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Growth and Development of *Spodopter litura* (fab.) on Dual Toxin Transgenic Bt Cotton

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A B S T R A C T

The study was conducted to know the effect of dual toxin *Bt* cotton on *Spodoptera litura* larvae at regional agricultural research station, Lam, Guntur, A.P. during 2014-2015. The data revealed that survival rate of 3rd instar larvae was higher and recorded only 30 - 35 per cent mortality, whereas the influence of BG II hybrids on grown up 4th and 5th instar larvae was very minimal no mortality was recorded and BG I and non *Bt* hybrids had shown no mortality. The mean weight of larva fed on BG II cotton leaves was found to be very low, whereas 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.

Introduction

Advances made in the genetic engineering led to the development of first biotechnological tool in the world, the *Bacillus thuringiensis* (*Bt*) *Cry1Ac* gene (crystal protein delta endotoxin) incorporated cotton (Bollgard) which was commercially cultivated since 2002 in India. The first successful example of the biotechnology in crop protection is Bollgard. 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 (Perlak *et al.,* 1990). The technology has been anticipated to address bollworm infestation and significant reduction in the overall use of insecticides (Fernandez and McBride, 2000). *Bt* cotton technology has a capability of reducing insect pest infestations by 60-90 per cent under field conditions (Kranthi *et al.,* 2004).

India is planning to produce 40 million bales of lint by 2050 AD to meet the anticipated domestic and export requirements. To fulfill

this projected requirement, the cotton production has to be increased by 15 per cent over existing levels which has to come mainly from increased productivity. 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.

It has been reported that 162 insect pests attack cotton in India (Lingappa, 2001). But key production constraints are sucking pests and bollworms are which cause losses to the tune of 30-80% (Patil, 1998). Leaf worm, *Spodoptera litura* Fab. (Noctuidae: Lepidoptera) is one of the most destructive pests of cotton which feeds on foliage and sometimes bolls, is a secondary pest of cotton (Allen *et al.*, 2000).

The three R's (Resistance, Resurgence and Residue) are the most potential problems associated with indiscriminate use of insecticides in cotton agro-ecosystem (Armes *et al.*, 1992). Moreover, the modern production technologies which rely heavily on the use of chemicals have significantly lowered the cost benefit ratio in cotton.

It has been found that *S. litura* has a greater potential to survive in the presence of *Bt* toxins when compared to other bollworms. In the present study, two different plant parts namely leaves and squares of *Bt* and non *Bt* cotton hybrids were tested for their affect on third, fourth and fifth instar larvae of *S. litura*.

Materials and Methods

Growth and development of *Spodoptera litura* (Fab.) On Dual Toxin Transgenic *Bt* Cotton 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 CRD design in the lab with 6 treatments and 4 replications for each replication with 10 larvae.

Investigation was conducted in the laboratory on the leaves and squares of 70 to 80 days old crop with the third, fourth and fifth larval instars by feeding the leaves of *Bt* and stacked *Bt* cotton and their corresponding non *Bt* versions as control. Laboratory reared larvae were released separately on leaves and squares of 70 to 80 days old crop with four replications.

Comparative growth and development studies on *S. litura* larval instars were conducted for third, fourth and fifth larval instars by allowing them to feed on leaves and squares of different transgenic *Bt* cotton hybrids and non *Bt* cotton hybrids. Bioassay was conducted with BG I (Cry1Ac) and stacked *Bt* (Cry1Ac + 2Ab) (BG II) cotton hybrids of Mallika, Jaadoo and their corresponding non *Bt* versions against *S. litura* to study the per cent mortality, larval survival, pupal weight at 3, 7 and 11days interval of third, fourth and fifth larval instars and finally percent pupation and percent adult emergence was recorded.

Statistical analysis

The larval survival and pupal weight was subjected to square root transformation and the variance was calculated. The data obtained on per cent 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 (Duncan, 1951).

Results and Discussion

Effect of test hybrids on larval mortality

Leaves

Third instar

The mortality was nil on leaves of 70-80 days old crop of BG I and non *Bt* hybrids at 3, 7 and 11 days after release, while mortality was recorded on the stacked *Bt* (BG II) hybrids. The mortality at 3 days after release was 22.50 and 17.50 per cent with significant difference on Jaadoo BG II and Mallika BG II hybrids respectively.

