Advances in Entomology, 2016, 4, 61-74
Published Online April 2016 in SciRes. http://www.scirp.org/journal/ae
http://dx.doi.org/10.4236/ae.2016.42008

Scientific Research Publishing

Impact Analysis of Genetically Modified (*Bt*) Cotton Genotypes on Economically Important Natural Enemies under Field Conditions

Dalip Kumar[1*], Surender Singh Yadav[1], Vivek Kumar Saini[2], Krishan Kumar Dahiya[3]

[1]Department of Entomology, College of Agriculture, CCS HAU, Hisar, India
[2]Government College, Hisar, India
[3]Cotton Section, Department of Plant Breeding and Genetics, CCS HAU, Hisar, India
Email: *dilipshroff@rediffmail.com

Received 20 December 2015; accepted 1 February 2016; published 4 February 2016

Abstract

Field studies were conducted at Hisar during *Kharif*, 2009-2010 and 2010-2011 under natural and unsprayed condition. RCH 134 *Bt*, HS 6 (non *Bt*), H 1117 and *Ganganagar Ageti* (non *Bt*) were selected for the studies. The experiment was laid down in Randomized Block Design replicated thrice having plant spacing 67.5 × 60 cm. Among the bollworms, *Erias* spp. exhibited positive correlation with rainfall, minimum temperature and relative humidity morning hours significantly at 5 percent level whereas *Helicoverpa* and *Pectinophora* displayed positive relations only with evening hours relative humidity significantly while *Spodoptera* were significantly positive correlated with relative humidity of morning and evening hours. Bollworm complex was negatively correlated with all the weather parameters employed to study although being non-significant in case of rainfall, maximum and minimum of temperature, morning and evening hours of relative humidity. Among the sucking pests, leafhoppers, whitefly, thrips and aphids population showed significantly negative correlation with weather parameters. The comparison of natural bio-agents in cotton hybrids under study revealed that overall mean population of natural enemies were higher in *Bt* cotton hybrid as compared to non-*Bt*. These results confirm that use of genetically modified (*Bt*) cotton in lieu of conventional genotypes could positively impact non-target and beneficial insect species by preserving their host populations.

Keywords

***Bt* Cotton, Natural Enemies, Sucking Pests, Bollworm Complex, Population Dynamics, Correlation Co-Efficient, Abiotic Factors**

*Corresponding author.

How to cite this paper: Kumar, D., Yadav, S.S., Saini, V.K. and Dahiya, K.K. (2016) Impact Analysis of Genetically Modified (*Bt*) Cotton Genotypes on Economically Important Natural Enemies under Field Conditions. *Advances in Entomology*, **4**, 61-74. http://dx.doi.org/10.4236/ae.2016.42008

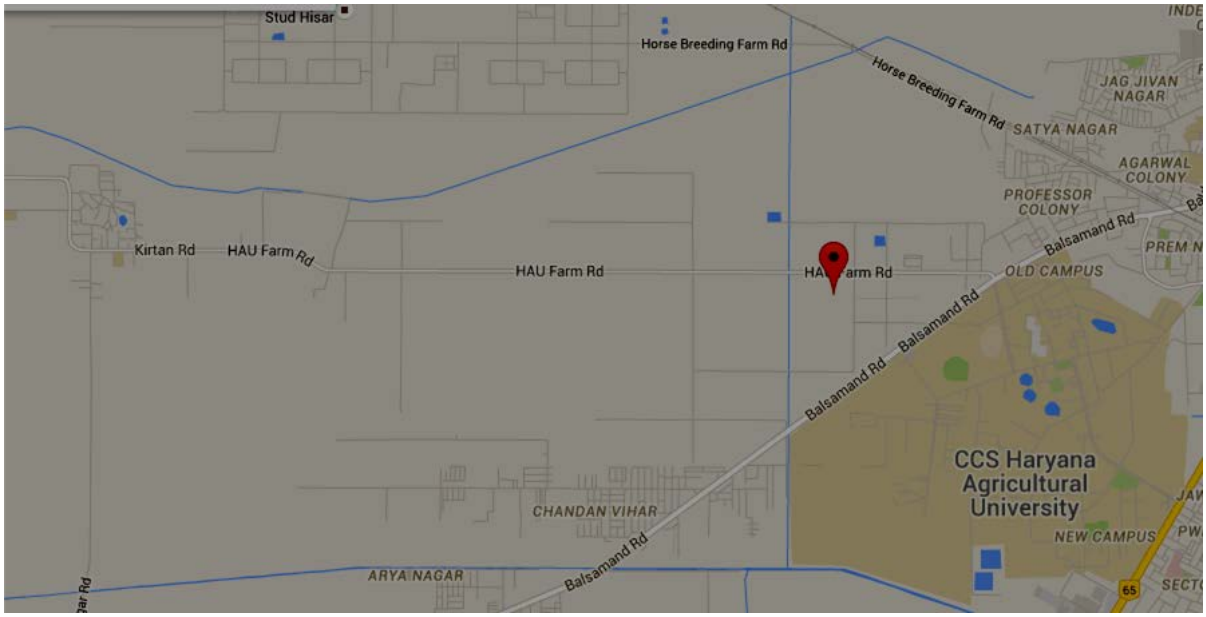
1. Introduction

Cotton is one of the major commercial crops and backbone of textile industry in India which provides employment to vast majority of population directly or indirectly. It provides livelihood of 60 million people depending on cotton cultivation, processing trade and textiles. Textile industry contributes 4% of GDP, 14% of total industrial product, 20% of total work force, 17% of country's exports earning and employment to 30 million people [1]. It is also one of the major sources that accounts for more than 30% of exports, making it India's largest net foreign exchange industry to the tune of $10 - 12 billion annually from exports of cotton yarn, thread, fabrics, apparel and made-ups [2]. India produces around 11 percent of the world's cotton from 20 percent of the area. In India, cotton area was 11.7 million ha with productivity of 496.4 kg lint/ha and total production of 35.6 million bales [3].

