

Original Research Article

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Impact of Environmental Resistance Factors on Abundance of Spotted Bollworm, *Earias vittella* Fabricius and *Helicoverpa armigera* Hubner on *Bt* and Non-*Bt* Cotton in Odisha

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ABSTRACT

Keywords

Seasonal incidence, *Earias vittella*, *Helicoverpa armigera*, Environmental resistance factor, *Bt* and non-*Bt* cotton

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The field study aimed to assess impact of environmental resistance factors on population dynamics of *Earias vittella* Fabricius and *Helicoverpa armigera* Hubner on *Bt* and non-*Bt* cotton was conducted at the Regional Research and Technology Transfer Station, Bhawanipatna, Kalahandi. The results revealed that the transgenic Bunny *Bt* cotton incorporated with Cry 1Ac and Cry 2Ab remained absolutely free from bollworms infestation throughout the crop season in 2013 and 2014. However, in non-*Bt* of same Bunny hybrid, the peak incidence of *E. vittella* with damage of terminal shoots (5.96%), squares (12.97%) and bolls (9.55%) were noticed at 35th, 45th and 38th SMW. Similarly, the peak occurrence of *H. armigera* damage to squares (6.07 %) and bolls (11.08 %) was recorded at 41st and 40th SMW in both the years. Maximum larval population *E. vittella* and *H. armigera* were noticed during 38th to 41st SMW in both the years. The correlation coefficient of larval population of both the bollworms and oviposition by *H. armigera* with the weather parameters remained non-significant.

Introduction

Cotton (*Gossypium hirsutum* L., Malvaceae) known as 'white gold' enjoys a predominant position amongst all cash crops in India and plays a significant role in the national economy. India was a leading country in terms of area under cotton cultivation and raw cotton production (28500 million bales) during 2017-18 in the world. However, the productivity in India was decreased from 541 Kg/ha during 2016-17 to 524 Kg/ha during 2017-18. In

Odisha the area under cotton cultivation was increased from 1.36 lakh ha in the year 2016-17 to 1.45 lakh ha in the year 2017-18 whereas, the productivity was lowest (351 Kg/ha) in comparison to normal average (524 Kg/ha) (Anonymous, 2018). About 162 species of insect pests invade cotton crop in its various growth stages and cause 50-60% losses. The bollworms viz., *Helicoverpa armigera* (Hubner), *Pectinophora gossypiella* (Saunders) and *Earias vittella* (Fabricius) were major serious insect species (Puri *et al.*,

2005). Prior to *Bt* cotton cultivation in India it was the single largest pesticide consuming crop accounting for about half of the total pesticides used in agriculture (Birthal *et al.*, 2000). Which resulted in undesirable ecological and economic consequences and unfortunately, almost all the insecticides had inadvertent adverse effects on beneficial insects (Kranthi and Russell, 2009). Considering the inevitability to safeguard the environment, Government of India approved the commercial cultivation of *Bt* cotton since 2002 and subsequently there was phenomenal increase in its acreage (Padaria *et al.*, 2009). In India *Bt* cotton area increased to 119.40 lakh hectares out of 128.19 lakh hectares in 2014-15 showing more than 93.14 % adoption within a span of thirteen years (Status Paper of Indian Cotton, 2017, Directorate of Cotton Development).

Transgenic crops with insecticidal toxins producing Cry1Ac and Cry2Ab2 genes from the bacterium, *Bacillus thuringiensis* (*Bt*) (Sharma and Pampapathy, 2006) showed high degree of resistance against bollworms viz., *Helicoverpa armigera* (Hubner), *Pectinophora gossypiella* (Saunders) and *Earias vittella* (Fabricius) in laboratory and field conditions (Manjunatha *et al.*, 2009; Sarma and Senguttuvan, 2011). Looking into the significant increase in adoption of *Bt* cotton cultivation which played potential role in IPM, the *Bt* transgenic technology need to be harnessed appropriately for sustainable crop production and better environment (Swamy *et al.*, 2009). In IPM population dynamics of insect pests, natural enemies and monitoring of abiotic resistance factors would play a significant role for development of a sound and economically sustainable IPM modules for the insect pest management (Fakhri and Khawaja, 2012). The present study was conducted to analyze the cotton agro-ecosystem as a whole and to identify the environmental resistance factors governing the

population dynamics of major bollworms on *Bt* and non *Bt* cotton crop,

Materials and Methods

The field experiment was conducted to study the population dynamics of major bollworm species viz., *Earias vittella* and *Helicoverpa armigera* on *Bt* and non *Bt* cotton and the impact of the abiotic environmental resistance factors viz., temperature (Mean minimum, mean maximum and the average of both), morning and evening relative humidity and the rainfall during *Kharif*, 2013 and 2014 under rainfed situations at Regional Research and Technology Transfer Station (RRTTS), Bhawanipatna located at 19⁰40' North latitude and 83⁰00' East longitude with an altitude of 247 meters above MSL.