The mortality was 15.00 per cent and 12.50 per cent on leaves of both the stacked *Bt* (BG II) hybrids at 7 days after release, while the total mortality was 35.00 and 32.50 per cent with significant difference when fed on leaves of Jaadoo BG II and Mallika BG II hybrids respectively at 11 days after release.

Fourth and fifth instar

The 4^{th} and 5^{th} instar larvae recorded no mortality on leaves of 70 – 80 days old crop of Jaadoo BG II and Mallika BG II and their corresponding BG I, non *Bt* cotton hybrids at 3, 7, and 11 days after release. The stacked *Bt* (BG II) hybrids were found more resistant to fourth and fifth instars as no mortality was recorded on both the stacked *Bt* (BG II) hybrids at 3, 7 and 11 days after release. There is no significant difference between Jaadoo BG II and Mallika BG II cotton hybrids and their corresponding BG I and non- *Bt* hybrids (Table 1).

Squares

Third instar

The mortality was nil on squares of BG I and non *Bt* hybrids at 3, 7 and 11days after release, while mortality was recorded on the stacked *Bt* (BG II) hybrids. The mortality at 3 days after release was 12.50 per cent on both Jaadoo BG II and Mallika BG II hybrids. The mortality was 12.50 per cent on both the stacked *Bt* (BG II) hybrids at 7 days after release, while the total mortality was 25.00 per cent with significant difference when fed on squares of Jaadoo BG II and Mallika BG II and BG I and non *Bt* hybrids at 11 days after release (Table 2).

Fourth and fifth instar

No mortality on squares of Jaadoo BG II and Mallika BG II and their corresponding BG I, non *Bt* cotton hybrids at 3 and 7 days after release. The stacked *Bt* (BG II) hybrids were found more resistant to fourth and fifth instars as no mortality was recorded on both the stacked *Bt* (BG II) hybrids at 3 and 7 days after release. No significant difference between Jaadoo BG II and Mallika BG II cotton hybrids and their corresponding BG I and non- *Bt* hybrids at all the observations (Table 2).

Effect of test hybrids on larval weight

The mean weight of larvae that survived beyond 3 and 7 days after release on leaves and squares of 70-80 days old crop from all the six test hybrids was recorded for third, fourth and fifth instars and presented in table 3.

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 was significantly superior over other test hybrids. The mean larval weight of third instar larvae fed on leaves was minimum in Mallika (146.56 mg/larva) and Jaadoo (150.17 mg/larva) BGII hybrids at 3 days after feeding compared to other test hybrids. The maximum weight gained was on Mallika non-*Bt* (283.75 mg/larva) followed by Jaadoo non-*Bt* (201.65 mg/larva), Mallika BG I (178.80 mg/larva) and Jaadoo BG I (175.38 mg/larva) (Table 3).

At 7 days after release maximum weight gain was on Mallika non-*Bt* (602.22 mg/larva) followed by Mallika BG I (559.25mg/larva), Jaadoo non *Bt* (529.50 mg/larva), Jaadoo BG I (528.87 mg/larva) and minimum weight gain was in Jaadoo BG II (452.12 mg/larva) followed by Mallika BG II (470.12 mg/larva). It means Jaadoo BG II and Mallika BG II on a par and recorded lowest weight gain compared to other hybrids. The per cent weight gain after 7 days after feeding was maximum in Mallika non *Bt* (90.30 %) followed by Mallika BG I (89.56 %), Jaadoo non *Bt* (88.97 %), Jaadoo BG I (88.96 %) and the per cent weight gain during third instar was lowest (87.08 %) in Jaadoo BG II, followed by (87.58 %) in Mallika BG II which were statistically superior over other hybrids.

The mean larval weight of fourth instar larvae after feeding for 3 days was maximum in Mallika non-*Bt* (537.10 mg/larva) followed by Jaadoo non-*Bt* (519.93 mg/larva) Mallika BG I (480.00 mg/larva) and Jaadoo BG I (466.23 mg/larva) and minimum in Jaadoo BGII hybrid (389.23 mg/larva) followed by Mallika BG II (389.78mg/larva). After three days of feeding the per cent weight gain was low (53.73 %) in Jaadoo BG II and Mallika BG II (53.79%) compared to other test hybrids. The maximum weight gain was noticed in Mallika non-*Bt* (66.47%) followed by Jaadoo non *Bt* (65.36%), Mallika BG I (62.48%), and Jaadoo BG I (61.37%) All these hybrids are statistically on par and significantly different from Jaadoo and Mallika BGII hybrids. The decreased mortality, lower larval and pupal weight growth of *S. litura* on Jaadoo and Mallika BGII observed in the present studies are in conformity with the results of Soujanya (2011), Naik, *et al.*, (2013).