The pest spectrum of cotton is quite complex and as many as 1326 species of insects have been recorded in the world [4]. Cotton has the most fragile ecosystem amongst the field crops where approximately 162 insect-pests damage the crop in India [5]. Among the vast array of insect pests, major insect-pests which cause economic losses in cotton are bollworm complex includes American bollworm (*Helicoverpa armigera*), pink bollworm (*Pectionphora gossypiella*) and spotted bollworm (*Earias* spp.) while sucking pests are white fly, *Bemisia tabaci* (Gennadius); leafhopper, *Amrasca biguttula biguttula* (Ishida); mealy bug, *Pnenacoccus solenopsis* Tinsley; thrips, *Thrips tabaci* Lindeman; and aphid, *Apis gossypii* Glover [6]. Since the introduction of *Bt* cotton in agriculture in 1987 in USA by Monsanto, Delta and Pine companies [7] scenario has been changed as *Bt* replaced the conventional cotton and provided growers with a new tool for managing bollworms in cotton. In this context, amazingly, *Bt* cotton is one of the few technologies that have the safest bio-safety profile. It comes as an alternative to the previously used hazardous concoction of insecticides mixtures. Insecticides used on cotton were known to have ravaged ecology, disrupted the environment, played havoc with human and animal health, were toxic to honey bees, insect-parasitoid and predators. *Bt* cotton removed that to a great extent [8]. Criticism also focused on the bio-safety issues starting from adverse impact on soil microbes, pet animals and reported presence of *Bt* in human blood and placenta. Most of these reports were characterized by methodology errors and clearly lacked scientific credence in establishing a clear, cause and effect relationship [9]. Moreover, it's a common myth that *Bt* cotton has adverse effect on the population of economically important arthropods particularly natural enemies, which we have tried to study in these investigations. As bio-control agents considered to be an integral part of Integrated Pest Management (IPM) strategies, many workers have made assiduous study to nullify the assumptions of adverse effect on insects particularly of beneficial species [10] observed low incidence of plant damage, low density of lepidopteran and homopteran pests with relatively high densities of *Chrysoperla* spp in *Bt.* cotton hybrids as compared to non-*Bt* hybrids. Similarly, higher populations of spiders, predatory bugs (*Geocoris* spp.), green lace wing (*Chrysopa* spp.) and coccinellids (*Coccinella* spp.) were observed [11] [12] in *Bt* hybrids than non-*Bt* hybrids of cotton. An increase of 25 percent population of natural enemies in *Bt* cotton fields was observed [13] than non-*Bt* fields. Keeping in the mind regarding the assumption of adverse effect on living organism particularly of natural enemies of insect-pests in cotton, in present studies the attempt has been made to study the population dynamics and correlation of important insect-pests along with natural enemies on *Bt* as well as non-*Bt* cotton hybrids.

2. Materials and Methods

The experiments were conducted at the Cotton Research Farm, Department of Plant Breeding and Genetics, CCS Haryana Agricultural University, Hisar during 2009-2010 and 2010-2011 under natural conditions. Hisar city also known as city of steel and traditional cotton growing area, geographically located in Indo-Gangetic plains of North-West India at 215.2 meter (705 ft MSL) coordinates at 29˚10'0"N, 75˚43'0"E on map, receives average precipitation 490.6 mm annually with average summer and winter temperature 32.5˚C and 17.6˚C, respectively. RCH 134 *Bt*, HS 6, H 1117 (non-*Bt*) and *Ganganagar Ageti* (non-*Bt*) were selected for the study. RCH 134 *Bt* is popularly grown *Bt* hybrid, H 1117 and HS 6 are highly susceptible to bollworm complex and *Ganganagar Ageti* highly susceptible for sucking pests and moderately susceptible to bollworms. Seeds of RCH 134 *Bt* is of Rasi Seed Company, HS 6 and H 1117 procured from Haryana Agricultural University, Hisar and Ganganagar Ageti made available by Regional Research Station, Swami Keshwanand Rajasthan Agricultural University, Sri Ganganagar.



Research Farm-layout plan

The experiment was laid down in Randomized Block Design (RBD) replicated thrice having plant spacing 67.5 × 60 cm in a plot of 50 × 20 square meter. All agronomical practices were followed as per the recommendations of "Package of Practices of *Kharif* Crops" except plant protection measures [14]. Fertilizers namely Nitrogen, Phosphorous, Potassium and Zinc sulphate were applied at the rate of 70, 24, 24 and 2.100 kg in the field of cotton crop during the crop season. Of the total fertilizers, one third of nitrogen, total of Phosphorous, Potassium and Zinc Sulphate were applied at the time of sowing followed by one third of nitrogen at the time of square formation and remaining one third at the time of flowering. First irrigation was provided to crop after 30 to 40 days after sowing, subsequently field irrigated at the interval of 15 - 20 days. Irrigation of cotton field synchronized especially with flowering and boll formations during the crop season. Standard procedures were adopted to record the observations on population of economically important insect-pests damaging cotton crop namely bollworms included American, *Helicoverpa armigera*; pink, *Pectinophora gossypiella*, spotted, *Earias insulana*, *E. vittella* (Fabricius) and *Spodoptera litura*. The observations on the population of bollworms were 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. Population and damage in open bolls and loculi was taken at the time of maturity. The sample size and method employed for sampling the population of bollworms was as under.

