Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

J E Z S Journal of Entomology and Zoology Studies

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2017; 5(4): 1721-1728
© 2017 JEZS
Received: 11-05-2017
Accepted: 12-06-2017

Venkatesh YN
Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi, India

Prasad NVVSD
Regional Agricultural Research Station, ANGRAU, Lam, Guntur, Andhra Pradesh, India

Varun Saini
Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi, India

Satyapriya Singh
Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi, India

Correspondence
Venkatesh YN
Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi, India

Studies on the influence of Bollgard II *Bt* cotton (Cry 1Ac + Cry 2Ab) plants against I and II instar larvae of *Spodoptera litura* (Fab.)

Venkatesh YN, Prasad NVVSD, Varun Saini and Satyapriya Singh

Abstract
The present investigation was conducted at Regional Agricultural Research Station, Lam, Guntur, A.P. during *kharif*, 2014-15. To study the affect of BG II cotton plants against I and II instar larvae of *Spodoptera litura.* The mortality of 1st instar larvae of *S. litura* was recorded 100 % and 2nd instar larvae recorded 92.5 % on BG II hybrids, where as the mortality was very low and more or less similar in BG I and non *Bt* cotton hybrids 15-17 % and 10- 12% respectively. The mean weight of larva fed on BG II cotton leaves was found to be very low, where as BG I hybrids shows marginal influence and non *Bt* versions did not affect the larval or pupal weight and weight gains were more or less similar.

Keywords: Cotton, *Spodoptera litura,* Bollgard II

1. Introduction
Cotton, *Gossypium* spp. (L.) the "King of fibers" is an important commercial crop grown in more than 70 countries under diverse agro-climatic conditions [1]. Cotton plays a predominant role in Indian economy as it provides 80 percent of raw material to the textile industry and livelihood for more than 100 million people through its production, processing and marketing [2]. India is an important grower of cotton on a global scale. India ranks first in cultivated area (118.77 lakh ha) and second in production (338.00 lakh bales) and productivity (484 kg ha^{-1}) in the world [3].

Reasons for the low productivity of cotton in India are cultivation under rainfed conditions, predominance of pests and diseases, inadequate and unscientific method of cultivation. The Bollgard imparts insect resistance by virtue of which the cotton plant is able to resist attack of lepidopteron insect pests. This in-built protection in Bollgard cotton is provided by the presence of the *Bt* gene in the seed. Bollgard cultivars express the Cry1Ac protein and are active against larval stages of selected lepidopteron insects [4].

Among the bollworms, tobacco caterpillar (*Spodoptera litura)* is one of the key pests on cotton. Tobacco caterpillar *S. litura* has been noted as emerging pest in BG-I genotypes in India with the advent of *Bt* genotypes [5]. Transgenic *Bt* cotton with *Cry1Ac* proved not to be effective against *S. litura* [6 - 8]. It has been found that *S. litura* has a greater potential to survive in the presence of *Bt* toxins when compared to other bollworms [9]. Dual gene (stacked) genotypes known as Bollgard II (BG-II) event, where *Cry 2Ab* is incorporated along with *Cry1Ac* have assumed significance and provide season long control of key bollworms [10]. The stacked *Bt* cotton technology (Bollgard II) has two genes working at the same time, which delays the development of resistance to *Bt* toxin. Thus, there is a necessity to generate the information on bio-efficacy of these events to potential pest *S. litura* with an objective to study the influence of Bollgard II *Bt* cotton (Cry 1Ac + Cry 2Ab) plants against I and II instar larvae of *S. litura* (Fab.).

2. Materials and Methods
The present investigation was conducted at Regional Agricultural Research Station, Lam, Guntur, A.P. during *kharif*, 2014-15. The two cotton hybrids *viz*., Mallika BG I and Jaadoo BG I containing Cry1Ac, the two stacked *Bt* cotton hybrids *viz*., Mallika BG II and Jaadoo BG II containing Cry 1Ac + Cry 2Ab and their corresponding non *Bt* versions *i.e.*, Mallika non *Bt* and Jaadoo non *Bt* were chosen for the research work. Seed material was obtained from M/S Kaveri seeds Pvt. Ltd and Nuzuveedu seeds Pvt. Ltd, Guntur.

A bulk plot of 19.44 m^2 each of BG I (Cry1Ac), stacked *Bt* (Cry1Ac + Cry2Ab) (BG II) cotton hybrids of Mallika, Jaadoo and their corresponding non *Bt* hybrids were raised by following recommended agronomic practices with insecticidal protection to control sucking pests during the crop season. The experiment was conducted in complete randomized design in the lab with 6 treatments and 4 replications for each replication with 10 larvae.

2.1 Procedure

Comparative growth and development studies on *S. litura* I and II larval instars were conducted by allowing them to feed on leaves and squares of different transgenic *Bt* cotton hybrids and non *Bt* cotton hybrids.

Plant parts namely tender leaves (top) and squares of 70-80 days old plants were plucked from transgenic and corresponding non transgenic *Bt* hybrids at experimental field. They were carried to the laboratory in polythene covers, washed with distilled water and blot dried. The cleaned leaves and squares were placed individually in small boxes. The field collected egg masses of *S. litura* were used to initiate the mass culturing under laboratory conditions. The egg masses were kept in the egg cage. After emergence, first instar larvae were transferred to the castor leaves which were changed and the fecal pellets removed from the container for every 24 hrs. The grown up larvae were allowed to pupate in soil. Moths were collected on emergence and released in oviposition cage for egg laying. The required larvae for the different treatments were taken from the culture. Prior to larval release, the larvae were weighed with electronic balance. First instar larvae were weighed in mass, while IInd instar were weighed individually. After bioassay, larvae were observed daily and changed to respective fresh food material up to pupation.