Squares

The mean larval weight of third instar larvae fed on leaves was minimum in Mallika (128.81 mg/larva) and Jaadoo (164.42 mg/larva) BGII hybrids at 3 days after feeding compared to other test hybrids. The maximum weight gain was on Mallika BG I (350.40 mg/larva) followed by Jaadoo BG I (297.00 mg/larva), Jaadoo non-*Bt* (268.95mg/larva) and Mallika non-*Bt* (239.80mg/larva) (Table 4).

At 7 days after release maximum weight gain was on Mallika non-*Bt* (565.73 mg/larva) followed by Jaadoo BG I (502.88mg/larva), Jaadoo non-*Bt* (488.58 mg/larva), Mallika BG I (451.33 mg/larva) and minimum weight gain was in Jaadoo BG II (314.55 mg/larva) followed by Mallika BG II (366.43 mg/larva). It means Jaadoo BG II and Mallika BG II significantly differ in larval weight gain compared to other hybrids. The per cent weight gain after 7 days after feeding was maximum in Mallika non *Bt* (84.90 %) followed by Jaadoo BG I (83.08 %), Jaadoo non *Bt* (82.52 %), Mallika BG I (81.08 %) and the per cent weight gain during third instar was lowest (72.85 %) in Jaadoo BGII, followed by (76.69 %) in Mallika BG II which are statistically superior over other hybrids.

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

Treatments	% mortality							
	III instar			Total mortality	IV instar		Total mortality	V instar
	3DAR	7DAR	11DAR		3DAR	7DAR		
Jaadoo BG I	0.00 (0.00)^{c}	0.00 (0.00)^{b}	0.00 (0.00)	0.00	0.00 (0.00)	0.00 (0.00)	0.00	0.00
Mallika BG I	0.00 (0.00)^{c}	0.00 (0.00)^{b}	0.00 (0.00)	0.00	0.00 (0.00)	0.00 (0.00)	0.00	0.00
Jaadoo BG II	22.50 (28.28)^{a}	12.50 (20.46)^{a}	0.00 (0.00)	35.00	0.00 (0.00)	0.00 (0.00)	0.00	0.00
Mallika BG II	17.50 (24.67)^{b}	15.00 (22.50)^{a}	0.00 (0.00)	32.50	0.00 (0.00)	0.00 (0.00)	0.00	0.00
Jaadoo non- *Bt*	0.00 (0.00)^{c}	0.00 (0.00)^{b}	0.00 (0.00)	0.00	0.00 (0.00)	0.00 (0.00)	0.00	0.00
Mallika non- *Bt*	0.00 (0.00)^{c}	0.00 (0.00)^{b}	0.00 (0.00)	0.00	0.00 (0.00)	0.00 (0.00)	0.00	0.00
F-Test	Sig	Sig	NS		NS	NS		NS
SEM ±	0.6	1.27	-		-	-		-
CD (P=0.05)	1.79	3.77	-		-	-		-

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

Treatments	% mortality							
	III instar			Total mortality	IV instar		Total mortality	V instar
	3DAR	7DAR	11DAR		3DAR	7DAR		
Jaadoo BG I	0.00 (0.00)^{b}	0.00 (0.00)^{b}	0.00 (0.00)	0.00	0.00 (0.00)	0.00 (0.00)	0.00	0.00
Mallika BG I	0.00 (0.00)^{b}	0.00 (0.00)^{b}	0.00 (0.00)	0.00	0.00 (0.00)	0.00 (0.00)	0.00	0.00
Jaadoo BG II	12.50 (20.61)^{a}	12.50 (20.46)^{a}	0.00 (0.00)	25.00	0.00 (0.00)	0.00 (0.00)	0.00	0.00
Mallika BG II	12.50 (20.46)^{a}	12.50 (20.46)^{a}	0.00 (0.00)	25.00	0.00 (0.00)	0.00 (0.00)	0.00	0.00
Jaadoo non- *Bt*	0.00 (0.00)^{b}	0.00 (0.00)^{b}	0.00 (0.00)	0.00	0.00 (0.00)	0.00 (0.00)	0.00	0.00
Mallika non- *Bt*	0.00 (0.00)^{b}	0.00 (0.00)^{b}	0.00 (0.00)	0.00	0.00 (0.00)	0.00 (0.00)	0.00	0.00
F-Test	Sig	Sig	NS		NS	NS		NS
SEm±	0.98	1.17			-	-		-
CD (P=0.05)	2.90	3.49			-	-		-

