Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(3): 1583-1588

Received: 04-03-2018
Accepted: 05-04-2018

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Population dynamics of spotted bollworms and their correlation with abiotic factors

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Abstract
Nineteen genotypes comprising seventeen *Bt* hybrids, one conventional hybrid and one variety were evaluated during kharif season of 2008-2009 and 2009-2010 for their reaction to bollworms under unsprayed conditions at Cotton Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar. Spotted bollworm infestation remained below economic threshold (ET) in all the genotypes, however, from 34th week onwards the infestation crossed economic threshold (5% infestation) in non-Bt variety H-1226. On mean basis maximum infestation was recorded in H-1226 (19.47 and 17.95 percent during 2008 and 2009 respectively) whereas minimum infestation was observed in RCH-134 *Bt* (1.28%) in 2008 and NCEH-6 *Bt* (0.21%) in 2009. Larval population was ranged from 0.00-4.00 larvae/5 plant in 2008 and 0.00- 4.65 larvae/ 5 plant in 2009. While maximum population was recorded in H-1226 non-*Bt* (4.00 larvae/5 plant in 2008 and 4.65 larvae/5 plant in 2009) at 40th standard week. Spotted bollworm population were found significantly negative correlation with temperature, relative humidity and rainfall while positive correlation with sunshine hours.

Keywords: Abiotic factors, Bt cotton, correlation coefficient, population dynamics, spotted bollworms

Introduction
Cotton is grown principally for the fiber and the seed is used as fodder for livestock Surulivelu *et al*. [1]. In India, during 2010-11, it was grown on an area of 110 Lakh ha with the production of 325 Lakh bales with the average yield of 503 kg lint /ha [1]. Among the vast array of insect pests, bollworms [American bollworm, *Helicoverpa armigera* (Hubner); pink bollworm, *Pectinophora gossypiella* (Saunders) and spotted bollworms, *Earias insulana* (Boisduval) and *E. vittella* (Fabricius)] not only cause tremendous reduction in yield but adversely affect the quality of lint and seed Deepika *et al.* [2]. Recently a novel method for the management of lepidopterans is the use of *Bt* Cry toxin obtained from soil bacterium, *Bacillus thruingiensis* (*Bt*). Since the release of Bt cotton hybrids has been able to reduce the use of chemical insecticides, thereby lowering the risks pertaining to environment hazards, human health and production costs Deepika *et al.* [2]. In India, hybrid cotton carrying cry1Ac gene was approved for commercial cultivation in March 2002 in six South Indian states [3] by Genetic Engineering Approval Committee (GEAC). Since its release has been able to reduce the use of chemical insecticides, thereby lowering the risks pertaining to environment hazards, human health and production costs. *Bt* produces δ-endotoxin (crystal proteins) during the sporulation process. The introduction of *Bt* cotton in India is likely to prove useful in the management of the bollworm, *H. armigera* with reduced dependence on pesticides [4]. In 2006, three new events were approved for incorporation in *Bt* hybrids in India. These events were, Bollgard II event, event I71, having modified Cry1Ac gene and event GFM having Cry1Ab and Cry1Ac genes. During 2002-2007, 131 *Bt* cotton hybrids were approved for commercial cultivation in India at various zones [5]. Mohapatra [6] studied the incidence of three species of lepidopteran bollworm species i.e. *E. vittella* (Fab.), *Helicoverpa armigera* (Hubner) and *Pectinophora gossypiella* (Saunders). *E. vittella* was found active during July to January while *Helicoverpa armigera* during September to December with their peak incidence during 1st week of November. The main objective was to study the population dynamic and impact of weather parameter on *E. vittella* in *Bt* and non-*Bt* genotypes.