2.1. 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:

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

Pink Bollworm; *Pectinophora gossypiella* (Saund.)

For pink bollworm infestation, 50 unopened green bolls were plucked from each plot randomly at 80, 110 and 140 days after sowing.

2.2. Open Bolls

Boll infestation was recorded in open bolls on boll and locule basis from randomly selected 5 plants/treatment.

2.2.1. Boll Basis

Total number of open bolls from randomly selected 5 plants were counted from each plot and examined critically for bollworm infestation. The per cent bollworm infestation in the bolls was calculated by following formula:

$$\text{Percent boll infestation}\left(\text{Boll basis}\right)=\frac{\text{No. of bolls infested}}{\text{Total number of bolls}}\times 100$$

2.2.2. Locule Basis

To work out the bollworm infestation on locule basis, the total number of open bolls of randomly selected 5 plants was counted. All the loculi of these bolls were examined carefully for bollworms infestation. Presence of hole in the septa of the locule was considered as infected. The per cent infestation was calculated with the following formula:

$$\text{Percent boll infestation}\left(\text{locule basis}\right)=\frac{\text{No. of infested loculi}}{\text{Total number of loculi}}\times 100$$

Simultaneously, to record the bollworm complex on pheromones (Make PCI, India ltd) trap catches basis, trap catches were installed in the field at the rate of four trap per plot. Pheromones capsules were replaced at ten days interval. Observations were recorded daily and then total numbers of catches per day were cumulated to weekly pheromones trap catch of an individual bollworm species.

2.3. Sucking Insect-Pests

The sucking pests included white fly, *Bemisia tabaci*; leafhopper, *Amrasca biguttula biguttula*; mealy bug, *Pnenacoccus solenopsis*; thrips, *Thrips tabaci*; aphid, *Apis gossypii* and mirid bugs of different genera. The observations on sucking pests were recorded at weekly intervals, starting from 24th standard week to the end of 42nd standard week. The observations of whitefly, leafhopper, aphids and thrips were recorded from randomly selected five plants on the lower surface of 3 randomly selected leaves (one each from upper, middle and lower plant canopy) per plot at weekly intervals. Mirid bugs were recorded from 100 squares (20 top squares/plant from 5 plant).

2.4. Natural Enemies

The natural enemies viz., lady bird beetle, *Coccinella septumpuncata*; green lace wing, *Chrysoperla carnea*; spiders, yellow wasps etc. were recorded at weekly intervals on randomly selected 5 plants in each variety and standard method *i.e.*, beat basket method (dimension of basket-diameter 30 cm, ht. 37.5 cm) to record the natural enemies was used for sampling. Total trap catch was observed per day of a particular bollworm and then counted cumulatively per standard week.

2.5. Statistical Analysis

The data collected during studies in the above experiments were got computed for analysis of variance [15]. In case of sucking pest population the data were analyzed for variance by adopting n + 1 transformation. Significant differences were set at $P \leq 0.05$ and $P \leq 0.01$ to workout correlations coefficient in between weather parameters, insect-pests population and natural enemies counts for the statistical analysis of the data [15].

3. Results

The results of studies conducted at during *Kharif* 2009-2010 and 2010-2011 revealed that the sucking pest's population started their build up from 24th standard week and continued till 42nd standard week in *Bt* as well as non-*Bt* hybrids. On the other hand, presence of bollworms in the field recorded in-between 29th to 31st of standard week.

3.1. Population Dynamics of Insect Pests during 2010-2011

3.1.1. Sucking Insect-Pests

In non-*Bt* cotton hybrids (*Ganganagar Ageti* and HS 6) leaf hopper population 6.5 per three leaves was maximum in 33rd standard meteorological week (SMW), while whitefly population was maximum 5.55 per three leaves 26th SMW in the crop season 2010-2011 (**Figure 1**). Leaf hoppers 4.9 per three leaves in 30th and whitefly 7.44

per three leaves in 25th standard week recorded maximum in *Bt* cotton hybrid RCH 134 (**Figure 2**).

The population of mirid bugs was observed only in non-*Bt* hybrids while in *Bt* Hybrid (RCH 134 *Bt*) their population was almost negligible (**Figure 2**). Population of thrips was observed as maximum in the 29th SMW whereas, mirid bug population was recorded maximum in the 40th, SMW. However the presence of aphids in cotton field was recorded 42nd SMW in late growth stages of crop (**Figure 1** and **Figure 2**).

3.1.2. Bollworm Complex

It has been observed that the pheromones trap catches of all the bollworms were first noticed in 32nd SMW except pink bollworm. The trap catch of *Erias* spp. increased up to 40th week then decreased. In case of trap catches, *Helicoverpa armigera* peaked in 40th SMW and then decreased and again increased in 44th SMW. There were gradual increase in catches of *Spodoptera* up to 40th SMW and afterwards a decline was observed and again there was a spurt of Spodoptera population in 44th SMW. *Pectinophora gossypiella* catches were noticed in 38th SMW and peak was in 40th SMW (**Figure 3(a)** and **Figure 3(b)**). Bollworms infestation throughout the fruiting season remained above economic threshold (5 per cent infestation in shed fruiting bodies) from mid August till crop maturity.