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 III instar after		Weight gain (%)	Mean weight (mg/larva) of IV instar after	Weight gain (%)
	3 DAR	7 DAR		3 DAR	
Jaadoo BG I	175.38 (13.25)^{bc}	528.87 (23.02)^{b}	88.96	466.23 (21.59)^{ab}	61.37
Mallika BG I	178.80 (13.39)^{bc}	559.25 (23.66)^{ab}	89.56	480.00 (21.93)^{a}	62.48
Jaadoo BG II	150.17 (12.23)^{c}	452.12 (21.27)^{c}	87.08	389.23 (19.70)^{b}	53.73
Mallika BG II	146.56 (12.11)^{c}	470.12 (21.70)^{c}	87.58	389.78 (19.69)^{b}	53.79
Jaadoo non- *Bt*	201.65 (14.23)^{b}	529.50 (23.03)^{b}	88.97	519.93 (22.82)^{a}	65.36
Mallika non- *Bt*	283.75 (16.79)^{a}	602.22 (24.54)^{a}	90.30	537.10 (23.17)^{a}	66.47
F- Test	Sig	Sig		Sig	
SEm ±	0.61	0.42		0.65	
CD (P = 0.05)	1.80	1.25		1.93	
Initial weight	58.4			180.1	

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 III instar after		Weight gain (%)	Mean weight of (mg/larva) of IV instar after	Weight gain (%)
	3 DAR	7 DAR		3 DAR	
Jaadoo BG I	297.00 (17.25)^{ab}	502.88 (22.44)^{b}	83.02	486.93 (22.09)^{a}	65.44
Mallika BG I	350.40 (18.74)^{a}	451.33 (21.22)^{c}	81.08	480.00 (21.93)^{a}	64.94
Jaadoo BG II	164.42 (12.57)^{c}	314.55 (17.76)^{e}	72.85	389.23 (19.70)^{b}	56.76
Mallika BG II	128.81 (11.37)^{c}	366.43 (19.16)^{d}	76.69	339.78 (18.43)^{b}	50.47
Jaadoo non- *Bt*	268.95 (16.34)^{ab}	488.58 (22.12)^{bc}	82.52	527.43 (22.98)^{a}	68.09
Mallika non- *Bt*	239.80 (15.51)^{b}	565.73 (23.80)^{a}	84.90	537.10 (23.17)^{a}	68.67
F- Test	Sig	Sig		Sig	
SEm ±	0.81	0.41		0.51	
CD (P = 0.05)	2.40	1.21		1.51	
Initial weight	85.4			168.3	

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

Table.5 Per cent pupation of surviving larvae of *S. litura* on test hybrids

Treatments	Pupation (%)					
	Leaves			Squares		
	III instar	IV instar	V instar	III instar	IV instar	V instar
Jaadoo BG I	100.00 (90.00)[a]	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)[a]	100 (90.00)	100 (90.00)
Mallika BG I	100.00 (90.00)[a]	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)[a]	100 (90.00)	100 (90.00)
Jaadoo BG II	65.00 (53.77)[b]	100.00 (90.00)	100.00 (90.00)	75.00 (60.11)[b]	100 (90.00)	100 (90.00)
Mallika BG II	67.50 (55.28)[b]	100.00 (90.00)	100.00 (90.00)	75.00 (60.63)[b]	100 (90.00)	100 (90.00)
Jaadoo non- *Bt*	100.00 (90.00)[a]	100.00 (90.00)	100.00 (90.00)	100 (90.00)[a]	100 (90.00)	100 (90.00)
Mallika non- *Bt*	100.00 (90.00)[a]	100.00 (90.00)	100.00 (90.00)	100 (90.00)[a]	100 (90.00)	100 (90.00)
F-test	Sig			Sig	NS	NS
SEm±	0.94	-	-	1.98	-	-
CD (P=0.05)	2.40	-	-	5.90	-	-