The experiment was laid out in two fixed plots, in one plot with transgenic (*Bt*) Bunny hybrid and the other plot with non-transgenic Bunny hybrid in the last week of June in the years 2013 and 2014. The genes incorporated in *Bt* Bunny are Cry1Ac + Cry2Ab (Event MON 15985). The crop was raised with a spacing of 90 cm x 60 cm for both *Bt* and non-*Bt* cotton with recommended agronomical practices (Narayana *et al.*, 2007) excepting the plant protection measures.

Observations were recorded on the damage to buds, squares and bolls due to spotted bollworm, *E. vittella* and American bollworm, *H. armigera*. Simultaneously, the larval population of both the bollworms were counted on whole plant from randomly selected 25 plants/ plots in each observation at weekly interval commencing from 30 days after germination (DAG) till final harvesting of seed cotton. In addition, the terminal shoot damage due to *E. vittella* incidence at vegetative stage was also recorded. The eggs laid by adults of *H. armigera* were recorded on whole plant from randomly selected 25

plants/ plot from 45 (DAG) onwards. The data on per cent shoot, squares and boll damage by bollworms were worked with the help of formula.

$$\text{Damage(\%)} = \frac{\text{Damaged fruiting bodies}}{\text{Total number of fruiting bodies}} \times 100$$

The observations on various parameters were averaged individually at different periods and subjected to T- test analysis for comparison of the mean population of the insect pests on *Bt* and non-*Bt* cotton and finding out the correlation co-efficient between the insect pest population and the weather factors by using the following formulae as per Gomez and Gomez (1984) and computed with the help of MS-excel,

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2 + S_2^2}{n}}}$$

Where, $\bar{X}_1 = \frac{\sum x_1}{n_1}$, $\bar{X}_2 = \frac{\sum x_2}{n_2}$,
 $S_1^2 = \frac{\sum x_1^2 - \frac{(\sum x_1)^2}{n_1}}{n_1}$, $S_2^2 = \frac{\sum x_2^2 - \frac{(\sum x_2)^2}{n_2}}{n_2}$

$$r = \frac{\sum xy}{\sqrt{(\sum x^2)(\sum y^2)}}$$

Where, $x = X - \bar{x}, y = Y - \bar{y}$; r = Simple correlation coefficient;

X = Variable i.e. mean number of insect pests;

Y = Variable i.e. abiotic component (Average temperature, relative humidity and rainfall)

The correlation coefficient (r) values were subjected to the test of significance using t- test:

$$t = \frac{r}{\sqrt{1 - r^2}} \times \sqrt{n - 2}$$

Results and Discussion

Seasonal incidence of bollworm on *Bt* and non- *Bt* cotton hybrids

Incidence of spotted bollworm, *Earias vittella* larvae

The results of the study on incidence of *E. vittella* larvae (Table 2) indicated that the spotted boll worm first appeared on non-*Bt* cotton at 32nd SMW (6th-12th August) whereas, the *Bt* cotton remained absolutely free from the incidence throughout the cropping season in both 2013 and 2014. Kengegowda *et al.*, (2005) observed that the larval population of *E. vittella* was very low in *Bt* cotton hybrid. Occurrence of significantly lower larval population on *Bt* than non-*Bt* cotton under unprotected condition was also reported by Manjunathan *et al.*, (2009) and Arshad *et al.*, (2015). The mean larval population in non-*Bt* cotton varied from 0.04 to 0.42 larva per plant in both the years with maximum population recorded between mid-September to mid-October.

Shoot damage by spotted bollworm, *E. vittella*

The present experimental findings revealed that *E. vittella* caused shoot damage in non-*Bt* cotton crop whereas, the *Bt* cotton remained completely free from the damage. The results obtained from the investigation was in line with the view of Sharma and Pampapathy (2006) who reported that transgenic hybrids suffered low shoot damage by spotted bollworm, *E. vittella*. The present investigation showed that the *Bt* cotton was immune to SBW infestation which was obviously due to the effect of Cry1Ac and Cry2Ab genes incorporated into the *Bt* hybrid cotton (BG-II). The incidence was recorded in non-*Bt* cotton during 1st week of August and continued up to 1st week of November with a

peak (5.96 %) at last week of August (Table 1). There after the shoot damage was declined.