Materials and Methods

The present study was carried out at Cotton Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar under unsprayed conditions on the nineteen genotypes comprising seventeen *Bt* hybrids, one conventional hybrid and one variety. The seeds were dibbled with line-to-line spacing of 67.5 cm and plant-to plant at 60 cm in case of hybrids and 30 cm in case of the varieties. Two to three seeds of respective genotypes were put at a depth of 3-4 cm in each hill in the well prepared soil. Sowing was done on 25th May, 2008 and 15th of May, 2009 in a randomized block design (RBD). The experiment was replicated thrice in a plot size of 24.3 m^2 each. Thinning of the crop was also done one month after sowing. All the other cultural practices were adopted as per the recommendation of "Package of Practices of *Kharif* crops" of CCS Haryana Agricultural University, Hisar [7]. The observation on the population of spotted bollworms was recorded at weekly intervals during period of study. The observation on bollworms infestation in green fruiting bodies (buds, flowers, squares and bolls) was started from August for both the years of study. The sample size and method employed for sampling the population of bollworms was as under:

Intact fruiting bodies

Observations on the incidence of bollworm complex on the intact fruiting bodies (square, flower, bolls) were recorded at weekly interval from randomly selected five plants from each plot. The infestation was calculated by following formula: -

$$\text{Percent bollworm infestation} = \frac{\text{No. of fruiting bodies infested}}{\text{Total number of fruiting bodies}} \times 100$$

Statistical analysis

The data obtained during studies in the above experiments were got computed for analysis of variance using the methods of Panse and Sukhatme [8]. In case of bollworms infestation (%) the data were analyzed for variance by adopting angular transformation.

Results and Discussion

The present study data indicated that under unsprayed conditions the bollworm infestation in green fruiting bodies (Plate -1) varied significantly among *Bt* and non-*Bt* genotypes, and was significantly higher in non-*Bt* genotypes except hybrid HHH-223 in which the reverse was true. The infestation started from 33rd (2008) and 34th (2009) standard week onwards. During both crop seasons, bollworm infestation remained below economic threshold in all the genotypes barring non *Bt* variety H-1226. Amongst the genotypes in 2008 (1st crop season) (Table-1), no infestation was recorded in KDCHH-441 BG-II, MRC-7031 BG-II, RCH-134 BG-II, ANKUR 2534 *Bt* and NCS-913 *Bt* while least average infestation was recorded in non Bt hybrid HHH-223 (1.27%) and RCH-134 *Bt* (1.28%). Maximum average infestation was recorded in non *Bt* variety H-1226 (19.47%) followed by SIGMA *Bt* (2.16%) Amongst the genotypes, minimum infestation was first recorded in MRC-6301 *Bt* (0.26%) during 34th week and HHH-223 (0.32%) during 35th week, while maximum infestation was recorded in H-1226 non-*Bt* (31.54%) during 40th standard week. Weekly mean values of the genotypes indicated that maximum infestation was recorded during 41st week (4.38%).

In 2009 (Table-1) in the following crop season, no infestation was found in TULSI-45 BG-II, MRC-6301 *Bt*, RCH-134 BG-II and VBCH-1501 BG-II. Mean value indicated that maximum infestation was observed in H-1226 (17.95%) followed by SIGMA *Bt* (1.91%) while minimum infestation was recorded in NCEH-6 *Bt* (0.21%) Amongst the genotypes, minimum infestation was recorded in KDCHH-441 BG-II (0.03%) during 32nd week and IT-905 *Bt* (0.11%) during 33rd week, while maximum infestation was recorded in H-1226 (32.14%) during 40th week. Weekly mean values indicated that maximum infestation was recorded during 41st week (4.30%). During both seasons maximum infestation was recorded in H-1226 and SIGMA *Bt*.

Results of the present studies are in conformity with Vennila *et al*. [9] who also recorded similar observations in different *Bt* genotypes. Similarly, Bambawale *et al*. [10] observed that total percent damage to fruiting bodies was low in *Bt* genotypes compared to non-*Bt* genotypes. Kumar and Stanley [11] also reported that non-*Bt* plots attracted more bollworm infestation than *Bt* plots and there was a significant difference in the bollworm infestation among the *Bt* and non-*Bt* genotypes. The present results got support from Nath and Sharma [12] who reported that the bollworm infestation was above economic threshold (*Bt* or non *Bt*) during second week of August to second week of September. The present results are not in line with the findings of Sharma *et al.* [13] who reported that the infestation of spotted bollworm started from mid July. Sharma *et al.* [13] reported that the peak infestation of spotted bollworm was recorded during mid August to early October and October to November, respectively which supports the present study. Mohapatra [6] reported the commencement of the activity of spotted bollworm from 31st standard week and reached to its peak in 46th standard week, are in contradiction to the present investigation. The present investigation corroborates with those of Sharma *et al*. [13] who reported spotted bollworm was active throughout the crop season.

