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Effect of Bt Cotton on Growth and Development of Tobacco Caterpillar, *Spodoptera litura* (Fab)

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ABSTRACT

The mortality of early larval instars of *S. litura* was higher compared to the later instars on both the leaves and squares of Bt_2 cotton hybrids. Moreover the mortality on leaves was higher compared to squares for all the larval instars in Bt_2 (Tulasi4BGII) compared to Bt_1 (Tulasi4Bt) and non-*Bt* (Bunny) cotton hybrids. Exposure of later instar larvae of *S. litura* to plant parts of Bt_2 cotton hybrids exhibited reduced larval weight, prolonged larval development period, reduced pupation, formation of small pupae with less weight, reduced adult emergence and low growth and survival index compared to Bt_1 and non-*Bt* cotton hybrids.

Key words : Bt_1, Bt_2, Non- *Bt* cotton hybrids, *Spodoptera litura*.

Cotton is a leading commercial crop grown for its valuable fiber. India ranks number one in the world accounting for 20% of the total area planted under cotton. However, even with highest area under cotton, nine million hectares, India ranks only third position with only 13% in production of cotton. India's average yield is only 319 kg/ha lint as compared to world average of 603 kg/ha. The major constraint in the productivity is the damage caused by large number of insect pests *viz*., spotted bollworm, *Earias vittella* (Fab.); American bollworm, *Helicoverpa armigera* (Hubner); tobacco caterpillar, *Spodoptera litura* (Fabricius); pink bollworm, *Pectinophora gossypiella* (Saunders); leafhopper, *Amrasca biguttula biguttula* (Ishida); aphid, *Aphis gossypii* (Glover) and whitefly, *Bemisia tabaci* (Gennadius) causing 50-60 per cent losses (Dhawan *et al*., 2004). Among them the tobacco caterpillar, *Spodoptera litura* (Fabricius) is a polyphagous lepidopterous pest reported to infest about 112 crop species throughout the country such as cotton, tobacco, chilli, groundnut, castor *etc*. (Fletcher, 1919; Ramakrishna Ayyar, 1942 and Jotwani *et al*., 1961). Fifty percent of the total insecticides consumed in the country are used only on cotton crop. The chemical control to suppress these insect pests are proving to be ineffective as these pests have developed high level of resistance for most of such chemical used for the control of bollworm complex. Such a high level of resistance require repeated application of insecticides leading to heavy expenditure, crop failures, and viscous cycle of debt for farmers. Therefore, it has been argued that adoption of Bt cotton could help in protecting the crop against potentially the most damaging bollworms and thus reduce the risk of crop failures.

MATERIAL AND METHODS

Bioassay for survival and development of *S.litura* on Bt_1, Bt_2 and non- *Bt* cottons was conducted with Bt_1 (Tulasi4*Bt*), Bt_2 (Tulasi4BGII) and non-*Bt* (Bunny) during *kharif 2007* and *kharif* 2008. The investigation was conducted to study the comparative development with all the larval instars *i.e*., from first to fifth instars by feeding with leaves and squares of Bt_1 (Tulasi4*Bt*), Bt_2 (Tulasi4BGII) and non-*Bt* (Bunny). Tender leaves (top) and squares were plucked from the crop and cleaned in the laboratory. The cleaned leaves and squares were kept individually in petriplates. With the help of camel hair brush, first instar larvae were released on the leaves and squares. Likewise other instars were also released. For each treatment five replications were maintained with 10 larvae per replication at room temperature in the laboratory. Before release on the plant parts the larvae were weighed with an electronic balance. First instar larvae were weighed in mass, while remaining instars were weighed individually. Larvae were

observed daily and changed to respective fresh food material upto pupation. The survival of *S.litura* larvae was recorded everyday. Larval and pupal mortalities were worked out as per cent of total neonates used in the experiments. The growth and survival index were calculated for different treatments using the following formulae (Vennila *et al*., 2006). Growth index = Per cent pupation / Larval development period (days), Survival index = Number of moths emerged / Total number of neonates used. Surviving pupae of *S. litura* were transferred to glass jars for emergence of adults.