Square damage by spotted bollworm, *E. vittella*

The *Bt* hybrid cotton exhibited immune reaction to *E. vittella* infestation throughout the cropping season in both the years (Table 1). Whereas, the non-*Bt* version of same hybrid (Bunny) was susceptible to pest damage. The pest appeared to cause damage on non-*Bt* cotton from 33rd SMW (mid-August) and continued till 50th SMW (mid-December) with its peak activity (12.97 % square damage) during 5th to 11th November in both the years. The findings of Dhaka and Pareek (2008) indicated that the infestation of spotted bollworm, *E. insulana* and *E. vittella* commenced in the second fortnight of June and reached its peak (25%) in the first week of August and first week of October. Our findings differed from the results of Dhaka and Pareek (2008).

Boll damage by spotted bollworm, *E. vittella*

The observation on boll damage in *Bt* cotton (Table 2) revealed that the green boll damage caused by *E. vittella* in non-*Bt* cotton was significantly higher as compared to *Bt* cotton hybrid. The results of the investigation were in accordance with the findings of Kengegowda *et al.*, (2005), Raja *et al.*, (2007) and Pal *et al.*, (2010) who reported the incidence of *E. vittella* was almost nil in *Bt* hybrids.

The green bolls damage in non- *Bt* cotton started from 2nd week of September (37th SMW) and continued till 2nd week of December (50th SMW) and it was maximum (9.55 %) during 3rd week of September (38th SMW). The results obtained by Tomar (2009) stated that the spotted bollworm activity continued up to 47th SMW with maximum incidence (12%) in 39th SMW. The finding of

author was similar with result of Tomar (2009) (Fig. 1).

Oviposition by American bollworm, *Helicoverpa armigera*

The results of investigation (Table 3) showed that egg laying by *Helicoverpa armigera* was first noticed in the last week of August in both *Bt* and non- *Bt* cotton crop. Significantly higher numbers of eggs (0.48 eggs/ plant) were laid by *H. armigera* in non-*Bt* cotton as compared to the *Bt* cotton (0.08 eggs/ plant). Kengegowda *et al.*, (2005) and Reed *et al.*, (2000) reported that the number of bollworms eggs laid did not differ much in *Bt* and non- *Bt* cotton hybrids.

Larval incidence of American bollworm, *H. armigera*

It was observed from the present studies that, there was cent per cent mortality of the *H. armigera* larvae in *Bt* cotton which corroborates with findings of Parker *et al.*, (2000) with a small difference that when neonate or 2-day old larvae were exposed to *Bt* cotton with Cry1Ac gene for 48 hours the survivability was significantly low. The finding was also in agreement with Ashfaq *et al.*, (2000) who reported that the mortality of *Helicoverpa zea* was high for first and third instars and it significantly increased with the increase in feeding period on *Bt*-cotton. Kumar and Grewal (2016) revealed that different larval instars (1st, 2nd, 3rd and 4th) of *H. armigera* when fed on the different plant parts viz., leaves and squares of transgenic *Bt* cotton hybrids caused cent per cent mortality. Observation on the larval population of *H. armigera* (Table 4) showed that maximum larval population observed in between 38th to 40th SMW. The peak larval population of 0.48 and 0.40 larvae/ plant recorded in non-*Bt* cotton at 40th SMW (1st week of October) in the year 2013 and 2014 respectively (Fig. 2).

Fig.1 Seasonal incidence of *E. vittella* on *Bt* and non-*Bt* cotton during 2013 and 2014