3.2. Population Dynamics of Insect Pests during 2009-2010

Sucking Insect Pests and Bollworm Complex

During the cotton crop season 2009-10, it was quite conspicuous that leafhopper and whitefly populations remained below the economic threshold in both varieties H 1117 (**Figure 4**) and RCH 134 *Bt* (**Figure 5**). However

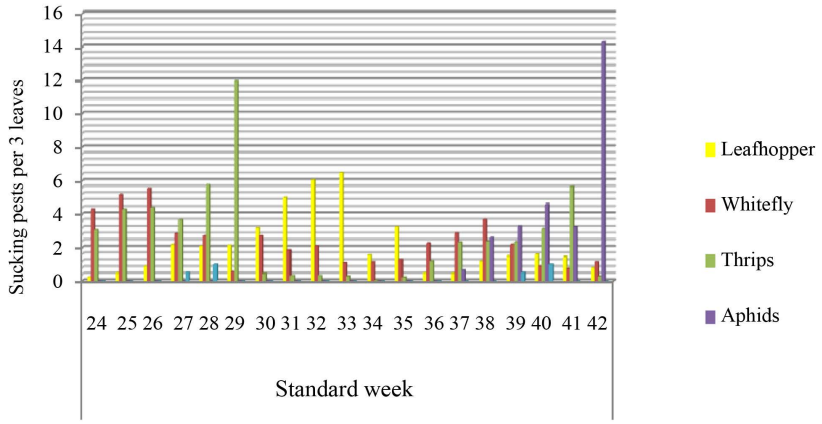


Figure 1. Population dynamics of sucking pests in ganganagar ageti and HS 6 (cummulative) crop season 2010-2011.

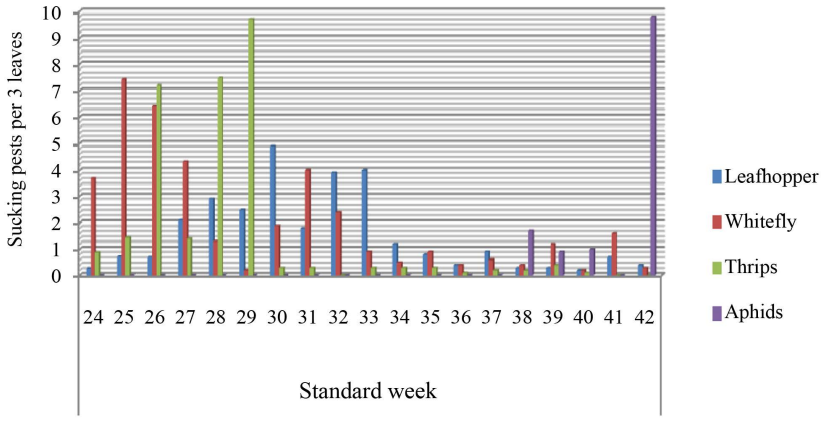


Figure 2. Population dynamics of sucking pests in RCH 134 *Bt* crop season 2010-2011.

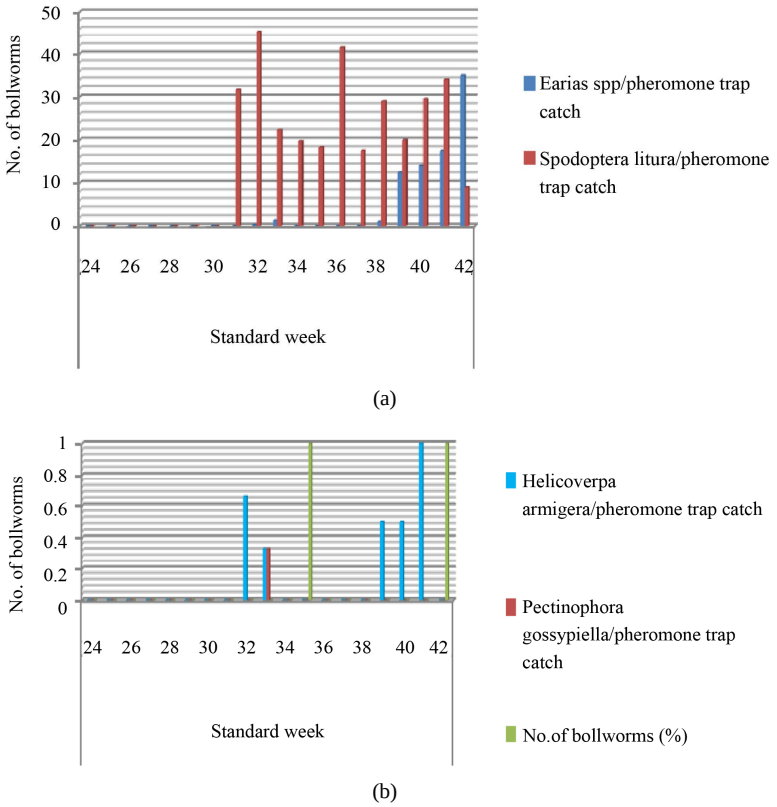


Figure 3. (a) Bollworms at different standard weeks on ganganagar ageti and HS 6 (cummulative) crop season 2010-2011; (b) Bollworms at different standard weeks on ganganagar Ageti and HS 6 (cummulatice) crop season 2010-2011.