Ten larvae of each instar were released on the leaves and squares of cotton with the help of camel hair brush in each of the replications. The mortality of I and II instars of *S. litura* on tender leaves and squares, weight of surviving larvae and pupae (with an electronic balance) were taken at 3, 7 and 11 days after release for each stage of the larvae in the lab. Adult emergence percentage was observed on all the three versions of Mallika and Jaadoo hybrids.

2.2 Statistical analysis

The larval survival and pupal weight was subjected to square root transformation and the variance was calculated. The data obtained on percent mortality in bioassay was subjected to arcsin transformation and statistically analyzed by Completely Randomized Design (CRD). Means in simple CRD analysis were separated by Duncan's multiple range test [11].

3. Results and Discussion

3.1 Effect of Test Hybrids on Larval Mortality

Mortality percent of *S. litura* larvae of I and II instars reared on leaves and squares of 70 - 80 days old crop of different cotton hybrids are presented in table 1.

3.1.1 Leaves

3.1.1.1 First instar

The larval mortality of *S. litura* was maximum on Jaadoo BGII and Mallika BG II compared to other test hybrids. Mortality of first instar larvae fed on leaves of Mallika BG II and Jaadoo BG II cotton hybrids were 52.50 and 47.50 percent, while it was 7.50 and 2.50 percent when fed on Jaadoo BG I and Mallika BG I and 5.00 and 2.50 percent fed on Mallika non-*Bt* and Jaadoo non-*Bt* hybrids at 3 days after release. The mortality on Jaadoo BG II and Mallika BG II cotton hybrids were 52.50 and 47.50 percent with significant differences from rest of the hybrids with cumulative mortality of 100 % at 7 days after release, while the total mortality was 17.50 percent on BG I and 12.50 percent on non-*Bt* hybrids at 11 day after release.

3.1.1.2 Second instar

The mortality of 2nd instar larvae fed on leaves of 70-80 days old crop at 3 days after release was 40.00 percent on Mallika BG II hybrid and 25.00 percent on Jaadoo BGII, 7.50 percent mortality on BG I cotton hybrids and 5.00 percent mortality on non-*Bt* cotton hybrids at three day after release, whereas at 7 days after release higher mortality rates of 47.50 and 40.00 percent were recorded on Jaadoo BG II and Mallika BG II cotton hybrids respectively, while it was 2.50 percent on BG I hybrids and non-*Bt* hybrids. The total larval mortality was 92.50 percent on leaves of both Jaadoo BG II and Mallika BG II hybrids at 11 days after release, while it was 10.00 percent in the BG I and 7.50 percent in non-*Bt* hybrids at 11 days after release (Table 1).

3.1.2 Squares

3.1.2.1 First instar

The larval mortality of *S. litura* was maximum on Jaadoo BG II and Mallika BG II compared to other test hybrids. Mortality of first instar larvae fed on squares of both Jaadoo BG II and Mallika BG II cotton hybrids was 92.50 percent, while it was 5.00 percent when fed on Jaadoo BG I and Mallika BG I and 5.00 and 2.50 percent fed on Mallika non-*Bt* and Jaadoo non-*Bt* hybrids at 3 days after release. The mortality on both Jaadoo BG II and Mallika BG II cotton hybrids was 7.50 percent with no significant differences from rest of the hybrids at 7 days after release. The total mortality on stacked *Bt* cotton hybrids was cent percent, while it was 15.00 percent on BG I and 10.00percent on non-*Bt* hybrids at 11 day after release (Table 2).

3.1.2.2 Second instar

The mortality of 2nd instar larvae fed on squares of 70- 80 days old crop at 3 day after release was 22.50 percent on Jaadoo BG II hybrid and 17.50 percent on Mallika BG II and 7.50 percent mortality on both BG I cotton hybrids and 2.50 percent mortality on non-*Bt* cotton hybrids at three day after release, whereas at 7 days after release higher mortality rates of 55.00 and 40.00 percent were recorded on Jaadoo BG II and Mallika BG II cotton hybrids respectively, while it was 2.50 percent on both BG I hybrids and non *Bt* hybrids. The total mortality was 87.50 percent on squares of Jaadoo BG II and 75.00 percent on Mallika BG II hybrids at 11 days after release, while it was 10.00 percent in the BG I and 5.00 percent in non *Bt* hybrids at 11 days after release (Table 2).

3.2 Effect of test hybrids on larval weight

The mean weight of larvae that survived beyond 3, 7 and 11 days after release on leaves and squares of 70-80 days old crop from all the six test hybrids was recorded for first and second instars and presented in (Table 3 and 4).