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		
	III instar	IV instar	V instar	III instar	IV instar	V instar
Jaadoo BG I	206.53 (14.40)[a]	281.75 (16.81)[a]	256.58 (16.02)[a]	160.83 (12.70)[a]	244.78 (15.65)[b]	268.25 (16.40)[a]
Mallika BG I	210.55 (14.54)[a]	267.57 (16.37)[a]	242.75 (15.60)[ab]	152.13 (12.37)[a]	281.58 (16.80)[a]	260.23 (16.15)[a]
Jaadoo BG II	167.27 (12.93)[b]	223.37 (14.97)[b]	210.90 (14.55)[c]	117.83 (10.89)[b]	208.53 (14.46)[c]	243.58 (15.63)[ab]
Mallika BG II	166.75 (12.95)[b]	213.80 (14.65)[b]	220.43 (14.87)[bc]	117.66 (10.88)[b]	202.95 (14.27)[c]	223.1 (15.07)[b]
Jaadoo non- *Bt*	224.13 (14.99)[a]	278.20 (16.70)[a]	261.05 (16.18)[a]	166.73 (12.94)[a]	249.3 (15.80)[ab]	260.6 (16.17)[a]
Mallika non- *Bt*	220.90 (14.89)[a]	271.75 (16.51)[a]	268.25 (16.39)[a]	165.38 (12.89)[a]	265.88 (16.32)[ab]	268.75 (16.40)[a]
F-test	Sig	Sig	Sig	Sig	Sig	Sig
SEm±	0.43	0.26	0.3	0.45	0.34	0.28
CD (P=0.05)	1.27	0.77	0.9	1.35	1.02	0.82

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

Table.7 Per cent adult emergence of *S. litura* on test hybrids

Treatments	Adult emergence (%)					
	Leaves			Squares		
	III instar	IV instar	V instar	III instar	IV instar	V instar
Jaadoo BG I	100.00 (90.00)[a]	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)[a]	100.00 (90.00)	100.00 (90.00)
Mallika BG I	100.00 (90.00)[a]	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)[a]	100.00 (90.00)	100.00 (90.00)
Jaadoo BG II	62.50 (52.33)[b]	100.00 (90.00)	100.00 (90.00)	70.00 (56.94)[b]	100.00 (90.00)	100.00 (90.00)
Mallika BG II	65.00 (53.99)[b]	100.00 (90.00)	100.00 (90.00)	70.00 (56.94)[b]	100.00 (90.00)	100.00 (90.00)
Jaadoo non- *Bt*	100.00 (90.00)[a]	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)[a]	100.00 (90.00)	100.00 (90.00)
Mallika non- *Bt*	100.00 (90.00)[a]	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)[a]	100.00 (90.00)	100.00 (90.00)
F-test	Sig	NS	NS	Sig	NS	NS
SEm±	1.99	-	-	1.49	-	-
CD (P=0.05)	5.9	-	-	3.78	-	-

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

The mean larval weight of fourth instar larvae after feeding for 3 days was maximum in Mallika non-*Bt* (537.10 mg) followed by Jaadoo non-*Bt* (527.43 mg) Jaadoo BG I (486.93 mg) and Mallika BG I (480.00 mg) and minimum in Mallika BG II hybrid (339.78 mg) followed by Jaadoo BG II (389.23). Both staked *Bt* cotton hybrids are significantly different from other hybrids. After three days of feeding the per cent weight gain was low (50.47 %) in Mallika BG II and Jaadoo BG II (56.76%) compared to other test hybrids. The maximum weight gain was noticed in Mallika non-*Bt* (68.67%) followed by Jaadoo non *Bt* (68.09%), Jaadoo BG I (65.44%), and Mallika BG I (64.94%), All these hybrids are statistically on par and significantly different from Jaadoo and Mallika BG II hybrids.

Effect of test hybrids on pupation

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

Leaves

There was 67.50% pupation in third instar in Mallika BG II and 65.00% pupation in Jaadoo BG II cotton hybrids and 100.00% in fourth and fifth instar larvae when fed on Jaadoo and Mallika BG II hybrids and this is significantly superior over other hybrids.

In fourth and fifth instars larvae, there was no mortality, hence all the larvae pupated at the end on all the hybrids.

In Jaadoo and Mallika BG II hybrids also 100.00% pupation was recorded in fourth and fifth instar larvae.