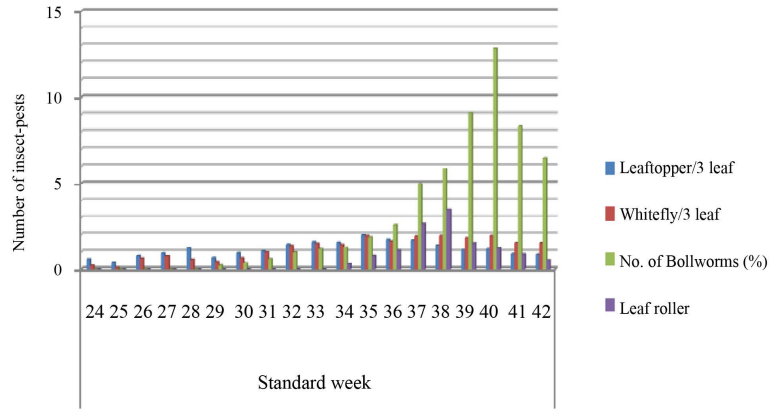


Figure 4. Population dynamics key pests on H 1117, crop season 2009-2010.

there was a gradual increase followed by a decrease in the population of these two sucking pests.

During the crop season 2009-2010, maximum leafhopper population was observed in 35th SMW, while whitefly population buildup was maximum in 40th SMW in H-1117. Bollworm complex remained above five per cent level during crop season from 38th till the end of the cotton season registering highest in 40th SMW. Leaf roller was recorded during 34th to 43rd standard week and marked their peak in 38th SMW (**Figure 4**).

In RCH 134*Bt* maximum population of sucking pests was observed in 35th SMW, while bollworm complex remained below economic threshold from 36th SMW till the end of fruiting satges. Leaf roller remained confined in ends of crop season from 35th to 42nd SMW showing a peak in 38th SMW 1.95 per plant (**Figure 5**).

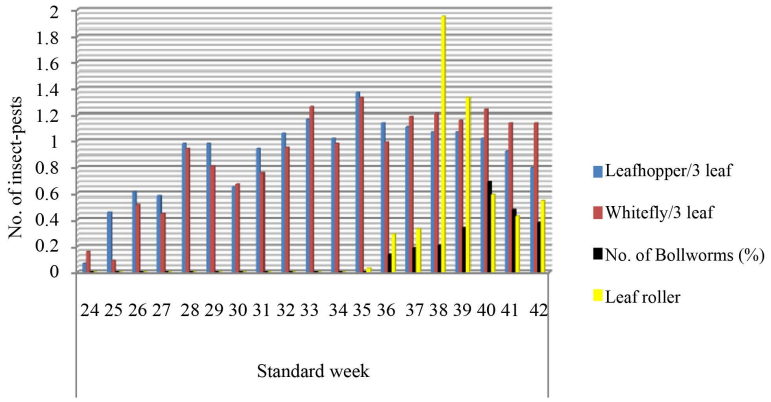


Figure 5. Population dynamics key pests on RCH 134 Bt, crop season 2009-2010.

3.3. Population Dynamics of Natural Enemies 2010-2011

3.3.1. Spiders

The population of spiders was present throughout the crop season on all three hybrids. *Ganganagar Ageti* harboured the maximum number of spiders which was higher than that on other two hybrids. However in case of HS 6, spiders were recorded continuously throughout the season whereas the spiders could not be recorded on *Ganganagar Ageti* during 33 SMW and on RCH 134 *Bt* during 31 and 42 SMW. *Ganganagar Ageti* was observed supporting maximum numbers of spiders (0.23) followed by 0.19 in RCH 134 *Bt* and 0.18 in HS 6 per plant.

3.3.2. Chrysoperlla

The mean number of *Chrysoperla* recorded as 0.08, 0.09 and 0.06 in HS 6, *Ganganagar Ageti* and RCH 134 *Bt* per plant, respectively (**Table 1**).

3.3.3. Coccinellid

Number of *Coccinellid* was in HS 6 and *Ganganagar Ageti* whereas it was 0.01 in RCH 134 *Bt*. Population of *Coccinellids* on hybrids was lower as compared to other two natural enemies.

3.3.4. Others

The natural enemies like dragonflies, damselflies, yellow wasp etc. was also recorded on the test cultivars. Their population was *i.e.*, maximum 0.53 and 0.33 per plant on HS 6 and RCH 134 *Bt*. During 37th SMW with mean population of 0.15 and 0.13 per plant, respectively. On *Ganganagar Ageti* it was maximum (0.63 per plant) in 25th SMW with an average of 0.19 per plant.

3.4. Population Dynamics of Natural Enemies 2009-2010

3.4.1. Spiders

RCH 134 *Bt* supported maximum numbers of spiders (0.29 per plant) as compared to 0.20 spiders in H 1117 (**Table 2**). Maximum spiders were observed at 29th standard week in RCH 134 *Bt* while it was 33rd week in H 1117.

3.4.2. Chrysoperlla

Mean number of *Chrysoperla* (0.17/plant) was higher in RCH 134 *Bt* as compared to (0.10/plant) in H 1117. Maximum population (0.34/plant) was recorded in RCH 134 *Bt* in 37th SMW while in H 1117 maximum population (0.25/plant) was observed in 33rd SMW.

3.4.3. Coccinellid

Mean population of Coccinellids in both the hybrids seems to be comparable with each other. Maximum numbers, 0.15 and 0.40/plant were observed in 37th and 34th SMW in RCH 134 *Bt* and H 1117, respectively.

Table 1. Population of natural enemies during the crop season in cotton hybrids, 2010-2011.