RESULTS AND DICUSSION

Effect of Bt_1, Bt_2 and non-*Bt* cotton on larval mortality

The mortality of I instar larvae when fed on leaves of 60 days old Bt_2 hybrid crop was significantly high with 100 per cent mortality compared to 14.00 and 12.00 per cent on Bt_1 and non-*Bt* hybrids, respectively. However, the I instar larvae recorded 74.00 per cent mortality when fed on squares of Bt_2 as against 16.00 per cent on Bt_1 and 12.00 per cent on non-*Bt* hybrids. With regard to II instar larvae, the mortality was 82.00 per cent when fed on leaves of 60 days old crop of Bt_2, which differed significantly from Bt_1 and non-*Bt* hybrids which recorded 14.00 per cent larval mortality. The mortality of II instar larvae when fed on squares was only 46.00 per cent on Bt_2 but differed significantly from Bt_1 and non-*Bt* hybrids both of which recorded 14.00 per cent larval mortality. The mortality of III instar larvae when fed on leaves of 60 days old crop was 58.00 per cent on Bt_2 hybrid, while it was 38.00 per cent on squares of Bt_2. The IV instar larvae were found more resistant to Bt_2 plant parts since they recorded only 26.00 per cent mortality when fed on leaves of Tulasi 4BGII, while it was 0.60 per cent when fed on squares. Mortality was nil in case of III and IV instar larvae on both leaves and squares of Bt_1 and non-*Bt* hybrids. Both Bt_2 and Bt_1 plant parts were found ineffective against V instar larvae since no mortality was found on both leaves and squares of Bt_1, Bt_2 and non-*Bt* hybrids (Table.1)

Effect of Bt_1, Bt_2 and non-*Bt* cotton on larval weights

The weight of I instar larvae could not be recorded since no larvae survived beyond four to five days when fed on leaves and squares of Bt_2 hybrids. The weight of larvae of II, III and IV instar on Bt_2 differed significantly from Bt_1 and non-*Bt* hybrids. The weight of V instar was not taken since they pupated.

The present findings are in conformity with Henneberry *et al*. (2001) who studied the effects of transgenic cotton on cabbage looper, tobacco budworm, beet armyworm and the mortality was found to be 95, 100 and 57 per cent respectively. Sparks and Norman (2002) studied one day old larvae of beet armyworm fed on leaves of Bt_2 and reported 88.30 per cent mortality. Donglin *et al*. (2006) studied the effect of Bt_2 and non-*Bt* hybrids on *S. litura* and found higher mortality on Bt_2 over non- *Bt* hybrids. Sivasubramanium *et al*. (2008) reported that the second instar larvae of *H. zea* showed 90 per cent mortality on Bt_2 compared with 30-80 per cent on Bt_1 cotton. Similarly, feeding on leaf discs from Bt_2 cotton resulted 69-93 per cent mortality whereas exposure to Bt_1 cotton yielded 20-69 per cent mortality in *S. frudiferda*. The larval development of *S. litura* on both the leaves and squares of Bt_2 hybrids indicated that there was a decrease in mortality as the larval age advanced. The present findings are in conformity with Parker *et al*. (2000), Henneberry *et al*. (2001) and Ushashelkar and Regupathy (2004) reported the higher mortality of neonate larvae than the later instars on both leaves and squares. The mortality of all the larval instars was high on leaves when compared to squares of Bt_2 hybrids.

Effect of Bt_1, Bt_2 and non-*Bt* cotton on pupation

The I instar larvae when fed on Bt_2 leaves did not survive, hence there was no pupation where as 84.00 and 88.00 per cent pupation was observed on leaves of Bt_1 and non-*Bt* hybrids, respectively. In contrast, 26.00, 84.00 and 88.00 per cent pupation was observed from the surviving larvae of I instar when fed with squares of Bt_2, Bt_1 and non-*Bt* hybrids, respectively, among which Bt_1 and non-*Bt* being significantly different from Bt_2. The weight of pupae developed from I instar larvae fed with leaves was 135.20 mg / pupa on Bt_1 and 137.40 mg / pupa on non-*Bt*. While it was 105.40, 132 and 135.60 mg / pupa on squares of Bt_2, Bt_1 and non-*Bt* hybrids, respectively, among which Bt_1 and non-*Bt* being significantly different from Bt_2. The morality of II instar larvae was high on leaves

Table1. Per cent mortality of larval instars of *S. litura* on test hybrids.

Treatments	Leaves					Squares				
	I instar	II instar	III instar	IV instar	V instar	I instar	II instar	III instar	IV instar	V instar
Tulasi4*Bt*	14.00 (21.68)^{b}	14.00 (21.68)^{b}	0.00 (0.00)^{b}	0.00 (0.00)^{b}	0.00 (0.00)	16.00 (23.31)^{b}	14.00 (21.68)^{b}	0.00 (0.00)^{b}	0.00 (0.00)^{b}	0.00 (0.00)
Tulasi4BGII	100 (90.00)^{a}	82.00 (65.36)^{a}	58.00 (49.66)^{a}	26.00 (30.13)^{a}	0.00 (0.00)	74.00 (59.57)^{a}	46.00 (42.69)^{a}	38.00 (37.97)^{a}	0.60 (2.77)^{a}	0.00 (0.00)
Non-*Bt* (Bunny)	12.00 (20.06)^{b}	14.00 (21.68)^{b}	0.00 (0.00)^{b}	0.00 (0.00)^{b}	0.00 (0.00)	12.00 (20.06)^{b}	14.00 (21.68)^{b}	0.00 (0.00)^{b}	0.00 (0.00)^{b}	0.00 (0.00)
F TEST	Sig	Sig	Sig	Sig	—	Sig	Sig	Sig	Sig	—
SEm±	2.95	2.29	1.26	2.04	—	2.09	1.81	1.27	1.00	—
CD (p=0.05)	9.10	7.07	3.91	6.30	—	6.44	5.60	3.93	3.09	—

Figures in parentheses are angular transformed values
Numbers followed by same superscript are not statistically different

Table 2. Per cent pupation of surviving larvae of *S. litura* on test hybrids.