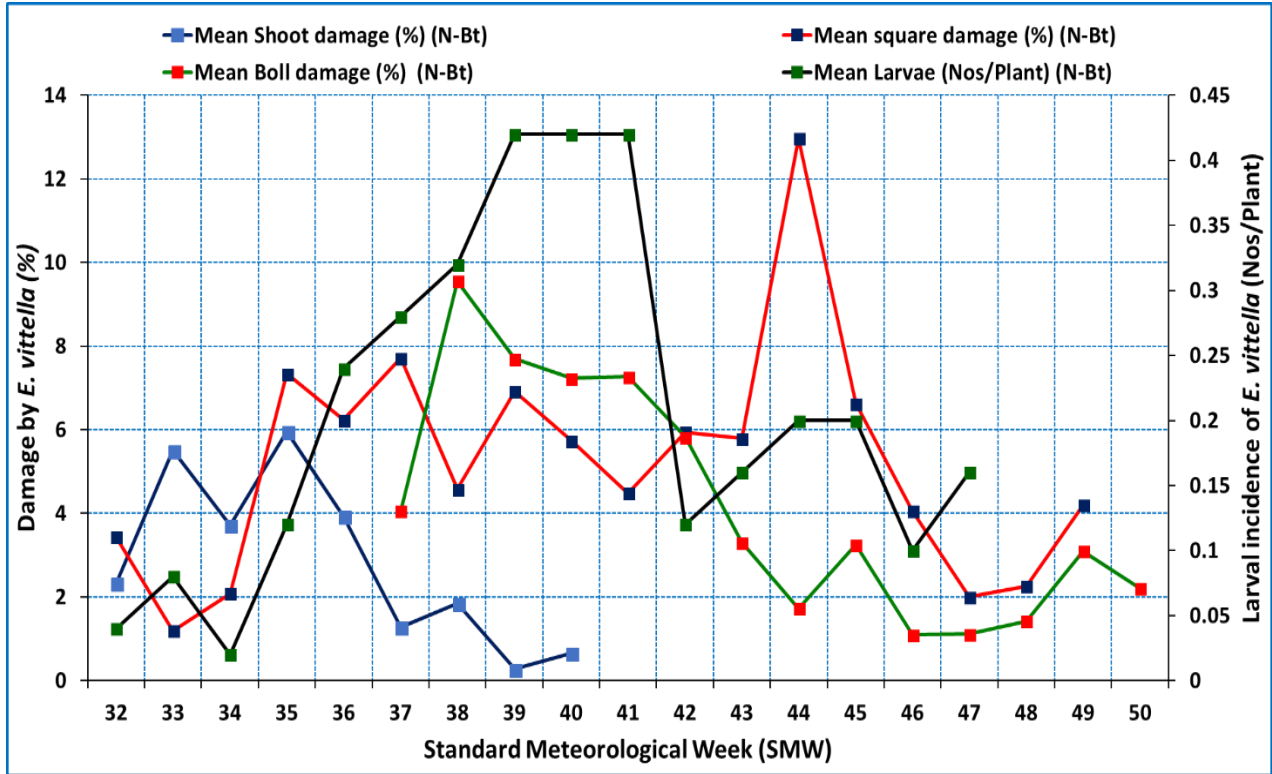


Fig.2 Seasonal incidence of *H. armigera* on *Bt* and non-*Bt* cotton during 2013 and 2014

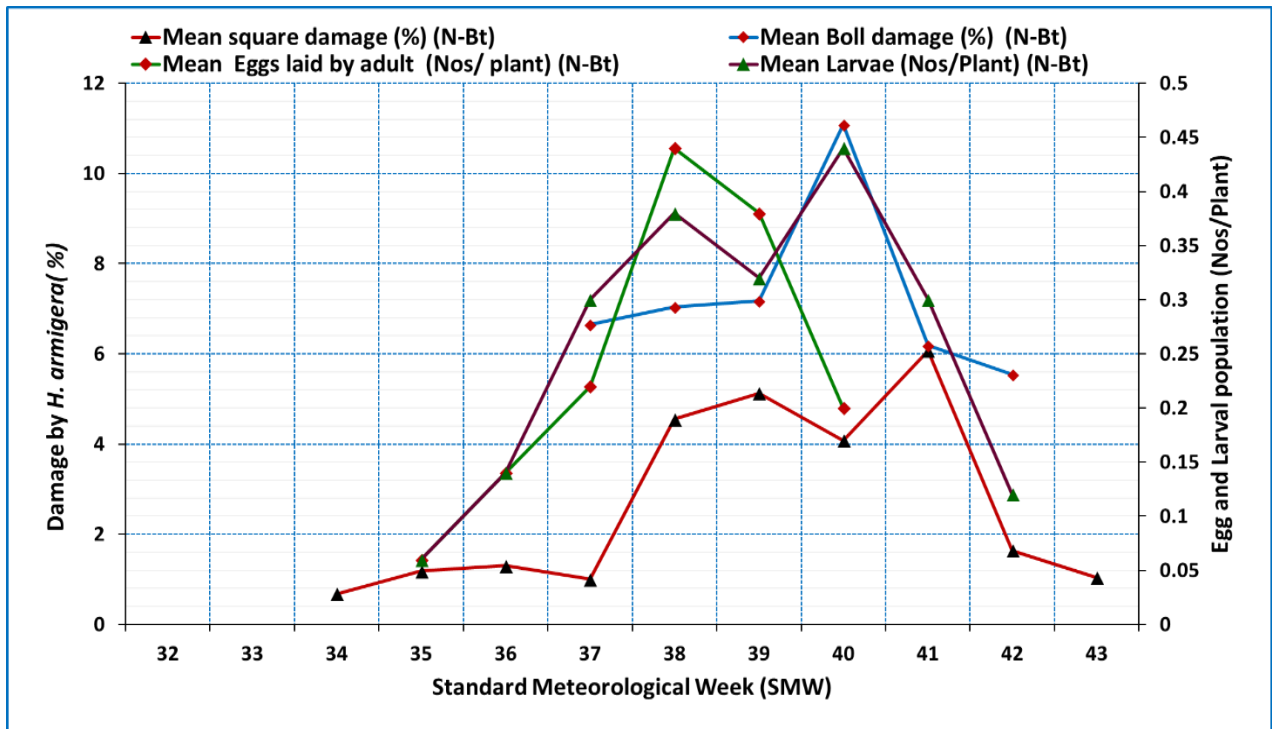


Table.1 Seasonal incidence of spotted bollworm, *Earias vittella* on *Bt* and non-*Bt* cotton during 2013 and 2014