Standard week	HS 6				*Ganganagar Ageti*				RCH 134 Bt			
	No. of. Spider/plant	No. of *Chrysoperla*/ plant	No. of Coccinellid/ plant	Others*/plant	No. of. Spider/ plant	No. of *Chrysoperla*/ plant	No. of Coccinellid/ plant	Others*/plant	No. of Spider/plant	No. of *Chrysoperla*/ plant	No. of Coccinellid/ plant	Others*/plant
24	0.20	0.04	0.00	0.13	0.20	0.10	0.02	0.17	0.08	0.04	0.04	0.08
25	0.08	0.00	0.04	0.06	0.80	0.40	0.40	0.63	0.04	0.04	0.00	0.04
26	0.20	0.00	0.10	0.14	0.10	0.10	0.00	0.13	0.30	0.10	0.00	0.21
27	0.20	0.00	0.10	0.16	0.10	0.10	0.00	0.11	0.30	0.10	0.00	0.19
28	0.20	0.20	0.00	0.19	0.20	0.00	0.10	0.19	0.20	0.00	0.10	0.14
29	0.20	0.20	0.00	0.16	0.10	0.20	0.00	0.16	0.10	0.10	0.00	0.10
30	0.30	0.10	0.00	0.21	0.30	0.10	0.10	0.27	0.20	0.10	0.00	0.16
31	0.03	0.02	0.00	0.03	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.00
32	0.02	0.01	0.00	0.02	0.01	0.00	0.00	0.03	0.02	0.01	0.00	0.03
33	0.01	0.01	0.01	0.02	0.00	0.01	0.00	0.05	0.03	0.00	0.00	0.02
34	0.01	0.01	0.00	0.01	0.02	0.00	0.00	0.01	0.02	0.00	0.01	0.09
35	0.10	0.10	0.00	0.09	0.10	0.10	0.00	0.11	0.20	0.10	0.00	0.11
36	0.10	0.00	0.10	0.11	0.30	0.10	0.00	0.21	0.30	0.00	0.00	0.14
37	0.50	0.30	0.20	0.53	0.60	0.20	0.10	0.48	0.50	0.20	0.00	0.33
38	0.20	0.10	0.10	0.21	0.30	0.10	0.00	0.28	0.40	0.20	0.00	0.29
39	0.20	0.10	0.00	0.16	0.40	0.00	0.00	0.21	0.50	0.00	0.00	0.24
40	0.50	0.20	0.10	0.42	0.60	0.00	0.00	0.32	0.06	0.03	0.00	0.01
41	0.30	0.00	0.00	0.13	0.20	0.00	0.00	0.17	0.30	0.10	0.00	0.19
42	0.10	0.20	0.00	0.16	0.10	0.10	0.00	0.11	0.00	0.00	0.00	0.00
Mean	**0.18**	**0.08**	**0.04**	**0.15**	**0.23**	**0.09**	**0.04**	**0.19**	**0.19**	**0.06**	**0.01**	**0.13**

*Dragonflies, damselflies, yellow wasp etc.

3.4.4. Others

As regards the population of other natural enemies like dragonflies, damselflies, yellow wasp, etc. in test hybrids, H 1117 harboured maximum number (0.49 per plant) and the peak reached in 34th SMW having mean of 0.18 per plant, whereas, in case of RCH 134 *Bt* maximum number (0.43 per plant) was recorded in 29th SMW having average number (0.24 per plant) of these natural enemies.

3.5. Correlation between Natural Enemies and Insect-Pests of Cotton 2010-2011

During 2010-2011 crop season (**Table 3**)-Correlation worked out between natural enemies and insect-pests of cotton, it was quite interesting to note that bollworms have exhibited negative association with the natural bio-control agents *i.e.*, Chrysoperla in HS 6 for Erias (r = −0.277), in Ganganagar Ageti (GA) for Helicoverpa (r = −0.475), in GA for Spodoptera (r = −0.469), Coccinellids in GA and RCH 134 *Bt* for Spodoptera (r = −0.387, −0.342) and spiders in HS 6 for Pectinophora (r = −0.289) during the course of study. Leaf hopper has shown negative correlation with natural enemies in all cotton hybrid HS6, GA and RCH 134 *Bt* particularly at significant level; spiders (r = −0.375, −0.490, −0.291, respectively). Coccinellids in HS 6 against leafhopper have r = −0.379

Table 2. Population of natural enemies during the crop season in cotton hybrids, 2009-2010.

Standard week	H 1117				RCH 134 Bt			
	No. of Spider/plant	No. of *Chrysoperla*/plant	No. of Coccinellid/plant	Others*/plant	No. of. Spider/plant	No. of *Chrysoperla*/plant	No. of Coccinellid/plant	Others*/plant
24	0.0	0.0	0.0	0.0	0.0	0.0	0.02	0.01
25	0.0	0.0	0.09	0.05	0.0	0.0	0.0	0.00
26	0.04	0.0	0.03	0.04	0.03	0.0	0.03	0.03
27	0.09	0.03	0.0	0.06	0.09	0.03	0.01	0.06
28	0.21	0.0	0.0	0.11	0.19	0.07	0.0	0.13
29	0.26	0.25	0.05	0.30	0.56	0.17	0.15	0.43
30	0.31	0.07	0.00	0.21	0.32	0.11	0.04	0.23
31	0.32	0.15	0.00	0.25	0.35	0.26	0.14	0.37
32	0.32	0.11	0.17	0.32	0.41	0.27	0.06	0.36
33	0.34	0.25	0.02	0.33	0.34	0.24	0.09	0.33
34	0.29	0.22	0.40	0.49	0.37	0.26	0.04	0.33
35	0.31	0.17	0.00	0.26	0.32	0.22	0.00	0.27
36	0.27	0.15	0.00	0.23	0.38	0.28	0.00	0.33
37	0.18	0.13	0.01	0.17	0.32	0.34	0.04	0.34
38	0.21	0.09	0.00	0.16	0.38	0.16	0.09	0.31
39	0.17	0.05	0.09	0.17	0.32	0.23	0.02	0.28
40	0.11	0.06	0.00	0.09	0.39	0.21	0.00	0.30
41	0.16	0.04	0.00	0.11	0.36	0.15	0.03	0.27
42	0.16	0.07	0.03	0.14	0.33	0.14	0.00	0.23
Mean	0.20	0.10	0.05	0.18	0.29	0.17	0.04	0.24

*Dragonflies, damselflies, yellow wasp etc.