3.2.1 Leaves

The minimum larval weight gain was recorded when fed on leaves of Jaadoo and Mallika BG II hybrids. Jaadoo and Mallika BG II hybrids with least increase in larval weight were significantly superior over other test hybrids (Table 3). The mean larval weight of first instar larvae was minimum

(0.79 mg/larva, 1.10mg/ larva) in both Jaadoo and Mallika BG II hybrids at 3 days after release on leaves. The maximum larval weight (6.85 mg/ larva) was recorded on Jaadoo *Bt* followed by Mallika non- *Bt* (5.32 mg/ larva), Mallika *Bt* (4.76mg/ larva), Jaadoo non *Bt* (4.29 mg/ larva) at 3 days after release on leaves. All the BG I and non *Bt* hybrids were statistically on par and significantly inferior over the Jaadoo and Mallika BG II hybrids. There was no surviving larvae in Jaadoo and Mallika BG II hybrid, due to 100 percent mortality, and the maximum weight gain (99.21 %) at 11days after release was recorded in Jaadoo BG I hybrid followed by Mallika BG I (99.08), Mallika non *Bt* (99.00%), and Jaadoo non-*Bt* (98.88%). All these are statistically on par with each other.

The mean larval weight of second instar larvae was minimum (38.95 mg/ larva) in Mallika BG II hybrid and (41.08 mg/ larva) in Jaadoo BG II the maximum larval weight (58.45 mg/larvae) was recorded on Mallika non *Bt* followed by Jaadoo non *Bt* (55.45 mg/ larva), Mallika BG I (50.40 mg/ larva), and Jaadoo BG I (50.03 mg/ larva) at 3 days after fed with leaves. All these hybrids are statistically on par and significantly inferior over the Jaadoo and Mallika BG II hybrids. The percent weight gain was lowest in Mallika BGII hybrid (80.01%) and in Jaadoo BG II hybrid (80.84 %). The maximum weight gain (92.27 %) at 11 days after exposure was recorded in Mallika non *Bt* hybrid followed by Jaadoo non *Bt* (45.68%), Mallika BG I (87.35), and Jaadoo BG I (85.08%). All the BG II hybrids superior over BG I and non *Bt* hybrids with each other.

3.2.2 Squares

The growth of larvae fed on Jaadoo and Mallika BG II squares was minimum with less weight gain in first and second instar larvae. The Jaadoo and Mallika BG II hybrids was superior over the other hybrids tested in having less preference for feeding by *S. litura* (Table 4).

The mean larval weight of first instar larvae was minimum (3.17 mg/larva) in Mallika BG II hybrid and (3.60 mg/larva) in Jaadoo BG II hybrid at 3 days after release on squares. The maximum larval weight (35.75 mg/larva) was recorded on Mallika BG I, followed by Mallika non- *Bt* (31.53mg/larva), Jaadoo non *Bt* (31.15 mg) and Jaadoo BG I (28.85mg) at 3 days after release on squares. All these hybrids are statistically on par and significantly inferior over the Jaadoo and Mallika BG II hybrid. The percent weight gain could not be recorded in Jaadoo and Mallika BG II hybrid, due to 100 percent mortality. The maximum weight gain (98.58 %) at 11days after release was recorded in Mallika non-*Bt* hybrid followed by Jaadoo non-*Bt* (98.29 %), Jaadoo BG I (98.28%), and Mallika BG I (98.16%). All these are statistically on par with each other.

The mean larval weight of second instar larvae was minimum (42.68 mg/larva) in Jaadoo BG II hybrid and (42.93 mg/larva) in Mallika BG II the maximum larval weight (61.13 mg/larva) was recorded on Jaadoo non-*Bt*, followed by Mallika non *Bt* (60.68 mg/larva), Mallika BG I (57.70 mg/larva), and Jaadoo BG I (54.20 mg/larva) at 3 days after exposure to leaves. All these hybrids are statistically on par and significantly inferior over the Jaadoo and Mallika BG II hybrids. The percent weight gain was lowest (84.49 %) in Jaadoo BGII hybrid and (85.58 %) in Mallika BG II hybrid. The maximum weight gain (91.24 %) at 11 days after exposure was recorded in Mallika non *Bt* hybrid followed by Jaadoo non *Bt* (91.02%), Mallika BG I (87.46), and Jaadoo BG I (87.01%).

3.3 Effect of test hybrids on pupation

The percent pupation of surviving larvae of *S. litura* on leaves and squares of different test cotton hybrids. (Table 5)

3.3.1 Leaves

The Jaadoo and Mallika BG II hybrids were resistant to *S. litura* attack and therefore the percent pupation of survived larvae fed on leaves of this hybrid was low compared to other test hybrids and they are statistically superior over other test hybrids. The first instar larvae fed on leaves of Jaadoo and Mallika BG II hybrids died completely before pupation.

The percent pupation in second instar larvae was very less 7.50% in both Jaadoo BG II and Mallika BG II hybrids. Whereas in BG I cotton hybrids 90.00% pupation and in non-*Bt* hybrids 95.00% pupation was observed.

3.3.2 Squares

The first instar larvae when fed on Jaadoo and Mallika BG II hybrid squares resulted in complete mortality before pupation. The pupation percent in other test hybrids varied between 80.00 to 90.00 % and all are statistically on par. In second instar, the pupation percent was 12.50% in Jaadoo BG II and 25.00 % in Mallika BG II and > 90.00% in other hybrids.

3.4 Effect of test hybrids on pupal weight

The mean pupal weight of *S. litura* reared on different test hybrids was given in (Table 6).