SMW	Periods	Shoot damage (%)						Square damaged (%)					
		2013		2014		2013 & 2014		2013		2014		2013 & 2014	
		<i>Bt</i>	N- <i>Bt</i>	<i>Bt</i>	N- <i>Bt</i>	Mean (<i>Bt</i>)	Mean (N- <i>Bt</i>)	<i>Bt</i>	N- <i>Bt</i>	<i>Bt</i>	N- <i>Bt</i>	Mean (<i>Bt</i>)	Mean (N- <i>Bt</i>)
32	6 th – 12 th Aug	0.00	0.00	0.00	4.65	0.00	2.33	0.00	1.27	0.00	5.58	0.00	3.43
33	13 th – 19 th Aug	0.00	4.30	0.00	6.72	0.00	5.51	0.00	1.35	0.00	1.02	0.00	1.19
34	20 th – 26 th Aug	0.00	3.33	0.00	4.11	0.00	3.72	0.00	1.62	0.00	2.54	0.00	2.08
35	27 th – 02 nd Sep	0.00	5.67	0.00	6.25	0.00	5.96	0.00	7.14	0.00	7.54	0.00	7.34
36	3 rd – 09 th Sep	0.00	4.15	0.00	3.70	0.00	3.93	0.00	6.71	0.00	5.77	0.00	6.24
37	10 th – 16 th Sep	0.00	1.08	0.00	1.47	0.00	1.28	0.00	7.43	0.00	7.98	0.00	7.71
38	17 th – 23 rd Sep	0.00	1.18	0.00	2.51	0.00	1.85	0.00	4.48	0.00	4.68	0.00	4.58
39	24 th – 30 th Sep	0.00	0.56	0.00	0.00	0.00	0.28	0.00	7.49	0.00	6.34	0.00	6.92
40	1 st – 07 th Oct	0.00	1.32	0.00	0.00	0.00	0.66	0.00	6.04	0.00	5.43	0.00	5.74
41	8 th – 14 th Oct	-	-	-	-	-	-	0.00	3.56	0.00	5.39	0.00	4.48
42	15 th – 21 st Oct	-	-	-	-	-	-	0.00	6.57	0.00	5.30	0.00	5.94
43	22 nd – 28 th Oct	-	-	-	-	-	-	0.00	5.10	0.00	6.48	0.00	5.79
44	29 th – 04 th Nov	-	-	-	-	-	-	0.00	13.23	0.00	12.71	0.00	12.97
45	5 th – 11 th Nov	-	-	-	-	-	-	0.00	7.22	0.00	6.03	0.00	6.63
46	12 th – 18 th Nov	-	-	-	-	-	-	0.00	3.89	0.00	4.23	0.00	4.06
47	19 th – 25 th Nov	-	-	-	-	-	-	0.00	2.44	0.00	1.55	0.00	2.00
48	26 th – 02 nd Dec	-	-	-	-	-	-	0.00	3.45	0.00	1.06	0.00	2.26
49	3 rd – 09 th Dec	-	-	-	-	-	-	0.00	4.69	0.00	3.70	0.00	4.20
	Range	-	0.00-5.67	-	0.00-6.72	-	0.28-5.96	-	1.27-13.23	-	1.02-12.71	-	1.19-12.97
	Mean±SD	-	2.40±1.99	-	3.27±2.47	-	2.83±2.06	-	5.20±2.93	-	5.19±2.79	-	5.19±2.76
			S		S		S	-	S		S		S

SMW- Standard Meteorological Week; S- Significant, NS- Not significant

Table.2 Seasonal incidence of spotted bollworm, *Earias vittella* on *Bt* and non-*Bt* cotton at RRTTS, Bhawanipatna during 2013 and 2014

