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Influence of Transgenic Cotton Cultivars on Growth and Development of *Pectinophora gossypiella* (Saunders)

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***Abstract*:** The reinvasion of pink bollworm, *Pectinophora gossypiella* has imposed threats in cultivation of Bt cotton in India. The information on life cycle of *P. gossypiella* on various transgenic cotton cultivars grown widely under Punjab conditions is lacking. Therefore, present research on four BG II cotton cultivars namely, Ankur Jassi, MRC 9024, RCH 776, SP 7172; two Bt cotton varieties namely, PAU Bt 2, PAU Bt 3 and non-Bt cotton variety, F 2228 was carried out. The mean larval span was significantly lower on BG II cotton cultivars and higher on non-Bt cotton cultivar. Larval and pupal weight, larval and pupal survival was higher on non-Bt cotton in comparison to BG II cotton cultivars. Except for fecundity, BG II cotton has significant detrimental effect on other vital parameters of *P. gossypiella*. Overall, it can be concluded that BG II cotton cultivars namely, Ankur Jassi and MRC 9024 have most detrimental effect on various biological parameters of *P. gossypiella* and these cultivars can be recommended for cultivation under Punjab condition in integration with other management tactics.

***Keywords*:** *Pectinophora gossypiella,* BG II cotton, Non-Bt cotton, Life cycle

Cotton (*Gossypium* spp.) is an important cash crop in India as well as in Punjab, and plays an important role in social and economic well being of people. India is the largest producer of cotton in the world having area of 130.07 lakh ha with a production of 353.84 lakh bales and productivity of 462.46 kg lint per ha during 2020-21 (Indiastat 2021). Among the various constraints, insect pests are posing major hurdle in the success of cotton cultivation. Various bollworms, including the pink bollworm, *Pectinophora gossypiella* (Saunders), cause serious losses leading to reduction in cotton yield. Bt cotton cultivars having *Cry* genes were introduced in India in 2002 (*Cry1Ac*) and 2006 (*Cry1Ac+ Cry2Ab*), for control of major bollworms of cotton particularly, American, spotted and pink bollworm. Bt cotton was working well against all the bollworms until 2009, when there was infestation of *P. gossypiella* in Gujarat reported to be feeding on single gene Bt cotton. Later, in 2015, the incidence of pink bollworm was again recorded on BG II cotton cultivars in Gujarat. *P. gossypiella* emerged again as a menace on Bollgard cultivars in central and south Indian cotton growing states like Andhra Pradesh, Gujarat, Maharashtra, Karnataka and Telangana after 2015 (Naik et al 2018). In 2021, outbreak of PBW was observed in northern states of Haryana and Punjab. As India is largest producer of cotton worldwide, the reinvasion of pink bollworm has imposed threats in cultivation of Bt cotton.

The pink bollworm, *P. gossypiella* is one of the most destructive bollworms of cotton around the world (Fand et al 2019). WW Saunders gave its first description in 1843 as *Depressaria gossypiella* in 1842 from Gujarat. *P. gossypiella* is considered as 'difficult to control bollworm' because of cryptic habitat of feeding of its larvae inside flowers and bolls. In Punjab, only scanty information is available on development of *P. gossypiella* on various Bt cotton cultivars. Therefore, present research was carried on BG II cotton, Bt cotton and non-Bt cultivars to study the various biological parameters of PBW for understanding its biology for its sustainable management.

MATERIAL AND METHODS

Test cultivars: Four BG II cotton cultivars namely, Ankur Jassi, MRC 9024, RCH 776, SP 7172; Bt cotton varieties namely, PAU Bt 2, PAU Bt 3 and non-Bt cotton variety, F 2228 were selected because of their larger area of cultivation under Punjab conditions. These were sown at Entomological Research Farm by following proper agronomic practices.

Rearing culture of *P. gosspiella:* Larval of *P. gossypiella* were collected from cotton fields of Bathinda district of Punjab and reared on fresh flowers of non-Bt cotton variety, F 2228 until their pupation in IPM Laboratory, PAU Ludhiana. The pupae were sexed based on size and morphological characteristics (Dharajothi et al 2016). The newly emerged adults obtained from the culture were released @ 10 pairs in one plastic jar (45 × 20 cm size) for egg laying as per procedure followed by Fand et al (2019). Two cotton swabs each of 10 per cent honey solution and water were hung in oviposition jars as adult food source. The jar was covered with black paper from outside to simulate dark conditions

ideal for egg laying. Adult moths were transferred to new jars having fresh twigs and food source throughout the oviposition period of female at an interval of two days. For carrying out biological studies of *P. gossypiella*, newly hatched first instar larvae were collected from these twigs and released on flowers of test cotton cultivars.