3.4.1 Leaves

The maximum mean pupal weight was recorded, when first instar larvae were reared on Jaadoo non *Bt* (269.96 mg/pupa) followed by Mallika non *Bt* (233.6 mg/pupa) and Jaadoo BG I (219.76 mg/pupa). In Jaadoo and Mallika BG II hybrid there was no pupation of first instar larvae. The maximum pupal weight of 149.94/pupa mg was recorded, when second instars larvae were fed on leaves of Jaadoo non-*Bt* and it is statistically on par with other hybrids except Jaadoo and Mallika BG II hybrids (Table 6).

3.4.2 Squares

The different instars fed on squares exhibited similar trend in pupal weight as those fed on leaves. The larvae of *S. litura* fed on Jaadoo and Mallika BG II hybrids recorded no pupation for first instar larvae. The first instar larvae fed on Mallika non-*Bt* squares recorded the maximum pupal weight (198.35 mg/pupa) and is on par with Jaadoo non *Bt* (183.55 mg/pupa), Mallika BG I (176.39 mg/pupa) and Jaadoo BG I (171.35 mg/pupa). The mean pupal weight has increased gradually with increase in age of larvae on Jaadoo and Mallika BGII hybrids.

3.5 Effect of different test hybrids on adult emergence

3.5.1 Leaves

None of the first instar larvae fed with leaves of Jaadoo and Mallika BG II hybrids reached adult stage. The second instar larvae reared on Jaadoo and Mallika BG II hybrids recorded 5.00%, the percent adult emergence when first and second instar larvae reared on other test hybrids was more than 85.00% and all are statistically on par with each other except Jaadoo BG I which is recorded 72.50 % (Table 7)

3.5.2 Squares

None of the first instar larvae fed with squares of Jaadoo and Mallika BG II hybrids reached adult stage. The adult emergence was very poor when second instars were fed on

squares of Jaadoo and Mallika BG II hybrids. There was only 10.50% in Jaadoo BG II and 15.00 % in Mallika BG II adult emergence. These hybrids are least preferred by the *S. litura*. The other test hybrids recorded > 90.00% adult emergence when second instar larvae were reared on those hybrids.

The results from the present investigation clearly suggest that the BG I cotton hybrids which contains Cry1Ac protein, offer marginal influence on 1st and 2nd instar. These findings are in close association with the results of development of *S. exigua* on BG I cotton was normal[12]. The BG I cotton hybrids which were efficient against *H. armigera* as revealed from the references of [13-14] have not offered any efficacy against *S. litura* during the 70-80 days old crop.

The Stacked *Bt* (BG II) cotton hybrids with Cry 1Ac + Cry 2Ab dual proteins exhibited higher mortality for first and second instars of *S. litura* than BG I and non *Bt* cotton hybrids. The present findings derive support from [15-20] who reported that Bollgard II cultivars exhibited far lower number of beet armyworm, *S. exigua* than BG I and non *Bt* varieties. The present findings are also in conformity with [10, 21-24] who found higher mortality of *S. litura* on stacked *Bt* (BG II) cotton over non *Bt* hybrids. The mortality of early larval instars was higher on leaves of stacked *Bt* (BG II) cotton hybrids, The duration of mortality of *S. litura* on leaves of all the test hybrids was studied for I and II instar larvae during 70 to 80 days old crop. In BG II hybrids, the 1st instar larvae showed 100 percent mortality at 7 days after release. In case of 2nd instar, there was decrease in mortality rate compared to 1st instar and took longer time for mortality and recorded more than 92.00 percent mortality. The findings clearly suggest that BG II cotton hybrids can effectively check the 1st& 2nd instar larva which was highly economical in cotton ecosystem as the pest can be controlled in initial stages itself [25].

The BG I and non *Bt* cotton hybrids did not affect any larval instar at 70- 80 days crop. Hence, it was evident from the results that BG I cotton hybrids which were resistant and showed higher mortality to *H. armigera* [26-27] cannot offer any protection to *S. litura*. It was clear from the results that larval or pupal weights of 1st and 2nd larval instars were maximum when fed on leaves of non *Bt* and BG I cotton hybrids. The present findings derive support from [27-28] who reported that larval weights were significantly higher on normal cotton leaves than transgenic *Bt* cotton leaves.

The results from the data also revealed that the larvae survived after exposure to stacked *Bt* (BG II) leaves weighed less and developed into smaller pupae than the larvae fed on BG I and non *Bt* hybrids. The present findings are in conformity with [14, 22] who reported significant reduction in the larval and pupal weights when fed with stacked *Bt* (BG II) cotton leaves.

The results of the BG II hybrids on the age of larvae revealed that the larval weight of 1st instar larvae was lower than 2nd instar larvae on leaves of stacked *Bt* (BG II) cotton hybrids compared to BG I and non *Bt* cotton hybrids, which was in accordance with the findings of [25, 29] who reported that the weight of early larval instars was higher than later instars on leaves of stacked *Bt* (BG II) hybrids than on BG I and non *Bt* cotton hybrids.