SMW	Periods	Boll damage (%)						Larval population (Nos /Plant)					
		2013		2014		2013 & 2014		2013		2014		2013 & 2014	
		<i>Bt</i>	N- <i>Bt</i>	<i>Bt</i>	N- <i>Bt</i>	Mean (<i>Bt</i>)	Mean (N- <i>Bt</i>)	<i>Bt</i>	N- <i>Bt</i>	<i>Bt</i>	N- <i>Bt</i>	Mean (<i>Bt</i>)	Mean (N- <i>Bt</i>)
32	6 th – 12 th Aug	-	-	-	-	-	-	0.00	0.00	0.00	0.08	0.00	0.04
33	13 th – 19 th Aug	-	-	-	-	-	-	0.00	0.04	0.00	0.12	0.00	0.08
34	20 th – 26 th Aug	-	-	-	-	-	-	0.00	0.04	0.00	0.00	0.00	0.02
35	27 th – 02 nd Sep	-	-	-	-	-	-	0.00	0.12	0.00	0.12	0.00	0.12
36	3 rd – 09 th Sep	-	-	-	-	-	-	0.00	0.28	0.00	0.20	0.00	0.24
37	10 th – 16 th Sep	0.00	4.41	0.00	3.70	0.00	4.06	0.00	0.32	0.00	0.24	0.00	0.28
38	17 th – 23 rd Sep	0.00	10.22	0.00	8.88	0.00	9.55	0.00	0.36	0.00	0.28	0.00	0.32
39	24 th – 30 th Sep	0.00	8.33	0.00	7.05	0.00	7.69	0.00	0.44	0.00	0.40	0.00	0.42
40	1 st – 07 th Oct	0.00	6.87	0.00	7.59	0.00	7.23	0.00	0.52	0.00	0.32	0.00	0.42
41	8 th – 14 th Oct	0.00	7.82	0.00	6.72	0.00	7.27	0.00	0.44	0.00	0.40	0.00	0.42
42	15 th – 21 st Oct	0.00	5.71	0.00	5.94	0.00	5.83	0.00	0.20	0.00	0.04	0.00	0.12
43	22 nd – 28 th Oct	0.00	2.61	0.00	3.99	0.00	3.30	0.00	0.12	0.00	0.20	0.00	0.16
44	29 th – 04 th Nov	0.00	2.24	0.00	1.21	0.00	1.73	0.00	0.28	0.00	0.12	0.00	0.20
45	5 th – 11 th Nov	0.00	3.72	0.00	2.78	0.00	3.25	0.00	0.24	0.00	0.16	0.00	0.20
46	12 th – 18 th Nov	0.00	1.02	0.00	1.15	0.00	1.09	0.00	0.12	0.00	0.08	0.00	0.10
47	19 th – 25 th Nov	0.00	1.27	0.00	0.94	0.00	1.11	0.00	0.28	0.00	0.04	0.00	0.16
48	26 th – 02 nd Dec	0.00	1.58	0.00	1.25	0.00	1.42	-	-	-	-	-	-
49	3 rd – 09 th Dec	0.00	3.73	0.00	2.47	0.00	3.10	-	-	-	-	-	-
50	10 th – 16 th Dec	0.00	2.70	0.00	1.71	0.00	2.21	-	-	-	-	-	-
	Range	-	1.02-10.22	-	0.94-8.88	-	1.09-9.55	-	0.00-0.52	-	0.04-0.40	-	0.04-0.42
	Mean±SD	-	4.45±2.90	-	3.96±2.76	-	4.20±2.80	-	0.24±0.16	-	0.18±0.12	-	0.21±0.13
			S		S		S		S		S		S

SMW- Standard Meteorological Week; S- Significant, NS- Not significant

Table.3 Seasonal incidence of American bollworm, *Helicoverpa armigera* on *Bt* and non-*Bt* cotton at RRTTS, Bhawanipatna during 2013 and 2014

