yield, respectively (Table X). The crop sown on 7th June 2002 (D_1) and 14th June 2002 (D_4) yielded more than that of 24th May 2002 (D_1) and 31st May 2002 (D_2) because D_3 and D_4 plants were terminated late in the season as compared to the D_1, and D_2 plants (terminated early). In literature no reports for decreasing seed cotton yield in response of early sowing were available; therefore comparison could not be possible. At all growth stages, the 100% simulation damages were also significantly different than that of undamaged control treatments. 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.

Table X.- Mean values of seed cotton yield harvested in response of sowing dates variation; and 100% simulated bollworm damage and undamaged control at early, mid and late flowering stage.

Treatments	Early yield (gm/plant)	Mid yield (gm/plant)	Late yield (gm/plant)
D_1S	57.30b	48.74b	59.66a
D_2S	68.14b	56.77b	55.59a
D_3S	83.93a	75.28a	46.06b
D_4S	85.69a	72.99a	38.89b
S	72.44b	50.98b	24.43b
S_0	75.09a	75.89a	75.66a

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

The % compensation in seed cotton yield for sowing dates was non-significantly different when investigating at early and late flowering stages. But the mean percent compensation in seed cotton yield of four sowing dates (F=9.35; df=3; P=0.01) was significantly different when demonstrating at mid flowering stage (1st August 2002 to 21st August 2002). D_3 and D_4 crop plants yielded more than that of D_1 and D_2 crop plants because D_3 and D_4 plants were terminated late in the season (Table XI).

Table XI.- Mean % compensation in seed cotton yield (gm/plant) sown at different dates in response of 100% simulated bollworm damage decreased than that of undamaged control treatments at mid flowering stage (1st August 2002 to 21st August 2002).

Treatments	% Compensation
D_1	-37.02b
D_2	-37.96b
D_3	-29.61a
D_4	-30.01a

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

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