Treatments	Leaves					Squares				
	I instar	II instar	III instar	IV instar	V instar	I instar	II instar	III instar	IV instar	V instar
Tulasi4*Bt*	84.00 (66.68)^{b}	84.00 (66.68)^{b}	100 (90.00)^{b}	100 (90.00)^{b}	100 (90.00)	84.00 (66.68)^{b}	86.00 (68.31)^{b}	100 (90.00)^{b}	100 (90.00)	100 (90.00)
Tulasi4BGII	0.00 (0.00)^{a}	18.00 (24.64)^{a}	42.00 (40.33)^{a}	74.00 (59.86)^{a}	100 (90.00)	26.00 (30.42)^{a}	54.00 (47.30)^{a}	62.00 (52.02)^{a}	94.00 (81.00)	100 (90.00)
Non-*Bt* (Bunny)	88.00 (72.00)^{b}	86.00 (68.31)^{b}	100 (90.00)^{b}	100 (90.00)^{b}	100 (90.00)	88.00 (69.93)^{b}	86.00 (68.31)^{b}	100 (90.00)^{b}	100 (90.00)	100 (90.00)
F TEST	Sig	Sig	Sig	Sig	—	Sig	Sig	Sig	Sig	—
SEm±	2.95	2.29	1.26	2.04	—	2.09	1.81	1.27	3.26	—
CD (p=0.05)	11.36	8.83	4.88	7.86	—	6.44	5.60	3.93	10.06	—

Figures in parentheses are angular transformed values
Numbers followed by same superscript are not statistically different

of Bt_2 with only 18.00 per cent pupation where as 84.00 and 86.00 per cent pupation was observed on leaves of Bt_1 and non-*Bt* hybrids, respectively. In contrary, 54.00, 86.00 and 86.00 per cent pupation was observed from the surviving II instar larvae when fed with squares of Bt_2-, Bt_1 and non-*Bt* hybrids, respectively.

The weight of pupae developed from II instar larvae fed with leaves were 110.00, 134.40 and 137.80 mg / pupa on leaves of Bt_2, Bt_1 and non-*Bt* hybrids. While it was 115.60, 132.40 and 135.20 mg / pupa on squares of Bt_2, Bt_1 and non-*Bt* hybrids. The mortality of III instar larvae was also high on leaves of Bt_2 which resulted in 42.00 per cent pupation where as 100 per cent pupation was observed on leaves of Bt_1 and non-*Bt* hybrids. 62.00, 100 and 100 per cent pupation was observed from the surviving larvae of III instar larvae when fed with squares of Bt_2-, Bt_1 and non-*Bt* hybrids. The weight of pupae developed from III instar larvae fed with leaves were 119.40, 136.80 and 137.20

mg / pupa on leaves of Bt_2, Bt_1 and non-*Bt* hybrids. While it was 114.40, 133.00 and 135.00 mg / pupa on squares of Bt_2, Bt_1 and non-*Bt* hybrids. Unlike the first three instars, the mortality of IV instar was very low when fed on leaves of Bt_2 with 74.00 per cent pupation as against 100 per cent pupation with Bt_1 and non-*Bt* hybrids, where as the IV instar larvae fed on squares of Bt_2 showed 94.00 per cent pupation as against 100 per cent pupation with Bt_1 and non-*Bt* hybrids. The weight of pupae developed from IV instar larvae fed with leaves were 123.20 mg / pupa on Bt_2 compared to 134.80 and 136.00 mg / pupa on Bt_1 and non-*Bt* hybrids, respectively. While it was 124.40, 133.80 and 135.80 mg / pupa on squares of Bt_2, Bt_1 and non-*Bt* hybrids. The mortality of V instar was nil on leaves and squares of Bt_1, Bt_2 and non-*Bt* hybrids which resulted in 100 per cent pupation. The weight of pupae developed from V instar larvae fed with leaves were 129.80 mg / pupa on Bt_2 compared to 135.20 and 136.80 mg / pupa on Bt_1 and non-*Bt* hybrids. While it was 125.00, 134.40 and 136.20 mg / pupa on squares of Bt_2, Bt_1 and non-*Bt* hybrids. (Table. 2).