Data presented in Table-2 indicated that spotted bollworm population varied significantly in *Bt* and non-*Bt* genotypes being very high in non-*Bt* genotypes. Weekly mean values indicated that incidence of spotted bollworm (Plate-2) started from 34th standard week onward while maximum mean incidence was recorded during 39th standard week during both the years i.e. 2008 and 2009 (0.42 larvae/plant and 0.46 larvae/plant respectively). Amongst *Bt* genotypes during 2008 (1st crop season), population was nil in KDCHH-441 BG-II, MRC-7031 BG-II, RCH-134 BG-II, VBCH-1504 BG-II, ANKUR 2534 *Bt* and NCS-913 *Bt*, while minimum mean incidence was recorded in MRC-6301 *Bt*, VBCH-1501 BG-II and NCS-145 *Bt*-II (0.06 larvae/plant) and difference was non significant. Maximum population was recorded in H-1226 non-*Bt* variety (four larvae/plant) at 40th week (Table-3). Whereas during 2009 (2nd crop season) among *Bt* genotypes, population was recorded nil in TULSI-45 BG-II, MRC-6301 *Bt*, RCH-134 BG-II and VBCH-1501 BG-II, while least population was recorded in MRC-7031 BG-II and RCH-134 *Bt* (0.05 larvae/plant). Maximum incidence was recorded in H-1226 non-*Bt* variety (4.65 larvae/plant) at 40th week (Table-3).

Spotted bollworm population showed significant and negative correlation with temperature (r = -0.52 in 2008, r = -0.68 in 2009 and r = -0.81 in pooled data), relative humidity (r = -0.59 in 2008, r = -0.18 in 2009 and r = -0.57 in pooled data) and rainfall (r = -0.08 in 2008, r = -0.03 in 2009 and r = -0.07 in pooled data), and while positive correlation with sunshine hours (r = 0.17 in 2008) and wind speed (r = 0.02 in 2008) morning relative humidity (r = 0.42 in 2009 and r = 0.38 in pooled data) (Table 3).

Findings of the present study that the spotted bollworm population varied significantly in *Bt* and non-*Bt* genotypes and Bt genotypes provided effective control of bollworms. These findings are similar to the findings of Cui and Xia [14] who reported that *Bt* cotton was highly resistant to cotton bollworm & cotton semi-looper and Dhillion and Sharma [15] reported that the bollworm damage was significantly lower in Bt-transgenic than in non-transgenic cotton. The result of that population of spotted bollworm (*Earias* spp.) started from 34th week onward are in conformity with [5] who reported that *E. vittella* was found active during July to January.

Bollworm population showed negative correlation with temperature, relative humidity and rainfall. A finding of present study accordance with Shivanna *et al.* [16] was observed significant negative correlation of *E. insulana* with afternoon relative humidity. Aziz *et al.* [17] reported that there was a positive correlation of spotted bollworm with temperature and negative correlation with relative humidity and rainfall, the present results are partially accordance with the findings.

Table 1: Evaluation of *Bt* and non-*Bt* genotypes of cotton against spotted bollworm during 2008 and 2009 crop season

