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Susceptibility of various Bt cotton hybrids to *Helicoverpa armigera* (Hubner)

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Abstract
Bt cotton, which confers resistance to important insect pests of cotton, was first adopted in India as hybrids in 2002. Five years later, in 2007 Bt cotton area had soared to 6.2 million ha grown by 3.8 million ha - a remarkably high proportion in a fairly short period of five years. The main objective of this study was field screening of Bt cotton hybrids against *H. armigera* (Hubner), for which observations of Bt hybrids were undertaken at weekly intervals from 15 to 135 days after emergence for recording larval population and damaged caused by *Helicoverpa armigera*. The lowest mean neonate larval count per five plants was observed on Tulshi-9 (0.17 to 0.53) followed by RCH-Alto (0.33 to 0.67), JK-99 (0.50 to 1.67) and RCH-2 (0.17 to 0.50) at all levels of observation. In case of percent damage to square, flowers, bolls (fruiting bodies) similar trend was observed. Mallika and MECH-162 recorded comparatively higher number of neonate larvae and percent damage. Tulshi-9 recorded highest yield (15.01 q/ha) followed by JK-99 (11.37 q/ha), RCH-Alto (10.95 q/ha) and Bunny (10.75 q/ha). All the Bt hybrids were found statistically superior over non-Bt in lowering larval count, reducing percent damage and increasing the yield.

Keywords: Bt cotton, *Helicoverpa armigera*, Hybrids, Field- efficacy.

1. Introduction
Cotton (*Gossypium* spp.) popularly known as 'White Gold' plays a prominent role in Indian economy. It is grown chiefly for its fiber used in the manufacture of cloth and extraction of oil from the cotton seed. The area under cotton in India during 2007-08 was 9.3 million ha with average productivity of 599 kg lint/ha. However, the productivity of Maharashtra was only 320 kg lint/ha as compared to national productivity [1]. Amongst the various factors responsible for low productivity, the cotton bollworms play a major role. It was estimated that insecticides worth Rs. 16 billion are used against bollworms alone [7]. This indiscriminate and excessive use of insecticides on cotton crop resulted into the problems of harmful residues, resurgence of secondary and minor pests, development of resistance, adverse effect on natural enemies of cotton, environmental pollution, etc. This prompted a development of another method for the management of bollworms. So on 26th March 2002, Mahyco Pvt. Ltd., Jalana (M.S.) in collaboration with Monsanto, USA had released first commercial hybrids of Bt cotton viz., MECH 12, MECH 162 and MECH 184. All hybrids of transgenic Bt cotton do not provide the same level of lepidopteran control. Cry1Ac expression levels among Bt cotton hybrids have been correlated to survival level in various lepidopterans that are intrinsically tolerant to Bt. The novel transgenic technology was found to be highly beneficial in almost all parts of the world in terms of its capability to keep the target pests under check. However, for the transgenic technology to be sustainable, it is important that the toxin expression levels should be expressed at adequate quantity in appropriate plant parts at the requisite time of the season to afford protection against major target insect pests, which primarily includes the bollworms. Hence, the present investigation on "Susceptibility of Various Bt Cotton Hybrids to *Helicoverpa armigera* (Hubner)" was carried out.

2. Material and Methods
The eight Bt-cotton hybrids, i.e. Bunny, Mallika, MECH-162, RCH-2, Ankur-651, JK-99, RCH-Alto and Tulshi-9 Bt along with non-Bt check, PKV Hy-2 were sown in Randomized Block Design (RBD) with three replications (plot size – 5.40m × 4.80m) in the field of Department of Entomology, Dr. PDKV, Akola, for two seasons *i.e.*, *kharif* 2007-08 and 2008-09. Recommended agronomic and crop management practices were followed. Five plants per

plot were selected randomly for recording observations and number of *H. armigera* larvae per plant was recorded at an interval of 15 days starting from 30 days after emergence (DAE) of crop. For assessing damage of fruiting bodies, total fruiting bodies and damaged bolls on selected five plants were counted and percent fruiting bodies damage were calculated at an interval of 15 days from 30 DAE of crop. Yield was collected in kg per plot were converted into quintal per hectar (q/ha). Data thus obtained was subjected to statistical analysis (By RBD and ANOVA) after appropriate transformations wherever necessary [3].

3. Results and Discussion

3.1 Larval population of *H. armigera*

At 75 DAE

The pooled data (Table 1) reveals that the Bt hybrid Ankur-651 recorded lowest population of 0.17 neonate larvae of *H. armigera* followed by JK-99, Tulshi-9, Mallika, RCH- 2, Bunny and RCH-Alto, recording, 0.33, 0.33, 0.50, 0.50, 0.50 and 0.67 larvae per five plants, respectively and all these seven treatments were found equally effective, statistically. However, MECH-162 Bt and PKV Hy-2 recorded significantly higher population of 1.67 and 2.17 larvae and were at par with each other. The non-Bt PKV Hy-2 recorded highest population and all other hybrids except MECH-162 were found significantly superior over PKV Hy-2.