Effect of Bt_1, Bt_2 and non-*Bt* cotton on adult emergence

There was no pupation from I instar larvae that were fed on leaves of Bt_2 since all the larvae died within four to five days of feeding hence no adult emergence was recorded whereas 84.00 and 86.00 per cent adult emergence was observed on Bt_1 and non-*Bt* hybrids, respectively. Where as the larvae fed on squares of Bt_2 showed 16.00 per cent of adult emergence while it was 78.00 per cent on Bt_1 and 84.00 per cent on non-*Bt* hybrids which Bt_1 and non-*Bt* being significantly different both on leaves and squares from Bt_2 .The adult emergence was 8.00, 82.00 and 80.00 per cent when fed on leaves of Bt_2, Bt_1 and non-*Bt* hybrids where as 34.00, 80.00 and 82.00 per cent of adult emergence when fed on squares of Bt_2, Bt_1 and non-*Bt* hybrids. The adult emergence was 28.00 per cent and 48.00 per cent when fed on leaves and squares of Bt_2. While 100 per cent adult emergence was observed from the larvae fed with leaves and squares of Bt_1 and non-*Bt* hybrids. The IV instar larvae fed on Bt_2 leaves and squares showed 56.00 per cent and 90.00 per cent adult emergence, while it was 100 per cent adult emergence from the larvae fed with leaves and squares of Bt_1 and non-*Bt* hybrids. With regard to adult emergence from V instar when fed with leaves and squares 100 per cent adult emergence was observed on all the three hybrids Bt_2, Bt_1 and non-*Bt* hybrids (Table. 3). The present findings are in conformity with Fitt *et al*. (1994), Donglin *et al*. (2006) and Soujanya (2008). In view of them the larvae of IV and V instar were able to survive when exposed to leaves and squares of Bt_2 but they were unable to develop normally with significant reduction in the weight of larvae, pupae and decreased adult emergence.

Effect of Bt_1, Bt_2 and non-*Bt* cotton on growth and survival index

The growth index values for *S. litura* were 1.88 and 2.89 when fed on leaves and squares of Bt_2, respectively where as the corresponding values were 10.16 and 11.22 when fed on leaves and 11.26 and 11.38 when fed on squares of Bt_1 and non-*Bt* hybrids, respectively which were significantly low compared to the larvae fed with Bt_2. The survival index values for *S. litura* were 0.26 and 0.40 when fed on leaves and squares of Bt_2, respectively where as the corresponding values were 1.00 when fed on both leaves and squares of Bt_1 and non-*Bt* hybrids. (Table. 4)

The lower growth and survival index can be attributed to longer developmental period, low pupation and low adult emergence on Bt_2 hybrids. The present findings are in accordance with Vennila *et al.* (2006) and soujanya (2008) who reported lower survival index of *S. litura* on Bt_2 and higher survival index for *S. litura* on Bt_1 and non-*Bt* cotton hybrids.

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Table 3. Per cent adult emergence of *S.litura* on test hybrids.

Treatments	Leaves					Squares				
	I instar	II instar	III instar	IV instar	V instar	I instar	II instar	III instar	IV instar	V instar
Tulasi4*Bt*	84.00 (66.68)^{b}	82.00 (65.35)^{b}	100 (90.00)^{b}	100 (90.00)^{b}	100 (90.00)	78.00 (62.10)^{b}	80.00 (63.73)^{b}	100 (90.00)^{b}	100 (90.00)	100 (90.00)
Tulasi4BGII	0.00 (0.00)^{a}	8.00 (14.74)^{a}	28.00 (31.75)^{a}	56.00 (48.51)^{a}	100 (90.00)	16.00 (23.31)^{a}	34.00 (35.61)^{a}	48.00 (43.79)^{a}	90.00 (78.04)	100 (90.00)
Non-*Bt* (Bunny)	86.00 (68.31)^{b}	80.00 (63.73)^{b}	100 (90.00)^{b}	100 (90.00)^{b}	100 (90.00)	84.00 (66.68)^{b}	82.00 (65.35)^{b}	100 (90.00)^{b}	100 (90.00)	100 (90.00)
F TEST	Sig	Sig	Sig	Sig	—	Sig	Sig	Sig	Sig	—
SEm±	1.62	2.91	1.37	1.71	—	1.79	2.27	1.65	4.27	—
CD (p=0.05)	5.01	9.24	4.24	5.29	—	5.54	7.01	5.11	13.15	—

Figures in parentheses are angular transformed values
Numbers followed by same superscript are not statistically different

Table 4. Growth and survival index for *S. litura* on test hybrids.

Treatments	Growth Index		Survival Index	
	Leaves	Squares	Leaves	Squares
Tulasi4*Bt*	10.16	11.26	1.00	1.00
Tulasi4BGII	1.88	2.89	0.26	0.40
Non-*Bt* (Bunny)	11.22	11.38	1.00	1.00

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