Table 1: Mortality of larval instars of *S. litura* on leaves of test hybrids

% mortality								
Treatments	**I instar**			**Total mortality**	**II instar**			**Total mortality**
	3DAR	**7DAR**	**11DAR**		**3DAR**	**7DAR**	**11DAR**	
Jaadoo BG I	7.50 (13.82)^{b}	7.50 (13.82)^{b}	2.50 (4.60)	17.50	7.50 (13.82)^{b}	2.50 (4.60)^{b}	0.00 (0.00)^{c}	10.00
Mallika BG I	2.50 (4.60)^{b}	7.50 (13.82)^{b}	5.00 (9.21)	15.00	7.50 (13.82)^{b}	2.50 (4.60)^{b}	0.00 (0.00)^{c}	10.00
Jaadoo BG II	47.50 (43.55)^{a}	52.50 (46.44)^{a}	0.00 (0.00)	100.00	25.00 (29.88)^{a}	47.50 (43.55)^{a}	20.00 (26.56)^{a}	92.50
Mallika BG II	52.50 (46.44)^{a}	47.50 (43.55)^{a}	0.00 (0.00)	100.00	40.00 (39.23)^{a}	40.00 (39.23)^{a}	12.5 (20.46)^{b}	92.50
Jaadoo non- *Bt*	2.50 (4.60)^{b}	5.00 (9.21)^{b}	2.50 (4.60)	10.00	5.00 (9.21)^{b}	0.00 (0.00)^{b}	0.00 (0.00)^{c}	5.00
Mallika non- *Bt*	5.00 (9.21)^{b}	5.00 (9.21)^{b}	2.50 (4.60)	12.50	5.00 (9.21)^{b}	2.50 (4.60)^{b}	0.00 (0.00)^{c}	7.50
F-Test	Sig	Sig	NS		Sig	Sig	Sig	
SEM ±	4.00	4.14	3.92		4.13	3.31	0.83	
CD (P=0.05)	11.90	12.33	11.64		12.29	9.84	2.47	

Figures in parentheses are angular transformed values

Numbers followed by same superscript are not statistically different (P=0.05)

Table 2: Mortality of larval instars of *S. litura* on squares of test hybrids

% mortality								
		I instar		Total mortality		II instar		Total mortality
Treatments	**3DAR**	**7DAR**	**11DAR**		**3DAR**	**7DAR**	**11DAR**	
Jaadoo BG I	5.00 (9.21)^{b}	5.00 (9.21)	2.50 (4.60)	12.50	7.50 (13.82)^{bc}	2.50 (4.60)^{b}	0.00 (0.00)^{c}	10.00
Mallika BG I	5.00 (9.21)^{b}	5.00 (9.21)	5.00 (9.21)	15.00	7.50 (13.82)^{bc}	2.50 (4.60)^{b}	0.00 (0.00)^{c}	10.00
Jaadoo BG II	92.50 (76.17)^{a}	7.50 (11.25)	0.00 (0.00)	100.00	22.50 (28.22)^{a}	55.00 (47.88)^{a}	10.00 (18.43)^{b}	87.50
Mallika BG II	92.50 (76.17)^{a}	7.50 (11.25)	0.00 (0.00)	100.00	17.50 (24.53)^{ab}	40.00 (39.23)^{a}	17.50 (24.53)^{a}	75.00
Jaadoo non- *Bt*	2.50 (4.60)^{b}	2.50 (4.60)	2.50 (4.60)	7.50	2.50 (4.60)^{c}	2.50 (4.60)^{b}	0.00 (0.00)^{c}	5.00
Mallika non- *Bt*	5.00 (9.21)^{b}	2.50 (4.60)	2.50 (4.60)	10.00	2.50 (4.60)^{c}	2.50 (4.60)^{b}	0.00 (0.00)^{c}	5.00
F-Test	Sig	NS	NS		Sig	Sig	Sig	
SEm±	4.98	5.61	3.92		3.91	3.94	0.83	
CD (P=0.05)	14.79	16.68	11.64		11.63	11.72	2.47	

Figures in parentheses are angular transformed values

Numbers followed by same superscript are not statistically different (P=0.05)

Table 3: Effect of test hybrids leaves on *S. litura* larval weight

Treatments	**Mean weight (mg/larva) of I instar after**			**Weight gain (%)**	**Mean weight (mg/larva) of II instar after**			**Weight gain (%)**
	3 DAR	**7 DAR**	**11 DAR**		**3 DAR**	**7 DAR**	**11 DAR**	
Jaadoo BG I	6.85 (2.80)^{a}	14.79 (3.97)^{b}	252.65 (15.87)^{a}	99.21	50.03 (7.14)^{b}	99.56 (9.99)^{bc}	226.61 (15.03)^{bc}	85.08
Mallika BG I	4.76 (2.39)^{b}	14.42 (3.93)^{b}	216.85 (14.75)^{ab}	99.08	50.40 (7.16)^{b}	125.39 (11.23)^{ab}	267.27 (16.35)^{b}	87.35
Jaadoo BG II	0.79 (1.33)^{c}	5.23 (2.49)^{c}	0.00 (1.00)^{d}	**	41.08 (6.48)^{c}	88.09 (9.33)^{c}	176.38 (13.21)^{c}	80.84
Mallika BG II	1.10 (1.45)^{c}	4.75 (2.38)^{c}	0.00 (1.00)^{d}	**	38.95 (6.32)^{c}	80.31 (9.00)^{c}	169.07 (13.04)^{c}	80.01
Jaadoo non- *Bt*	4.29 (2.29)^{b}	19.56 (4.53)^{a}	178.65 (13.36)^{c}	98.88	55.63 (7.52)^{ab}	104.82 (10.28)^{abc}	361.04 (18.99)^{a}	90.64
Mallika non- *Bt*	5.32 (2.51)^{b}	14.99 (3.99)^{b}	199.86 (14.17)^{bc}	99.00	58.45 (7.71)^{a}	129.96 (11.43)^{a}	437.53 (20.90)^{a}	92.27
F- Test	Sig	Sig	Sig		Sig	Sig	Sig	
SEm ±	0.09	0.12	0.43		0.14	0.45	0.71	
CD (P = 0.05)	0.27	0.35	1.28		0.42	1.34	2.11	
Initial weight	2				33.8			