At 90 DAE

The lower population (0.33 larvae) of *H. armigera* (Table 1) was recorded on Tulshi-9, RCH-2 and JK-99 followed by Ankur-651, RCH-Alto, Mallika, Bunny Bt (0.50 larvae each) and MECH-162 Bt (0.83 larvae). All these Bt hybrids were significantly superior over non-Bt hybrids in harbouring *H. armigera* populations. However, the non-Bt i.e. PKV Hy-2 recorded highest larval population of 2.17 per five plants.

At 105 DAE

The pooled data (Table 1) shows that all Bt hybrids were found significantly superior over non-Bt i.e. PKV Hy-2. Tulshi-9, RCH-Alto, JK-99, Ankur-651, RCH-2, Mallika and Bunny Bt were found equally effective treatment and significantly similar recording 0.33 larvae each and at par with MECH-162 Bt which recorded 0.67 neonate larvae per five plants. Whereas, PKV Hy-2 recorded highest larval population of *H. armigera* i.e. 1.67 larvae per five plants.

At 120 DAE

The pooled data (Table 1) shows that minimum population was observed on equally effective treatments of Tulshi-9, JK-99, RCH-2 and Ankur-651 Bt recording 0.17 larval populations each per five plants. Whereas, RCH-Alto and Bunny Bt recorded the population of 0.33 each per five plants followed by Mallika and MECH-162 Bt which recorded 0.50 larvae each per five plants. The non-Bt hybrid PKV Hy-2 recorded highest larval population of 0.83 per five plants and all these hybrids were found statistically at par with each other.

Table 1: Larval population of *H. armigera* per five plants

Sr. No	Treatments	No of larvae per five plants			
		75 DAE	90 DAE	105 DAE	120 DAE
1)	T_1 - Bunny Bt	0.50 (1.00)	0.50 (1.00)	0.33 (0.88)	0.33 (0.90)
2)	T_2 - Mallika Bt	0.50 (0.98)	0.50 (1.00)	0.33 (0.90)	0.50 (0.98)
3)	T_3 - MECH-162 Bt	1.67 (1.45)	0.83 (1.11)	0.67 (1.04)	0.50 (0.98)
4)	T_4 - RCH-2 Bt	0.50 (1.00)	0.33 (0.88)	0.33 (0.90)	0.17 (0.81)
5)	T_5 - Ankur-651 Bt	0.17 (0.81)	0.50 (0.98)	0.33 (0.90)	0.17 (0.81)
6)	T_6 - JK-99 Bt	0.33 (0.90)	0.33 (0.90)	0.33 (0.90)	0.17 (0.81)
7)	T_7 - RCH-Alto Bt	0.67 (1.07)	0.50 (1.00)	0.33 (0.88)	0.33 (0.90)
8)	T_8 - Tulshi-9 Bt	0.33 (0.90)	0.33 (0.90)	0.33 (0.90)	0.17 (0.81)
9)	T_9 - PKV Hy-2	2.17 (1.63)	2.17 (1.63)	1.67 (1.47)	0.83 (1.14)
	'F' test	Sig.	Sig.	Sig.	Sig.
	SE (m) ±	0.10	0.12	0.20	0.11
	CD at 5%	0.26	0.31	0.52	0.28

Figures in parenthesis are square root values

In general the larval population of *H. armigera* on field crop was low ranging zero to 2.67 per five plants. However amongst the Bt hybrids tested, it was very low ranging from zero to 2.00 larvae per five plants. The larvae recorded were only neonates. Whereas, the hybrid Tulshi-9 was recorded with the lowest larval count at all observations, followed by statistically similar hybrids like, RCH-Alto, JK-99, RCH-2, Ankur-651 and Bunny. MECH-162 and Mallika were recorded with comparatively higher population of *H. armigera* when observed fortnightly from 15 to 135 DAE. More or less similar trend was noticed in all observations. Similar findings were also recorded by Sumerford and Solomon [8]. They found significantly fewer larvae on Bt cotton than non-Bt cotton. Bagade *et al.* [2], however, observed minimum larval population on the three Bt cotton hybrids i.e. MECH-184, MECH-12 and MECH-162 Bt as compared to their non-Bt version and check hybrids. However, Kongming [5] reported that the field populations were susceptible to Cry1Ac and

monitoring indicated no apparent shifts in susceptibility in field populations of this important pest which confirm the present findings.