SMW	Periods	American bollworm eggs (Nos/ plant)						American bollworm damaged squares (%)					
		2013		2014		2013 & 2014		2013		2014		2013 & 2014	
		<i>Bt</i>	N- <i>Bt</i>	<i>Bt</i>	N- <i>Bt</i>	Mean (<i>Bt</i>)	Mean (N- <i>Bt</i>)	<i>Bt</i>	N- <i>Bt</i>	<i>Bt</i>	N- <i>Bt</i>	Mean (<i>Bt</i>)	Mean (N- <i>Bt</i>)
34	20 th – 26 th Aug	-	-	-	-	-	-	0.00	0.00	0.00	1.36	0.00	0.68
35	27 th – 02 nd Sep	0.04	0.08	0.00	0.04	0.02	0.06	0.00	1.08	0.00	1.27	0.00	1.18
36	3 rd – 09 th Sep	0.00	0.16	0.04	0.12	0.02	0.14	0.00	1.64	0.00	0.96	0.00	1.30
37	10 th – 16 th Sep	0.08	0.20	0.04	0.24	0.06	0.22	0.00	0.87	0.00	1.13	0.00	1.00
38	17 th – 23 rd Sep	0.00	0.40	0.08	0.48	0.04	0.44	0.00	4.39	0.00	4.71	0.00	4.55
39	24 th – 30 th Sep	0.04	0.44	0.00	0.32	0.02	0.38	0.00	4.98	0.00	5.28	0.00	5.13
40	1 st – 07 th Oct	0.00	0.24	0.04	0.16	0.02	0.20	0.00	3.59	0.00	4.57	0.00	4.08
41	8 th – 14 th Oct	-	-	-	-	-	-	0.00	5.56	0.00	6.58	0.00	6.07
42	15 th – 21 st Oct	-	-	-	-	-	-	0.00	1.66	0.00	1.62	0.00	1.64
43	22 nd – 28 th Oct	-	-	-	-	-	-	0.00	0.86	0.00	1.22	0.00	1.04
	Range	0.00-0.08	0.08-0.44	0.00-0.08	0.04-0.48	0.02-0.06	0.06-0.44	-	0.00-5.56	-	0.96-6.58	-	1.00-6.07
	Mean±SD	0.03±0.03	0.25±0.14	0.03±0.03	0.23±0.16	0.03±0.02	0.24±0.14	-	2.46±1.98	-	2.87±2.15	-	2.67±2.05
		S	S	S	S	S	S		S		S		S

SMW- Standard Meteorological Week; S- Significant, NS- Not significant

Table.4 Seasonal incidence of American bollworm, *Helicoverpa armigera* on *Bt* and non-*Bt* cotton at RRTTS, Bhawanipatna during 2013 and 2014

SMW	Periods	American bollworm damaged bolls (%)						American bollworm larval population (Nos /Plant)					
		2013		2014		2013 & 2014		2013		2014		2013 & 2014	
		<i>Bt</i>	N- <i>Bt</i>	<i>Bt</i>	N- <i>Bt</i>	Mean (<i>Bt</i>)	Mean (N- <i>Bt</i>)	<i>Bt</i>	N- <i>Bt</i>	<i>Bt</i>	N- <i>Bt</i>	Mean (<i>Bt</i>)	Mean (N- <i>Bt</i>)
35	27 th – 02 nd Sep	-	-	-	-	-	-	0.00	0.04	0.00	0.08	0.00	0.06
36	3 rd – 09 th Sep	-	-	-	-	-	-	0.00	0.12	0.00	0.16	0.00	0.14
37	10 th – 16 th Sep	0.00	5.88	0.00	7.41	0.00	6.65	0.00	0.28	0.00	0.32	0.00	0.30
38	17 th – 23 rd Sep	0.00	7.53	0.00	6.54	0.00	7.04	0.00	0.36	0.00	0.40	0.00	0.38
39	24 th – 30 th Sep	0.00	7.02	0.00	7.32	0.00	7.17	0.00	0.36	0.00	0.28	0.00	0.32
40	1 st – 07 th Oct	0.00	10.65	0.00	11.50	0.00	11.08	0.00	0.48	0.00	0.40	0.00	0.44
41	8 th – 14 th Oct	0.00	7.67	0.00	4.68	0.00	6.18	0.00	0.40	0.00	0.20	0.00	0.30
42	15 th – 21 st Oct	0.00	5.14	0.00	5.94	0.00	5.54	0.00	0.16	0.00	0.08	0.00	0.12
	Range	-	2.61-10.65	-	1.77-11.50	-	2.19-11.08	-	0.04-0.48	-	0.08-0.40	-	0.06-0.44
	Mean±SD	-	6.64±2.49	-	6.45±2.96	-	6.55±2.62	-	0.28±0.15	-	0.24±0.13	-	0.26±0.13
			S		S		S		S		S		S

SMW- Standard Meteorological Week; S- Significant, NS- Not significant

Table.5 Effect of weather parameters on incidence of the bollworms on *Bt* and non-*Bt* cotton

Meteorological parameters	Simple correlation coefficient (r) between meteorological parameters and bollworms population											
	SBW larvae				ABW eggs				ABW larvae			
	2013		2014		2013		2014		2013		2014	
	<i>Bt</i>	N- <i>Bt</i>	<i>Bt</i>	N- <i>Bt</i>	<i>Bt</i>	N- <i>Bt</i>	<i>Bt</i>	N- <i>Bt</i>	<i>Bt</i>	N- <i>Bt</i>	<i>Bt</i>	N- <i>Bt</i>
Temp. (Max)(°C)	-	0.000	-	0.098	0.028	-0.363	-0.117	-0.217	-	-0.184	-	0.015
Temp. (Min)(°C)	-	0.271	-	-0.209	0.594	0.458	-0.291	0.172	-	-0.002	-	0.292
Temp. (Mean) (°C)	-	0.088	-	0.035	0.467	0.053	-0.422	-0.075	-	-0.115	-	0.205
R H (Morning) (%)	-	0.039	-	0.177	-0.765	0.306	0.281	-0.159	-	0.356	-	-0.238
R H (Evening) (%)	-	0.131	-	0.108	-0.388	0.298	0.455	-0.065	-	0.131	-	-0.224
R H (Mean) (%)	-	0.096	-	0.144	-0.530	0.313	0.387	-0.104	-	0.226	-	-0.233
Rain fall (mm)	-	0.024	-	0.208	-0.828*	0.314	0.326	-0.205	-	0.422	-	-0.138
P=0.05		0.497			0.811					0.707		
P=0.01		0.623			0.917					0.834		