** No survival Larvae

Figures in parentheses are square root transformed values

Numbers followed by same superscript are not statistically different (P=0.05)

Table 4: Effect of test hybrid squares on *S. litura* larval weight

Treatments	**Mean weight (mg/larva) of I instar after**			**Weight gain (%)**	**Mean weight (mg/larva) of II instar after**			**Weight gain (%)**
	3 DAR	**7 DAR**	**11 DAR**		**3 DAR**	**7 DAR**	**11 DAR**	
Jaadoo BG I	28.85 (5.43)^{a}	75.09 (8.72)^{ab}	174.90 (13.25)^{ab}	98.28	54.20 (7.42)^{a}	116.30 (10.30)^{b}	275.59 (16.63)^{b}	87.01
Mallika BG I	35.75 (6.05)^{a}	72.89 (8.60)^{b}	162.90 (12.71)^{b}	98.16	57.70 (7.65)^{a}	117.25 (10.87)^{ab}	285.50 (16.92)^{b}	87.46
Jaadoo BG II	3.60 (2.11)^{b}	0.00 (1.00)^{c}	0.00 (1.00)^{c}	**	42.68 (6.60)^{b}	75.18 (8.71)^{c}	230.80 (15.19)^{b}	84.49
Mallika BG II	3.17 (2.03)^{b}	0.00 (1.00)^{c}	0.00 (1.00)^{c}	**	42.93 (6.62)^{b}	76.28 (8.79)^{c}	248.19 (15.76)^{b}	85.58
Jaadoo non- *Bt*	31.15 (5.66)^{a}	81.43 (9.05)^{ab}	174.96 (13.25)^{ab}	98.29	61.13 (7.88)^{a}	126.76 (11.30)^{ab}	398.62 (19.91)^{a}	91.02
Mallika non- *Bt*	31.53 (5.69)^{a}	89.06 (9.45)^{a}	210.54 (14.53)^{a}	98.58	60.68 (7.85)^{a}	129.90 (11.44)^{a}	408.91 (20.09)^{a}	91.24
F- Test	Sig	Sig	Sig		Sig	Sig	Sig	
SEm ±	0.23	0.28	0.44		0.19	0.20	0.79	
CD (P = 0.05)	0.67	0.84	1.30		0.55	0.60	2.36	
Initial weight	3				35.8			

** No survival Larvae

Figures in parentheses are square root transformed values

Numbers followed by same superscript are not statistically different (P=0.05)

Table 5: Percent pupation of surviving larvae of *S. litura* on test hybrids

Treatments	Pupation (%)			
	Leaves		Squares	
	I instar	II instar	I instar	II instar
Jaadoo BG I	82.50 (65.46)^{b}	90.00 (71.56)^{a}	80.00 (63.80)^{b}	95.00 (80.78)^{ab}
Mallika BG I	85.00 (67.5)^{ab}	90.00 (71.56)^{a}	85.00 (67.50)^{ab}	92.50 (76.17)^{b}
Jaadoo BG II	0.00 (0.00)^{c}	7.50 (13.82)^{b}	0.00 (0.00)^{c}	12.50 (20.46)^{c}
Mallika BG II	0.00 (0.00)^{c}	7.50 (13.82)^{b}	0.00 (0.00)^{c}	25.00 (29.88)^{c}
Jaadoo non- *Bt*	87.50 (69.53)^{ab}	92.50 (76.17)^{a}	90.00 (71.56)^{a}	97.50 (85.39)^{ab}
Mallika non- *Bt*	90.00 (71.56)^{a}	95.00 (80.78)^{a}	87.50 (69.53)^{a}	100 (90.00)^{a}
F-test	Sig	Sig	Sig	Sig
SEm±	1.51	3.92	1.77	3.62
CD (P=0.05)	4.50	11.64	5.26	10.75

Figures in parentheses are angular transformed values
Numbers followed by same superscript are not statistically different (P=0.05)

Table 6: Effect of test hybrids on pupal weight of *S. litura*

Treatments	Pupal weight (mg/pupa)			
	Leaves		Squares	
	I instar	II instar	I instar	II instar
Jaadoo BG I	219.76 (14.78)^{bc}	126.28 (11.25)^{a}	171.35 (13.12)^{b}	118.54 (10.93)^{ab}
Mallika BG I	183.00 (13.54)^{c}	138.86 (11.81)^{a}	176.39 (13.30)^{b}	114.77 (10.75)^{ab}
Jaadoo BG II	0.00 (1.00)^{d}	92.90 (9.68)^{b}	0.00 (1.00)^{c}	63.93 (7.93)^{c}
Mallika BG II	0.00 (1.00)^{d}	98.31 (9.89)^{b}	0.00 (1.00)^{c}	102.16 (10.15)^{b}
Jaadoo non- *Bt*	269.96 (16.42)^{a}	149.94 (12.28)^{a}	183.55 (13.56)^{ab}	130.69 (11.44)^{ab}
Mallika non- *Bt*	233.6 (15.30)^{ab}	140.44 (11.88)^{a}	198.35 (14.11)^{a}	134.72 (11.61)^{a}
F-test	Sig	Sig	Sig	Sig
SEm±	0.48	0.38	0.24	0.44
CD (P=0.05)	1.43	1.12	0.72	1.32