3.2 Percent fruiting bodies damage by *H. armigera*

At 75 DAE

The pooled data presented in Table 2 shows that the lowest percent fruiting damage was recorded on Ankur-651 (0.43%) followed by Tulshi-9 (0.45%), JK-99 (0.53%), RCH-2 (0.67%), Mallika (0.75%), Bunny (0.74%). All these treatments were found statistically at par with each other. RCH-Alto and MECH-162 Bt recorded 0.99 and 2.07 percent damage, respectively and were at par with PKV Hy-2 (non-Bt) which recorded 10.20 percent damage. All the Bt treatments except RCH-Alto and MECH-162 Bt were found significantly superior over non-Bt i.e. PKV Hy-2.

At 90 DAE

The lowest fruiting damage (Table 2) was observed on RCH-2 (0.50%) followed by JK-99 and Tulshi-9 Bt recording 0.46 and 0.49 per cent damage, respectively. Whereas RCH-Alto, Ankur-651, Bunny, Mallika and MECH-162 Bt recorded 0.67, 0.69, 0.74, 0.81 and 1.65 percent, respectively. All these Bt treatments were found statistically at par with each other and significantly superior over non-Bt hybrid PKV Hy-2 which recorded highest damage of 8.95 percent.

At 105 DAE

The pooled data presented in Table 2 shows that all the Bt hybrids were found significantly superior over non-Bt i.e. PKV Hy-2. The minimum fruiting damage was observed on RCH-Alto (0.49%) followed by JK-99 (0.46), Tulshi-9 (0.51%), RCH-2 (0.52%), Bunny (0.63%), Ankur-651 (0.73%), Mallika (0.91%) and MECH-162 (1.33%). All these Bt treatments were seen statistically at par with each other. However, non-Bt PKV Hy-2 recorded highest damage of 7.43 percent.

At 120 DAE

The pooled data (Table 2) shows that Ankur-651 Bt, proved better against *H. armigera* recording zero fruiting damage. The lower fruiting damage was noticed on Tulshi-9 and JK-99 (0.22%) followed by RCH-Alto (0.42%), RCH-2 (0.45%) and Bunny (0.51%) and all Bt hybrids were seen statistically at par with each other. Whereas, MECH-162 and Mallika recorded 0.67 and 1.05 percent damage and were at par with non-Bt i.e. PKV Hy-2, which recorded highest damage of 5.01 per cent, All Bt treatments were found significantly superior over non-Bt i.e. PKV Hy-2.

Table 2: Percent fruiting bodies damage of *H. armigera*

Sr. No	Treatments	Percent fruiting bodies damage			
		75 DAE	90 DAE	105 DAE	120 DAE
1)	T_1 - Bunny Bt	0.74 (1.11)	0.74 (1.11)	0.63 (0.99)	0.51 (0.98)
2)	T_2 - Mallika Bt	0.75 (1.08)	0.81 (1.14)	0.91 (1.17)	1.05 (1.24)
3)	T_3 - MECH-162 Bt	2.07 (1.60)	1.65 (1.47)	1.33 (1.29)	0.67 (1.08)
4)	T_4 - RCH-2 Bt	0.67 (1.08)	0.50 (0.94)	0.52 (0.99)	0.45 (0.96)
5)	T_5 - Ankur-651 Bt	0.43 (0.95)	0.69 (1.09)	0.73 (1.07)	0.00 (0.71)
6)	T_6 - JK-99 Bt	0.53 (1.00)	0.46 (0.97)	0.46 (0.96)	0.22 (0.83)
7)	T_7 - RCH-Alto Bt	0.99 (1.21)	0.67 (1.08)	0.49 (0.94)	0.42 (0.94)
8)	T_8 - Tulshi-9 Bt	0.45 (0.96)	0.49 (0.98)	0.51 (0.99)	0.22 (0.83)
9)	T_9 - PKV Hy-2	10.20 (3.24)	8.95 (3.03)	7.43 (2.80)	5.01 (2.34)
	'F' test	Sig.	Sig.	Sig.	Sig.
	SE (m) ±	0.16	0.17	0.22	0.08
	CD at 5%	0.41	0.44	0.57	0.21

Figures in parenthesis are square root values

The fortnightly taken field observation from 15 to 135 DAE on percent fruiting bodies damage by *H. armigera* shows that the Bt hybrid Ankur-651 recorded lowest damage and proved best against *H. armigera*. This was followed by statistically equally effective Bt hybrids of Tulshi-9, JK-99, RCH-Alto, RCH-2 and Bunny when observed at 120 days after emergence. However, the Bt hybrids MECH-162 and Mallika recorded comparatively higher damage. In general the damage throughout the growth period of Bt cotton was found low i.e. zero to 2.18 percent as against 11.85 percent in non-Bt. Similar trend was seen when observed on 75,90 and 105 days after emergence. Similar results were also recorded by the past workers like, Mandaokar *et al*. [6] who reported that limited field trials of the transgenic plants confirmed the high levels of insect protection. Whereas, Gore *et al.* [4] observed the bollworm injury to white flowers and small bolls and provide a better understanding of larval behaviors on Bollgard cotton, which confirms the present findings.