Life cycle of *P. gossypiella* on test cultivars: The study on life stages of *P. gossypiella* on four Bollgard II cotton hybrids, two Bt cotton varieties and non-Bt cotton cultivars was carried out during August, 2021. The stage of test cultivars was of 90-120 days after sowing (31st to 34th SMW). For recording larval span, thirty first instar larvae were taken in three replications for each test cultivar. Fresh flowers of each cultivar were kept in three plastic jars (45 × 20 cm size) for first and second instar larvae. Third and fourth instar larvae were reared on the bolls of various test cultivars. The food was changed after two days (fresh flowers and bolls) depending upon the stage of the larvae till their pupation. The adults were reared as per procedure followed earlier. To record female pre-oviposition, oviposition and post-oviposition period and fecundity, three pairs of freshly emerged adults were released into oviposition jar. Male longevity was also recorded. Cotton bolls in each oviposition jars were replaced after every two days interval till the death of the female. The experiment was conducted under 30.95±0.44°C temperature and 72.63±3 per cent relative humidity in laboratory conditions. The observations on egg period, larval period, larval weight, pupal period, pupal weight, total developmental period, adult longevity, pre-oviposition, oviposition and post oviposition period, fecundity, larval and pupal mortality were recorded on each test plant. Observations were taken twice a day to keep record of various biological parameters of *P. gossypiella* on above-mentioned cultivars. Larval weight was recorded for fully matured fourth instar larva. Weight of pupae (male and female) was recorded 48 hours after pupation. By dividing the number of dead individuals by the total number of individuals used in the study, percent mortality was worked out for each cultivar.

Statistical analysis : One-way analysis of variance was used for analyzing various developmental parameters (Statistix 10 software) and the significance of various treatments was evaluated using Tukey's test.

RESULTS AND DISCUSSION

The larval period was shorter on BG II cotton cultivars, Ankur Jassi (15.08 days) being at par with SP 7172, MRC 9024, PAU Bt 3 and PAU Bt 2. However, it was significantly longer on F 2228 (19.93 days) being at par with RCH 776. Zinzuvadiya et al (2017) observed total larval span in range of 17.50 and 18.15 days for larvae separated as male and female, respectively. The pupal duration was in range of 7.94 (SP 7172) to 9.48 days (PAU Bt 2) and statistically no significant differences were observed among various cultivars. Total development period was significantly lower on Ankur Jassi (26.65 days) being at par with SP 7172 and MRC 9024. Our findings on pupal period are in agreement with the findings of Adkisson et al (1960) and Fand et al (2019). The longer developmental period was observed on non-Bt cotton cultivar, F 2228 (33.37 days) being at par with PAU Bt 2 and RCH 776 followed by PAU Bt 3.

No significant difference in pre-oviposition, oviposition and post-oviposition period and mean female longevity of *P. gossypiella* were recorded among various cotton cultivars (Table 1). Zinzuvadiya et al (2017) also reported the pre-oviposition, oviposition and post-oviposition period of 2.91, 8.00 and 4.30 days, respectively. Male longevity significantly ranged from 8.44 (MRC 9024) to 10.67 (PAU Bt 3) days, which was significantly longer on PAU Bt and non-Bt cotton varieties as compared to BG II cotton cultivars. Fand et al (2019) reported similar results.

Egg period was in range of 3.38 (Ankur Jassi) to 4.54

Table 1. Effect of cotton cultivars on various life stages of *Pectionophora gossypiella*

Cultivars	Duration of various stages (days)								
	Egg	Larval	Pupal	Total development	Pre-oviposition	Oviposition	Post-oviposition	Adult female	Adult male
MRC 9024	3.89^{bc}	15.73^{b}	9.08^{a}	28.70^{cde}	2.17^{a}	8.67^{a}	1.20^{a}	12.04^{a}	8.44^{ab}
SP 7172	4.21^{ab}	15.52^{b}	7.94^{a}	27.67^{de}	2.76^{a}	9.45^{a}	1.25^{a}	13.47^{a}	9.68^{abcd}
Ankur Jassi	3.38^{c}	15.08^{b}	8.19^{a}	26.65^{e}	2.60^{a}	9.21^{a}	1.44^{a}	13.26^{a}	8.55^{ab}
RCH 776	4.00^{abc}	18.56^{a}	9.43^{a}	31.99^{ab}	2.74^{a}	9.66^{a}	1.04^{a}	13.44^{a}	8.87^{ab}
PAU Bt 2	4.54^{a}	16.56^{b}	9.48^{a}	30.58^{abc}	2.61^{a}	9.18^{a}	1.35^{a}	13.14^{a}	10.43^{cd}
PAU Bt 3	4.40^{ab}	16.02^{b}	9.36^{a}	29.78^{bcd}	2.48^{a}	10.39^{a}	1.19^{a}	14.06^{a}	10.67^{d}
F 2228	4.35^{ab}	19.93^{a}	9.00^{a}	33.37^{a}	2.41^{a}	9.64^{a}	0.94^{a}	12.98^{a}	9.87^{bcd}

Values within each test followed by a different letter are significantly different at $p < .05$ by Tukey Test (one-way ANOVA); Mean of 3 replications

Table 2. Weight of larvae and pupae of *Pectionophora gossypiella* on various cotton cultivars