Genotypes	Percent infestation of spotted bollworm on green boll basis (Damaged bolls/5 plants) Standard week during 2008										Mean	Percent infestation of spotted bollworm on green boll basis (Damaged bolls/5 plants) Standard week during 2009										Mean
	32	33	34	35	36	37	38	39	40	41		32	33	34	35	36	37	38	39	40	41	
KDCHH-9810 BG-I	0.00 (1.81)	0.00 (1.81)	0.37 (3.43)	0.78 (5.04)	0.94 (5.53)	1.37 (6.72)	2.00 (8.13)	2.69 (9.43)	3.22 (10.33)	4.06 (11.62)	1.71	0.38 (3.52)	0.41 (3.65)	0.62 (4.49)	1.03 (5.82)	1.38 (6.74)	1.94 (8.01)	2.57 (9.20)	3.04 (10.03)	3.54 (10.82)	4.00 (11.53)	1.89
KDCHH-441 BG-II	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00	0.03 (0.85)	0.35 (3.37)	0.60 (4.12)	1.19 (6.26)	1.58 (7.20)	2.00 (8.13)	2.47 (9.02)	2.94 (9.86)	3.36 (10.55)	3.98 (11.50)	1.85
TULSI-45 BG-II	0.00 (1.81)	0.00 (1.81)	0.42 (3.70)	0.72 (4.87)	1.05 (5.87)	1.76 (7.61)	2.00 (8.11)	2.34 (8.80)	3.11 (10.15)	3.76 (11.17)	1.68	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00
MRC-7031 BG-II	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00	0.00 (1.81)	0.36 (3.43)	0.57 (4.31)	1.06 (5.90)	1.36 (6.69)	1.87 (7.85)	2.04 (8.2)	2.68 (9.41)	3.22 (10.32)	3.78 (11.20)	1.69
MRC-6301 *Bt*	0.00 (1.81)	0.00 (1.81)	0.26 (2.93)	0.89 (5.39)	0.98 (5.67)	1.05 (5.87)	1.67 (7.41)	2.46 (9.02)	3.56 (10.86)	4.10 (11.68)	1.66	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00
RCH-134 BG-II	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00
RCH-134 *Bt*	0.00 (1.81)	0.00 (1.81)	0.30 (3.12)	0.92 (5.48)	1.05 (5.87)	1.07 (5.93)	1.25 (6.41)	1.56 (7.16)	2.33 (8.76)	3.00 (9.96)	1.28	0.00 (1.81)	0.40 (3.59)	0.50 (4.03)	0.89 (5.38)	1.07 (5.92)	1.54 (7.10)	1.78 (7.65)	2.11 (8.33)	2.87 (9.75)	3.24 (10.37)	1.44
VBCH-1504 BG-II	0.00 (1.81)	0.00 (1.81)	0.34 (3.35)	0.58 (4.35)	0.76 (4.96)	1.00 (5.73)	1.78 (7.66)	2.47 (9.03)	3.95 (11.45)	4.67 (12.47)	1.73	0.33 (3.30)	0.46 (3.03)	0.53 (4.15)	1.02 (5.79)	1.19 (6.26)	1.68 (7.43)	2.00 (8.11)	2.33 (8.76)	3.00 (9.96)	3.84 (11.29)	1.64
VBCH-1501 BG-II	0.00 (1.81)	0.00 (1.81)	0.41 (3.67)	0.43 (3.75)	0.57 (3.51)	0.63 (4.56)	0.68 (4.67)	1.08 (5.97)	2.45 (8.99)	3.22 (10.32)	1.05	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00
VBCH-1006 *Bt*	0.00 (1.81)	0.00 (1.81)	1.00 (5.73)	1.07 (5.90)	1.07 (5.89)	1.16 (6.19)	1.26 (6.42)	1.90 (7.92)	2.98 (9.93)	3.11 (10.14)	1.51	0.00 (1.81)	0.35 (3.34)	0.66 (4.65)	1.00 (5.73)	1.21 (6.30)	1.54 (7.12)	1.87 (7.84)	2.21 (8.54)	2.89 (9.78)	3.65 (11.00)	1.54