Table 3. Correlation coefficient (=r) of natural enemies and insect-pests on cotton hybrid during crop season 2010-2011.

Cotton hybrid	Natural enemy	*Erias* spp.	*Helicoverpa armigera*	*Pectinophora gossypiella*	*Spodoptera litura*	Bollworm	Leafhopper	Whitefly	Thrips	Aphid	Mirid bugs
HS 6	Spiders	0.153^{NS}	0.162^{NS}	-0.289^{*}	-0.126^{NS}	-0.200^{NS}	-0.375^{**}	0.183^{NS}	0.500^{**}	0.156^{NS}	0.409^{**}
	Chrysoperla	0.277^{*}	-0.180^{NS}	-0.190^{NS}	-0.206^{NS}	0.248^{NS}	-0.200^{NS}	0.007^{NS}	0.246^{NS}	0.384^{**}	0.350^{**}
	Coccinellids	-0.175^{NS}	-0.207^{NS}	-0.122^{NS}	0.072^{NS}	-0.237^{NS}	-0.379^{**}	0.646^{**}	0.132^{NS}	-0.046^{NS}	0.089^{NS}
	Others	0.155^{NS}	-0.033^{NS}	-0.249^{NS}	-0.100^{NS}	-0.080^{NS}	-0.380^{**}	0.288^{*}	0.329^{*}	0.238^{NS}	0.387^{**}
Ganganagar Ageti	Spiders	0.042^{NS}	0.005^{NS}	-0.251^{NS}	-0.096^{NS}	-0.144^{NS}	-0.490^{**}	0.127^{NS}	-0.022^{NS}	0.014^{NS}	--
	Chrysoperla	-0.204^{NS}	-0.475^{**}	-0.183^{NS}	-0.469^{**}	0.034^{NS}	-0.286^{*}	0.340^{**}	0.417^{**}	-0.094^{NS}	--
	Coccinellids	-0.195^{NS}	-0.224^{NS}	-0.096^{NS}	-0.387^{**}	-0.096^{NS}	-0.148^{NS}	0.479^{**}	0.191^{NS}	-0.166^{NS}	--
	Others	-0.055^{NS}	-0.126^{NS}	-0.221^{NS}	-0.234^{NS}	-0.128^{NS}	-0.451^{**}	0.201^{NS}	0.109^{NS}	-0.046^{NS}	--
RCH 134 Bt	Spiders	-0.189^{NS}	0.050^{NS}	-0.228^{NS}	0.022^{NS}	--	-0.291^{*}	-0.126^{NS}	0.001^{NS}	-0.194^{NS}	--
	Chrysoperla	-0.223^{NS}	-0.156^{NS}	-0.217^{NS}	-0.156^{NS}	--	-0.124^{NS}	-0.028^{NS}	0.074^{NS}	-0.157^{NS}	--
	Coccinellids	-0.160^{NS}	-0.183^{NS}	-0.079^{NS}	-0.342^{*}	--	0.133^{NS}	-0.024^{NS}	0.423^{**}	-0.108^{NS}	--
	Others	-0.206^{NS}	-0.060^{NS}	-0.257^{NS}	-0.091^{NS}	--	-0.208^{NS}	-0.094^{NS}	0.086^{NS}	-0.238^{NS}	--

*Significant at 5% (p = 0.05), **Significant at 1% (p = 0.01), NSNon-significant.

correlation coefficient. While others bio-agents shown preference r = −0.380 and −0.451 in HS6 and GA, respectively. Whitefly shown the positive correlation with natural enemies particularly worth mention of Chrysoperla (r = 0.340) in GA, Coccinellids in HS6 (r = 0.646) and GA (r = 0.479). In HS 6 others[#] bio-agent were having positive association (r = 0.288). In case of thrips, it were learned that only spiders (r = 0.500) in HS 6, Chrysoperla (r = 0.417) in GA and Coccinellids (r = 0.423) in RCH 134 *Bt* shown positive association. In mirid bugs Spiders (r = 0.409), Chrysoperla (r = 0.350) and other[#] bio agents (r = 0.387) in HS 6 were positively correlated, while aphid shown positive association (r = 0384) with Chrysoperla in HS 6.

3.6. Correlation between Natural Enemies and Insect-Pests of Cotton 2009-2010

During 2009-2010 crop season (**Table 4**), natural enemies and insect-pest correlation shown that most of the bio-control agents were of preference to sucking pest at most. Spiders (r = 0.663, 0.752) and Chrysoperla (r = 0.554, 0.809) preferred leafhoppers in *Bt* and non-*Bt* cotton hybrid. The same trend were apparent in case of whitefly in RCH 134 *Bt* and H 1117 during the crop season for predation of spiders (r = 0.399, 0.740) and Chrysoperla (r = 0.345, 0.743). Only spiders (r = 0.304) preferred bollworm in RCH 134 *Bt*.