Figures in parentheses are square root transformed values
Numbers followed by same superscript are not statistically different (P=0.05)

Table 7: Percent adult emergence of *S. litura* on test hybrids

Treatments	Adult emergence (%)			
	Leaves		Squares	
	I instar	II instar	I instar	II instar
Jaadoo BG I	72.50 (58.45)^{b}	77.50 (61.77)^{b}	77.50 (61.77)^{a}	90.00 (71.56)^{a}
Mallika BG I	85.00 (67.50)^{a}	85.00 (67.50)^{b}	80.00 (63.80)^{a}	90.00 (71.56)^{a}
Jaadoo BG II	0.00 (0.00)^{c}	5.00 (9.21)^{c}	0.00 (0.00)^{b}	10.50 (18.43)^{b}
Mallika BG II	0.00 (0.00)^{c}	5.00 (9.21)^{c}	0.00 (0.00)^{b}	15.00 (22.50)^{b}
Jaadoo non- *Bt*	87.50 (69.53)^{a}	92.50 (76.17)^{a}	72.50 (58.45)^{a}	95.00 (80.78)^{a}
Mallika non- *Bt*	85.00 (67.50)^{a}	85.00 (67.50)^{b}	80.00 (63.80)^{a}	95.00 (80.78)^{a}
F-test	Sig	Sig	Sig	Sig
SEm±	1.73	3.91	1.99	3.82
CD (P=0.05)	5.13	11.60	5.92	9.56

Figures in parentheses are angular transformed values
Numbers followed by same superscript are not statistically different (P=0.05)

4. Conclusion

In the present investigation, growth and development of I and II instar larvae of *S. litura* showed mortality rates on BG II hybrids, whereas the mortality was more or less similar in BG I and non *Bt* cotton hybrids. The BG II cotton hybrids exerted higher mortality. This might be due to expression of high levels of dual toxin at early stages of plant development.

The mean larval weight of larva fed on BG II cotton leaves was found to be significantly lower than that of the larva fed on BG I and non *Bt* leaves. The mean larval weight of later instars of *S. litura* was higher than the early instars on the leaves of both the BG II cotton hybrids, whereas it was more or less similar in BG I and non *Bt* versions.

The exposure of late instar larvae to plant parts of Jadoo and Mallika BG II hybrids exhibited adverse effect on the growth and development such as reduced larval weight, prolonged larval development period, reduced pupation, formation of small pupae with less weight, reduced adult emergence and low growth.

5. Acknowledgements

The author is thankful to the Indian council of Agricultural research for providing JRF fellowship and Director, RARS, Lam, Guntur, AP, India for providing the necessary facilities.