SIGMA *Bt*	0.00 (1.81)	0.00 (1.81)	0.39 (2.87)	0.69 (4.77)	1.63 (7.30)	2.32 (8.74)	2.71 (9.47)	3.00 (9.97)	3.86 (11.33)	4.80 (12.64)	2.16	0.00 (1.81)	0.40 (2.94)	0.63 (4.38)	1.05 (5.86)	1.16 (6.18)	1.76 (7.60)	2.65 (9.35)	3.11 (10.14)	3.76 (11.17)	4.56 (12.32)	1.91
ANKUR 2534 *Bt*	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00	0.00 (1.81)	0.19 (2.46)	0.36 (3.43)	0.55 (4.21)	1.07 (5.88)	1.58 (7.19)	2.48 (9.03)	3.00 (9.97)	3.18 (10.26)	3.87 (11.34)	1.63
ANKUR JASSI BG-II	0.00 (1.81)	0.36 (2.76)	0.48 (3.95)	0.86 (5.32)	1.01 (5.76)	1.24 (6.39)	1.97 (8.06)	2.78 (9.59)	3.33 (10.51)	4.98 (12.89)	1.89	0.00 (1.81)	0.04 (0.63)	0.11 (1.51)	0.35 (3.38)	0.76 (4.91)	1.21 (6.31)	1.65 (7.35)	2.58 (9.22)	3.21 (10.32)	3.79 (11.22)	1.37
NCS-145 *Bt*-2	0.00 (1.81)	0.00 (1.81)	0.56 (4.27)	0.77 (5.02)	0.80 (5.11)	1.08 (5.97)	1.64 (7.35)	2.49 (9.07)	3.29 (10.45)	4.65 (12.44)	1.70	0.00 (1.81)	0.00 (1.81)	0.21 (2.58)	0.51 (4.10)	1.11 (6.02)	1.46 (6.94)	1.87 (7.84)	2.14 (8.39)	2.85 (9.71)	3.42 (10.62)	1.36
NCS-913 *Bt*	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00	0.00 (1.81)	0.00 (1.81)	0.36 (3.40)	0.58 (4.14)	1.06 (5.91)	1.34 (6.61)	1.98 (8.07)	2.57 (9.21)	2.98 (9.93)	3.68 (11.05)	1.46
NCEH-6 *Bt*	0.00 (1.81)	0.00 (1.81)	0.37 (3.41)	0.66 (4.63)	1.10 (6.01)	1.54 (7.13)	2.00 (8.13)	2.55 (9.18)	3.00 (9.97)	3.99 (11.52)	1.69	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.32 (3.22)	0.68 (4.69)	1.11 (6.03)	0.21
IT-905 *Bt*	0.00 (1.81)	0.00 (1.81)	0.36 (3.14)	0.86 (5.31)	1.07 (5.94)	1.70 (7.46)	2.09 (8.31)	2.78 (9.59)	3.00 (9.97)	4.05 (11.61)	1.77	0.00 (1.81)	0.11 (1.51)	0.26 (2.39)	0.76 (4.98)	1.02 (5.78)	1.36 (6.67)	1.87 (7.84)	2.16 (8.44)	2.54 (9.15)	2.98 (9.93)	1.31
HHH-223 (LC)	0.00 (1.81)	0.00 (1.81)	0.00 (1.81)	0.32 (3.25)	0.62 (4.51)	0.95 (3.72)	1.12 (6.07)	1.89 (7.90)	2.49 (9.05)	4.07 (11.64)	1.27	0.00 (1.81)	0.68 (4.65)	0.85 (5.29)	1.04 (5.84)	1.24 (6.37)	1.56 (7.15)	1.96 (8.03)	2.57 (9.22)	3.11 (10.16)	3.75 (11.16)	1.68
H-1226 (LC)	1.12 (6.07)	3.32 (10.48)	4.16 (11.76)	9.32 (17.76)	10.76 (19.14)	27.32 (31.48)	30.26 (33.36)	27.82 (31.82)	31.54 (34.15)	30.72 (33.65)	19.47	1.24 (6.37)	2.89 (9.74)	3.97 (11.49)	8.56 (16.99)	11.45 (19.76)	25.65 (30.41)	30.54 (33.54)	31.24 (33.97)	32.14 (34.68)	31.85 (34.34)	17.95
Mean	0.06	0.19	0.50	0.99	1.23	2.33	2.76	3.04	3.80	4.38	2.14	0.10	0.35	0.54	1.03	1.40	2.45	3.04	3.42	3.84	4.30	2.05
CD (p=0.05)	(0.28)	(0.99)	(1.17)	(0.62)	(1.32)	(1.53)	(0.62)	(0.56)	(0.66)	(0.43)		(0.38)	(1.79)	(1.52)	(1.04)	(0.85)	(1.94)	(0.84)	(083)	(0.71)	(0.72)	
SE(m) ±	(0.10)	(0.34)	(0.41)	(0.22)	(0.46)	(0.53)	(0.22)	(0.19)	(0.23)	(0.15)		(0.13)	(0.62)	(0.53)	(0.36)	(0.30)	(2.00)	(0.29)	(0.29)	(0.25)	(0.25)	