3.3 Yield of Cotton (q/ha)

First year (2007-08)

The yield data presented in Table 3 was statistically significant. The highest yield of 17.37 q/ha was recorded for Tulshi-9 Bt followed by JK-99 and Bunny i.e. 14.50 and 12.85

q/ha, respectively. However, RCH-Alto and RCH-2 Bt recorded 11.94 and 10.97 q/ha, followed by Ankur-651 (9.61 q/ha), Mallika (8.35 q/ha) and MECH-162 (8.08 q/ha). All the Bt hybrids were found statistically at par with each other and significantly superior over non-Bt PKV Hy-2 which recorded lowest yield of 7.83 q/ha.

Second year (2008-09)

The data collected during 2007-08 (Table 3) was statistically significant. The highest yield was recorded for Tulshi-9 (12.65 q/ha) followed by RCH-Alto (9.95 q/ha). Other hybrid like MECH-162, Bunny and JK-99 Bt recorded 8.93, 8.64 and 8.24 q/ha yields, respectively and were statistically similar one. However, Ankur-651, Mallika and RCH-2 recorded lower yields of 7.77, 7.49 and 6.20 q/ha, respectively. Significantly lowest yield of 4.99 q/ha was recorded for PKV Hy-2.

Pooled (2007-08 and 2008-09)

The pooled data presented in Table 3 shows that significantly highest yield of 15.01 q/ha was recorded for Tulshi-9 Bt. The hybrid JK-99, RCH-Alto and Bunny recorded higher yield of 11.37, 10.95 and 10.75 q/ha, respectively. However, the other hybrids like Ankur-651, RCH-2, MECH -162 and Mallika Bt recorded 8.69, 8.59, 8.51 and 7.92 q/ha yield, respectively. All the Bt hybrids were statistically at par with each other and superior over non-Bt PKV Hy-2, which recorded lowest yield of 6.41 q/ha.

Table 3: Yield of cotton (q/ha)

Sr. No.	Treatments	Yield of cotton q/ha					
		I year	(2007-08)	II year	(2008-09)	Pooled Analysis	
1)	T_1 - Bunny Bt	12.85	(3.33)	8.64	(2.24)	10.75	(2.79)
2)	T_2 - Mallika Bt	8.35	(2.16)	7.49	(1.94)	7.92	(2.05)
3)	T_3 - MECH-162 Bt	8.08	(2.09)	8.93	(2.36)	8.51	(2.21)
4)	T_4 - RCH-2 Bt	10.97	(2.84)	6.20	(1.61)	8.59	(2.23)
5)	T_5 - Ankur-651 Bt	9.61	(2.49)	7.77	(2.01)	8.69	(2.25)
6)	T_6 - JK-99 Bt	14.50	(3.76)	8.24	(2.14)	11.37	(2.95)
7)	T_7 - RCH-Alto Bt	11.94	(3.09)	9.95	(2.58)	10.95	(2.84)
8)	T_8 - Tulshi-9 Bt	17.37	(4.50)	12.65	(3.28)	15.01	(3.89)
9)	T_9 - PKV Hy-2	7.83 (2.03)		4.99	(1.29)	6.41	(1.66)
	'F' test	Sig.		Sig.		Sig.	
	SE (m) ±	0.62		0.61		0.57	
	CD at 5%	1.67		1.58		1.48	

Figures in parenthesis are yield Kg/plot values

The Bt hybrid Tulshi-9 was found as most effective in recording highest yield i.e. 15.01 q/ha and was significantly superior over all other hybrids. Whereas, JK-99, RCH-Alto and Bunny were the next effective hybrids as they recorded the yield from 10.75 to 11.37 q/ha and were statistically at par with each other. However, Ankur-651, RCH-2, MECH-162 and Mallika recorded comparatively lower yield i.e. 7.92 to 8.69 q/ha but were statistically equal and significantly superior over non-Bt hybrid i.e. PKV Hy-2 which yielded only 6.41 q/ha. The hybrids which recorded higher larval count and higher fruiting damage resulted into lower yields and vice-versa. Similar observations were also recorded by Anonymous [1] that Bt gene expression confers high level of tolerance to the bollworm complex which clearly established the superior performance of Bt cotton, as demonstrated by increased yield, increased profits and reduced pesticide application, which is in conformity with the present findings.

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