Cultivars	Fourth larval instar	Female pupa	Male pupa	Fecundity/ female
	Weight (mg)			
MRC 9024	15.89^{ab}	21.72^{a}	9.78^{b}	29.00^{b}
SP 7172	17.46^{ab}	16.75^{a}	11.28^{ab}	36.00^{b}
Ankur Jassi	12.54^{b}	18.90^{a}	9.83^{b}	51.00^{a}
RCH 776	19.69^{a}	18.80^{a}	14.13^{ab}	50.00^{a}
PAU Bt 2	21.21^{a}	18.29^{a}	15.97^{a}	32.00^{b}
PAU Bt 3	16.84^{ab}	17.39^{a}	11.66^{ab}	16.00^{c}
F 2228	22.50^{a}	20.10^{a}	16.63^{a}	50.00^{a}

Values within each test followed by a different letter are significantly different at $p < .05$ by Tukey Test (one-way ANOVA)

Table 3. Mortality of immature stages of *Pectionophora gossypiella* on various cotton cultivars

Cultivars	Mortality of immature stages (%)		
	Ist instar larvae	IInd to IVth instar larvae	Pupa
MRC 9024	23.33^{a}	17.26^{ab}	20.64^{a}
SP 7172	20.00^{ab}	25.27^{a}	16.99^{ab}
Ankur Jassi	23.33^{a}	12.17^{b}	14.29^{ab}
RCH 776	13.33^{bc}	19.45^{ab}	13.10^{ab}
PAU Bt 2	11.67^{c}	20.51^{ab}	20.38^{a}
PAU Bt 3	22.22^{a}	24.08^{a}	12.50^{ab}
F 2228	10.00^{c}	3.73^{c}	7.87^{b}

Values within each test followed by a different letter are significantly different at $p < .05$ by Tukey Test (one-way ANOVA)

days (PAU Bt 2) being lower on BG II cotton and higher on non-Bt and Bt cotton cultivars. The larval weight was higher on non-Bt cotton in comparison to BG II cotton hybrids. It was significantly lower on Ankur Jassi (12.54 mg) being at par with MRC 9024, PAU Bt 3 and SP 7172. However, it was significantly higher on F 2228 (22.50 mg) being statistically at par with PAU Bt 2 and RCH 776 (Table 2). Rajput et al (2018) also observed larval weight as 13.84 and 20.24 mg on Bt and non-Bt cotton, respectively. No significant differences were observed in female pupal weight on different cultivars. However, it was lowest on SP 7172 (16.75 mg) and higher on MRC 9024 (21.72 mg). The male pupal weights were lower on BG II cotton cultivars (9.78–14.13 mg) as compared to larvae reared on non-Bt cotton (16.63 mg). Pupal weight of male was significantly lower on MRC 9024 (9.78mg) being at par with Ankur Jassi, SP 7172 and PAU Bt 3 in comparison to all other treatments. However, it was significantly higher on F 2228 (16.63 mg) being at par with PAU Bt 2 and RCH 776. Rajput et al (2018) also found it to be 23.46 mg on non-Bt cotton and 17.41 mg on Bt cotton. The weight of male pupae on non-Bt and Bt cotton were 21.20 and 13.10 mg, respectively (Liu et al 2001).Similarly, Liu et al (2001) reported female pupal weights to be 23.10 and 17.70 mg on non-Bt and Bt cotton, respectively.

Fecundity ranged from 16 to 51 eggs per female on various cotton cultivars. It was significantly lower on PAU Bt 3 (16.00) followed by MRC 9024, PAU Bt 2 and SP 7172 in comparison to all other treatments (Table 2). However, fecundity was higher on Ankur Jassi (51.00) being at par with F 2228 and RCH 776. Liu et al (2001) and Fand et al (2019) recorded higher fecundity. The difference in fecundity may be due to cultivar, temperature, and laboratory conditions.

The mortality of Ist instar larvae was highest in Ankur jassi and MRC 9024 (23%) being at par with PAU Bt 3 and SP 7172. The survival was highest in F 2228 being at par with PAU Bt 1 and RCH 776 (Table 3). The observations on mortality of 2nd to 4th instar larvae were in range of 3.73- 25.27 per cent. The mortality of larvae was least in F 2228 (3.73%) followed by other cultivars being higher on selective BG II cotton cultivars. The pupal mortality was significantly in range of 7.87- 20.64 per cent being lowest on F 2228 and higher on MRC 9024. These observations clearly indicate that non-Bt cotton is suitable host for development of *P. gossypiella* while BG II cotton cultivars support least survival of pink bollworm larvae and pupae.

CONCLUSION

The mean larval span was significantly lower on BG II cotton cultivars and higher on non-Bt cotton cultivar. Larval weight, pupal weight, larval and pupal survival were more on non-Bt cotton in comparison to BG II cotton cultivars. Except for fecundity, BG II cotton has significant detrimental effect on other vital parameters of *P. gossypiella*. Overall study revealed that BG II cotton cultivars, Ankur Jassi and MRC 9024 have most negative effect on various biological parameters of pink bollworm and can be recommended for cultivation under Punjab condition in integration with other measures like pheromone-based mating disruption technology and chemical components.

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