*Figures in parentheses are angular transformed values

Table 2: Population of spotted bollworm on *Bt* and non-*Bt* genotypes of cotton during 2008 and 2009 crop season

Genotypes	Percent infestation of spotted bollworm on green boll basis (Damaged bolls/5 plants) Standard week during 2008										Mean	Percent infestation of spotted bollworm on green boll basis (Damaged bolls/5 plants) Standard week during 2009										Mean
	32	33	34	35	36	37	38	39	40	41		32	33	34	35	36	37	38	39	40	41	
KDCHH-9810 BG-I	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.13 (1.06)	0.13 (1.06)	0.20 (1.09)	0.27 (1.13)	0.13 (1.06)	0.07 (1.03)	0.10	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.07 (1.03)	0.11 (1.05)	0.13 (1.06)	0.23 (1.11)	0.27 (1.13)	0.13 (1.06)	0.05 (1.03)	0.10
KDCHH-441 BG-II	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.03 (1.02)	0.07 (1.03)	0.27 (1.13)	0.33 (1.15)	0.20 (1.09)	0.13 (1.06)	0.10
TULSI-45 BG-II	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.07 (1.03)	0.20 (1.09)	0.33 (1.15)	0.40 (1.18)	0.20 (1.09)	0.13 (1.06)	0.15	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00
MRC-7031 BG-II	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.07 (1.03)	0.00 (1.00)	0.07 (1.03)	0.13 (1.06)	0.13 (1.06)	0.07 (1.03)	0.07 (1.03)	0.05
MRC-6301 *Bt*	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.07 (1.03)	0.00 (1.00)	0.07 (1.03)	0.13 (1.06)	0.13 (1.06)	0.07 (1.03)	0.07 (1.03)	0.06	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00
RCH-134 BG-II	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00
RCH-134 *Bt*	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.20 (1.09)	0.33 (1.15)	0.40 (1.18)	0.33 (1.15)	0.20 (1.09)	0.13 (1.06)	0.18	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.07 (1.03)	0.20 (1.09)	0.10 (1.05)	0.07 (1.03)	0.05 (1.02)	0.05
VBCH-1504 BG-II	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.13 (1.06)	0.27 (1.13)	0.33 (1.15)	0.27 (1.13)	0.20 (1.10)	0.13 (1.06)	0.13
VBCH-1501 BG-II	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.07 (1.03)	0.20 (1.09)	0.13 (1.06)	0.07 (1.03)	0.07 (1.03)	0.06	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00
VBCH-1006 *Bt*	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.13 (1.06)	0.07 (1.03)	0.07 (1.03)	0.27 (1.12)	0.20 (1.09)	0.13 (1.06)	0.07 (1.03)	0.10	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.07 (1.03)	0.07 (1.03)	0.13 (1.06)	0.33 (1.15)	0.27 (1.13)	0.20 (1.09)	0.07 (1.03)	0.11
SIGMA *Bt*	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.27 (1.12)	0.40 (1.18)	0.60 (1.24)	0.53 (1.23)	0.40 (1.18)	0.27 (1.12)	0.27	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.20 (1.10)	0.33 (1.15)	0.40 (1.18)	0.50 (1.22)	0.21 (1.11)	0.13 (1.06)	0.18
ANKUR 2534 *Bt*	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.10 (1.05)	0.13 (1.06)	0.27 (1.13)	0.33 (1.15)	0.07 (0.03)	0.00 (1.00)	0.09
ANKUR JASSI BG-II	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.20 (1.09)	0.13 (1.06)	0.20 (1.09)	0.27 (1.12)	0.13 (1.06)	0.07 (1.03)	0.11	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.07 (1.03)	0.13 (1.06)	0.20 (1.10)	0.27 (1.13)	0.13 (1.06)	0.07 (1.03)	0.09