* Significant at P= 0.05, ** Significant at P=0.0

While, no incidence of *H. armigera* larvae recorded in *Bt* cotton which is in line with the revelation made by Manjunathan *et al.*, (2009). Jie and Yuan (2000) observed that *Bt* cotton was highly resistant to cotton bollworm, *H. armigera* which confirms our results. Sharma and Pampapathy (2006) indicated that *H. armigera* larvae were significantly lower on the transgenic hybrids which coincided with the present findings. Nagendra (2015) reported that the highest bollworm larval population observed in mid-September and last week of November in conventional cotton.

Square damage by *H. armigera*

The *H. armigera* damaging square was observed during last week of August in 2013 and 2014 on non-*Bt* cotton (Table 3). The squares damaged by *H. armigera* reached its peak (5.56 and 6.58 % in 2013 and 2014 respectively) at 41st SMW in the 2nd week of October during both the crop seasons. Saini *et al.*, (2004) reported that *H. armigera* incidence was at its peak in second fortnight of September to early October. Dhaka and Pareek (2008) reported that the ABW appeared from the mid-August and reached at its peak (8.25%) in the mid-October. Prasada Rao *et al.*, (2010) reported that, by growing the *Bt* cotton, the average reduction in square damage was from 78.8 to 89.3 per cent. The results obtained in present study was in accordance with the findings of the earlier workers (Saini *et al.*, 2004; Dhaka and Pareek, 2008 and Prasada Rao *et al.*, 2010)

Boll damage by *H. armigera*

The *Bt* hybrid cotton exhibited complete resistance against *H. armigera* damage. However, the non-*Bt* hybrid of same variety was susceptible to the *H. armigera* attack. The results obtained from the investigation substantiated with the findings of Hallad *et*

al., (2014) who revealed that second generation *Bt* genotypes, Tulasi 4 BG-II and Chiranjeevi-BG-II of MON-15985 event showed high degree of resistance against bollworm attack. Pal *et al.*, (2010) reported that larval incidence of American bollworm (*H. armigera*) was nil in all the *Bt* hybrids compared to non *Bt* hybrids

The boll damage commenced from 37th SMW (2nd week of September) and continued up to 43rd SMW (4th week of October) during both the growing season (Table 4). The boll damage by *H. armigera* reached its plateau (10.65 and 11.50 % in the year 2013 and 2014 respectively) at 40th SMW i.e., during the 1st week of October. On an average the boll damage varied from 2.19 to 11.08 per cent. Dhaka and Pareek (2008) stated that the damage by *H. armigera* reached at its peak (8.25%) in the middle of October. The result of the author was similar with result of Dhaka and Pareek (2008).

Correlation of bollworms incidence with weather parameters

The data presented in Table 5 revealed that the larval population of *E. vittella* showed non-significant but positive correlation with temperature, relative humidity and rainfall excepting the negative correlation observed in non-*Bt* population in the year 2014.

There was no significant correlation between egg laying by *H. armigera* and any of the weather factors during the study period. However, there was negative correlation with maximum and mean temperature, relative humidity and rainfall in non-*Bt* during 2014. Similarly, during 2013, negative correlation between relative humidity and rainfall and egg laying in *Bt* cotton was observed.

The incidence of *H. armigera* larvae showed negative but non-significant correlation with

maximum, minimum and mean temperature in non-*Bt* cotton in the year 2013, whereas, morning, evening, mean relative humidity and rainfall negatively affected the larval population in non-*Bt* cotton in the year 2014. Kumar *et al.*, (2016) reported that the bollworm, *E. vittella* exhibited positive correlation with rainfall, minimum temperature and relative humidity which supplement the present finding. Rawal *et al.*, (2017) also observed that bollworms infestation showed negative and significant correlation with mean minimum temperature ($r = -0.740$) and non-significant negative correlation with mean maximum temperature ($r = -0.309$), evening relative humidity ($r = -0.434$) and rainfall ($r = -0.074$).

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