6. References

1. Anonymous. The Economic Outlook for US Cotton-2011. National Cotton Council of America, 2011, 1-42.
2. Rakesh RC, Kathane TV. Cotton marketing federation and export of cotton in India (1980 -81 to 1987-88). Cotton Development. 1989; 18(3, 4):1-18.
3. Cotton Advisory Board. The cotton corporation of India Ltd. 2015-2016. http://cotcorp.gov.in/statistics.aspx#area.
4. Perlak FJ, Deaton RW, Armstrong TA, Fuchs RL, Sims SR, Greenplate JT *et al*., Insect resistant cotton plants. Biotechnology. 1990; 8:939-943.
5. Jeyakumar P, Tanwar RK, Jat MC, Dhandapani A, Bambawale OM, Monga D. *Spodoptera litura*: An emerging pest on *Bt* cotton (Cry1Ac) under North Indian conditions. Pesticide Research Journal. 2007; 19(2):197-200.
6. Arshad M, Suhail A. Field and laboratory performance of transgenic *Bt* cotton containing Cry 1Ac against beet armyworm larvae (Lepidoptera: Noctuidae). Pakistan Journal of Zoology. 2011; 43(3):529-535.
7. Selvi C, Krishnamoorty SV, Sivasubramanian P. Bioefficacy of *Bt* cotton hybrids containing the fusion gene *Cry 1 Ac- 1 Ab* against *Spodoptera litura*. Indian Journal of Plant Protection. 2012; 40(1):22-25.
8. Lalitha C, Muralikrishna T, Sravani S, Devaki K. Invitro evaluation of native *Bacillus thuringiensis* isolates against II instar *Spodoptera litura* (Fabricius). Annals of Plant Protection Sciences. 2012; 20(1):88-90.
9. Govindan K, Gunasekaran K, Kuttalam S, Aiswariya KK. Laboratory evaluation of transgenic *Bt* cotton and non *Bt* cotton plant parts against third instar larvae of *Spodoptera litura* (Fab.) (Noctuidae: Lepidoptera). Journal of Biopesticides. 2010; 3(2):432-436.
10. Hallad AV, Udikeri SS, Patil SB, Biradar DP, Khadi BM. Characterization of resistance to all bollworms and *Spodoptera litura* (Fab.) in different *Bt* transgenic events of cotton. International Journal of Current Microbiology and Applied Sciences.2014; 3(3):594-600.
11. Duncan DB. A significance test for differences between ranked treatment means in an analysis of variance. Virginia Journal of Science. 1951; 2:171-189.
12. Zeng XH, Zhang HY, Yu ZN, Hu C. Bioassay method of evaluating toxicity of *Bacillus thuringiensis* against larvae of *Spodoptera exigua*. Chinese Journal of Biological Control. 1998; 14(4):172-175.
13. Kranthi KR, Naidu S, Dhawad CS, Tatwawadi A, Mate K, Patil E *et al*. Temporal and intra-plant variability of Cry1Ac expression in *Bt* cotton and its influence on the survival of the cotton bollworm, *Helicoverpa armigera* (Hubner) (Noctuidae: Lepidoptera). Current Science. 2005; 89(2):291-298.
14. Seshamahalakshmi M. Impact of *Bt* cotton on the incidence and management of bollworm complex. 2007;Ph.D. Thesis. Acharya N. G. Ranga Agricultural University, Rajendranagar, Hyderabad.
15. Allen CT, Kharboutli MS, Capps C, Earnest LD. Effectiveness of Bollgard II cotton varieties against foliage and fruit feeding caterpillars in Arkansas. Proceedings Beltwide Cotton Conference. San Antonio, USA, 4-8 January. 2000; 2:1093-1094.
16. Greenplate JT, Penn SR, Mullins JW, Oppenhuizen M. Seasonal Cry IC levels in DP50B: The "Bollguard® basis for Bollguard II. Proceedings Beltwide Cotton Conference, held at Memphis, National Cotton Council. 2000, 1039-1040.
17. Chitkowski RL, Turnipseed SG, Sullivan MJ, Bridges WC. Berliner proteins for management of field and laboratory evaluations of transgenic cottons expressing one or two *Bacillus thuringiensis* var. *kurstaki* (Noctuid: Lepidoptera) Pests. Journal of Economic Entomology. 2003; 96(3):755-762.
18. Adamczyk JJ, Gore J. Laboratory and field performance of cotton containing Cry1Ac, Cry1F and both Cry1Ac and Cry1F (Widestrike®) against beet armyworm and fall armyworm larvae (Lepidoptera: Noctuidae). The Florida Entomologist. 2004; 87(4):427-431.
19. Santos WJ. Manejo das Pragas do Algodao com Destaquepara CerradoBrasileiro. Associacao Brasileira dos Produtores de Algodao. 2007, 403-521.
20. Buntin GD. Corn expressing Cry1Ab or Cry1F endotoxin for fall armyworm and corn earworm (Lepidoptera: Noctuidae) management in field corn for grain production. The Florida Entomologist. 2008; 91(4):523-530.
21. Sivasupramaniam S, Ruschke LG, Osborn JA, Oppenhuizen ME, Mullins JW, Watson KG *et al*. Bollguard II improvement in efficacy and spectrum against lepidopteran pests of cotton. Proceedings of Beltwide Cotton Conferences, National Cotton Council of Nashville. USA. 2003, 381-382.
22. Donglin H, Qin LH, Xia JS. Effects of Zhongmiansuo 45 and Zhongmiansuo 41 on experimental population of *Spodoptera litura*. Acta Phytophylacica Sinica. 2006; 33(1):1-5.
23. Bheemanna M, Patil BV, Hanchinal SG, Hosamani AC, Bansi AB. Comparative performance and economics of Bollgard-II *Bt* cotton under irrigated conditions. Journal of Cotton Research and Development. 2008; 22(1):118-121.
24. Saini MK, Dhawan AK. Variability of delta-endotoxin expression in dual and single-toxin cotton genotypes and on survival of *Helicoverpa armigera* (Hub.) and *Spodoptera litura* (Fab.). Annals of Plant Protection Sciences. 2013; 21(1):1-8.
25. Naik VCB. Spatial-Temporal distribution of *Bt*

insecticidal protein in different *Bt* events and their efficacy against bollworms under field and laboratory conditions. Ph.D Thesis. Acharya N.G Ranga Agricultural University, Hyderabad, 2009.
26. Vennila S, Panchbhai PR, Biradar VK. Growth and survival of *Helicoverpa armigera* (Hubner) and *Spodoptera litura* (Boisd.) on transgenic *Bt* cotton. Journal of Cotton Research and Development. 2006; 20(1):131-133.
27. Basavaraja H, Chhillar BS, Singh R. Impact of transgenic *Bt* cotton on biological parameters of *Spodoptera litura* (Fab.) (Lepidoptera: Noctuidae). Journal of Entomological research. 2008; 32(3):183-186.
28. Sparks AN, Norman JW. Effect of leaf age on efficacy of Bollgard II against beet armyworm *Spodoptera exigua*. Proceedings of the Beltwide Cotton Conferences, National cotton council of America, Nashville, USA. 2002, 238-240.
29. Soujanya LP. Effect of *Bt* toxins (Cry1Ac & Cry1Ac + Cry2Ab) on the development & management of bollworm complex with special reference to *Pectinophora gossypiella* (Saunders) & *S. litura* (Fabracius) on cotton. M. Sc Thesis. Acharya N.G Ranga Agricultural University, Hyderabad, 2009.