NCS-145 *Bt*-2	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.07 (1.03)	0.10 (1.10)	0.20 (1.09)	0.13 (1.06)	0.07 (1.03)	0.06	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.07 (1.03)	0.10 (1.05)	0.23 (1.11)	0.13 (1.06)	0.10 (1.05)	0.06
NCS-913 *Bt*	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.07 (1.03)	0.21 (1.11)	0.33 (1.15)	0.47 (1.21)	0.27 (1.13)	0.10 (1.05)	0.15
NCEH-6 *Bt*	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.07 (1.03)	0.20 (1.09)	0.47 (1.21)	0.53 (1.23)	0.47 (1.21)	0.27 (1.12)	0.22	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.07 (1.03)	0.20 (1.10)	0.40 (1.18)	0.50 (1.22)	0.20 (1.09)	0.13 (1.06)	0.15
IT-905 *Bt*	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.07 (1.03)	0.47 (1.21)	0.90 (1.40)	0.87 (1.36)	0.60 (1.26)	0.27 (1.12)	0.35	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.07 (1.03)	0.47 (1.21)	0.80 (1.34)	0.63 (1.28)	0.50 (1.23)	0.20 (1.10)	0.27
HHH-223 (LC)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.40 (1.18)	0.60 (1.26)	0.87 (1.37)	1.00 (1.41)	0.20 (1.09)	0.45	0.06 (1.03)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.33 (1.15)	0.40 (1.18)	0.87 (1.37)	1.05 (1.43)	1.17 (1.47)	0.39
H-1226 (LC)	0.00 (1.00)	0.00 (1.00)	0.07 (1.03)	1.97 (1.72)	2.60 (1.90)	2.67 (1.91)	2.93 (2.02)	3.33 (2.08)	4.00 (2.15)	3.67 (2.11)	2.36	0.00 (1.00)	0.07 (1.03)	1.07 (1.44)	1.07 (1.44)	2.33 (1.82)	2.47 (1.86)	2.97 (1.99)	3.64 (2.15)	4.65 (2.38)	3.29 (2.07)	2.16
Mean	0.00	0.00	0.00	0.11	0.19	0.27	0.39	0.42	0.40	0.33	0.24	0.00	0.00	0.06	0.07	0.17	0.27	0.39	0.46	0.43	0.30	0.21
CD (p=0.05)	(NS)	(NS)	(NS)	(0.05)	(0.09)	(0.11)	(0.11)	(0.11)	(0.11)	(0.11)		(NS)	(NS)	(0.00)	(0.04)	(0.07)	(0.10)	(0.10)	(0.10)	(0.10)	(0.08)	
SE(m) ±	(0.01)	(0.01)	(0.01)	(0.02)	(0.03)	(0.14)	(0.04)	(0.04)	(0.03)	(0.05)		(0.01)	(0.01)	(0.00)	(0.01)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	

* Figures in parentheses are angular transformed values

Table 3: Correlation coefficient (r) of bollworms incidence with abiotic factors

Weather parameters	Spotted bollworm		
	2008	2009	Pooled
Temperature (°C)			
Maximum	+0.08	-0.47**	-0.55**
Minimum	-0.80**	-0.71**	-0.76**
Average	-0.52**	-0.68**	-0.81**
Relative humidity (%)			
Morning	-0.24	+0.42**	+0.38**
Evening	-0.67**	-0.47**	-0.74**
Average	-0.59**	-0.18	-0.57**
Other factors			
Rainfall (mm)	-0.08	-0.03	-0.07
Sunshine	+0.17	-0.49**	-0.34**
Wind speed(Km/h)	+0.02	-0.65**	-0.36**

*Significant at 5%
**Significant at 1%

Plate 1: Spotted bollworm infestation

Plate 2: Spotted bollworm larva (*Earias vittella*) feeding inside the cotton boll

Conclusion

It was concluded from above studies that spotted bollworm infestation varied significantly in *Bt* and non-*Bt* genotypes, being very high in non-*Bt* genotypes while hybrid HHH-223 was statistically at par with *Bt* genotypes.

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