Squares

The per cent pupation of third instar larvae fed on squares of Jaadoo BG II and Mallika BG II was 75.00% and it was 100.00% in all the hybrids in third, fourth and fifth instars (Table 5).

Effect of test hybrids on pupal weight

Leaves

The third instar larvae fed on leaves of Jaadoo non *Bt* recorded 224.13 mg/pupa weight followed by Mallika non-*Bt* (220.90 mg/pupa), Mallika BG I (210.55 mg/pupa) and Jaadoo BG I (206.53 mg/pupa) hybrids and all are statistically on par with each other except Jaadoo and Mallika BG II hybrids with only (167.27 and 166.75 mg/pupa) of mean pupal weight respectively.

The maximum pupal weight of 281.75 mg/pupa was recorded, when fourth instars larvae were fed on leaves of Jaadoo BG I hybrid and it is statistically on par with other hybrids except Jaadoo and Mallika BG II hybrids (Table 6). The fifth instar larvae fed on leaves of Mallika non *Bt* recorded 268.25 mg/pupa of pupal weight followed by Jaadoo non-*Bt* (261.05 mg/pupa), Jaadoo BG I (256.58 mg/pupa) and Mallika BG I (242.75 mg/pupa) hybrids and all are statistically on par with each other except Jaadoo and Mallika BG II hybrid with only 210.90, 220.43 mg/pupa of mean pupal weight respectively. BG II cotton hybrids were statistically significant over the BG I and non-*Bt* hybrids.

Squares

The mean pupal weight has increased gradually with increase in age of larvae on Jaadoo and Mallika BGII hybrids. The maximum pupal weight (268.75 mg/pupa) was recorded on Mallika non *Bt* hybrid and it was statistically on par with Jaadoo BG I (268.25 mg/pupa), Mallika BG I (260.23 mg/pupa), Jaadoo non-*Bt* (260.6 mg/pupa) whereas Jaadoo BG II (243.58 mg/pupa) and Mallika BGII hybrid recorded lowest (223.10 mg/pupa) pupal weight when fifth instars larvae were reared on Mallika BG II hybrid.

Effect of different test hybrids on adult emergence

Leaves

Third instar larvae recorded 62.50, 65.00% adult emergence in Jaadoo and Mallika BG II hybrids respectively, In fourth and fifth instar there was 100 per cent adult emergence in all the test hybrids (Table 7).

Squares

Third instar 70% adult emergence was recorded on both Jaadoo and Mallika BG II hybrids. Where as in other hybrids 100.00% adult emergence was recorded and all these are on par. Adult emergence was 100% for fourth and fifth instars reared on the all test hybrids (Table 7).

The results from the present investigation also clearly suggest that the BG II cotton hybrids which contains Cry1Ac protein, offer marginal influence on only third instar larvae, these findings are in close association with the results of Zeng *et al.,* (1998) who reported that the development of *S. exigua* on BG I cotton was normal. The BG I cotton hybrids which were efficient against *H. armigera* as revealed from the references of Kranthi *et al.,* (2005) and Seshamahalakshmi (2007) have not offered any efficacy against *S. litura* during the 70-80 days old crop.

The duration of mortality of *S. litura* on leaves of all the test hybrids was studied for all the larval instars during 70 to 80 days old crop, pertaining to 3rd instar larvae, there was 35.00 per cent mortality of larvae at 7 days after release. The findings clearly suggest that BG II cotton hybrids have marginal mortality on third instar larvae only and The mortality of 4th and 5thinstar larvae were zero which was non economical in pest management of cotton ecosystem. The BG I and non *Bt* cotton

hybrids did not effect 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* (Vennila *et al.,* 2006; Jeyakumar *et al.,* 2007; Basavaraja *et al.,* 2008) cannot offer any protection to *S. litura*.

It was clear from the results that larval or pupal weights of third, fourth and fifth larval instars were maximum when fed on leaves of non *Bt* and BG I cotton hybrids. The present findings derive support from Sparks and Norman (2002) and Basavaraja *et al.,* (2008) 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 Camberos *et al.,* (2000), Donglin *et al.,* (2006), Fitt *et al.,* (2000) and Seshamahalakshmi (2007) who reported significant reduction in the larval and pupal weights when fed with stacked *Bt* (BG II) cotton leaves.

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