3.7. Correlation of Abiotic Factor and Insect-Pests of Cotton (Pooled)

Table 5 exhibited that Erias spp. positively correlated with rainfall (r = 0.516), minimum (r = 0.583) and maximum (r = 0.363) of temperature, relative humidity (RH) of morning (r = 0.578) and evening (r = 0.277) hours, significantly. Helicoverpa was positively related to RH of morning (r = 0.384) and evening (r = 0.572) hours. In pink bollworm, rainfall (r = −0.422) and minimum (r = −0.370) temperature were found negatively associated, while RH of evening (r = 0.690) hours was positive correlated. In Spodoptera, maximum (r = 0.381) temperature, RH of morning (r = 0.655) and evening (0.827) hours were found positive correlated. Overall bollworm complex was negative correlated with all the parameters studied, although minimum (r = −0.386) temperature and RH of

Table 4. Correlation coefficient (=r) of natural enemies and insect-pests on cotton hybrid during crop season 2009-2010.

Cotton hybrid	Insect	*Erias* spp.	*Helicoverpa armigera*	*Pectinophora gossypiella*	*Spodoptera litura*
H 1117	Spiders	0.663**	0.399**	−0.131NS	−0.003NS
	Chrysoperla	0.554**	0.345**	−0.129NS	0.026NS
	Coccinellids	0.150NS	0.040NS	−0.132NS	−0.159NS
RCH 134 Bt	Spiders	0.752**	0.740**	0.304*	0.260NS
	Chrysoperla	0.809**	0.743**	0.216NS	0.174NS
	Coccinellids	0.191NS	0.071NS	−0.288*	0.019NS

*Significant at 5% (p = 0.05), **Significant at 1% (p = 0.01), NSNon-significant.

Table 5. Correlation coefficient (=r) of abiotic factors and cotton insect-pests (pooled data) on crop season 2009-2010 & 2010-2011.

Factors	Erias spp.	*Helicoverpa*	Pectiniphora	*Spodoptera*	Bollworm copmlex	Leafhopper	Whitefly	Thrips	Aphid	Mirid bug
Rainfall	0.516**	0.005NS	−0.422**	0.128NS	−0.213NS	−0.768**	−0.531**	−0.734**	−0.621**	0.295*
Temp Max.	0.363**	0.169NS	−0.068NS	0.381**	−0.386**	−0.755**	−0.525**	−0.672**	−0.578**	0.320*
Temp. Min	0.583**	0.075NS	−0.370**	0.223NS	−0.203NS	−0.804**	−0.581**	−0.775**	−0.616**	0.365**
RH Morn	0.578**	0.384**	0.107NS	0.655**	−0.320*	−0.818**	−0.723**	−0.773**	−0.489**	0.357**
RH Even	0.277*	0.572**	0.690**	0.827**	−0.199NS	−0.319*	−0.358**	−0.288*	−0.105NS	−0.043NS

*Significant at 5% (p = 0.05), **Significant at 1% (p = 0.01), NSNon-significant.

morning (r = −0.320) hours are of worth mention. Leafhoppers, whitefly and thrips were of negative association significantly in all weather parameters. In case of aphid, all abiotic factors were positively correlated significantly except RH of evening hours. Mirid bug was positive correlated with rainfall (r = 0.295), minimum (r = 0.320) and maximum (r = 0.365) of temperature and RH of morning (r = 0.357) hours.

3.8. Correlation of Abiotic Factor and Natural Enemies of Insect-Pests of Cotton (2010-2011)

Correlations **Table 6** revealed that in HS 6 cotton hybrid, spiders were found negative associated with minimum (r = −0.424) temperature and RH of evening (r = −0.476) hours. Chrysoperla was negatively correlated in maximum (r = −0.265) and minimum (r = −0.369) temperature and RH of evening (r = −0.268) while, it was positive associated with RH of morning (r = 0.345) hours. In others category, which included dragonflies, damselflies, yellow wasp etc. were negative correlated with minimum (r = −0.366) temperature and RH of evening (r = −0.410).

In Ganganagr Ageti, spiders were negative correlated with RH morning (r = −0.276) and evening (r = −0.543) hours. Maximum (r = 0.415) and minimum (r = 0.270) temperature were found correlated positively with Chrysoperla, while RH of morning (r = −0.540) and evening (r = −0.370) hours found negative associated. Others category were negative associated with RH of morning (r = −0.351) and evening (r = −0.551) hours.

In RCH 134 *Bt*, Spiders, Chrysoperla and others were negatively associated with maximum (r = −0.310, −0.286, −0.318) temperature, respectively.

3.9. Correlation of Abiotic Factor and Natural Enemies of Insect-Pests of Cotton (2009-2010)

Chrysoperla was negative correlated with rainfall (r = −326), while Coccinellid was positive in RH of evening (r = 0.265) hours in non-*Bt* cotton hybrid (**Table 7**).

In *Bt* hybrid RCH 134, Chrysoperla was negative with the rainfall (r = −0.279), while in RH of morning (r = 0.269) hours was positively associated. Coccinellids positive associated with minimum (r = 0.301) temperature and RH of evening (r = 0.323) hours.

4. Discussion

The correlations between the populations of insect pests of cotton hybrids and their natural enemies were worked out are presented in **Tables 3-5**. Different meteorological parameters were correlated with insect pests invading cotton crop are presented in **Tables 5-7**.

Among the bollworms, *Erias* spp. exhibited significantly positive correlation with rainfall, minimum temperature and Morning RH whereas *Helicoverpa* and *Pectinophora* populations were positively related only with Evening RH and *Spodoptera* was significantly positive correlated with morning and evening RH. The overall population of bollworm complex was negatively correlated with all the weather parameters used in the study although it was statistically non-significant. In case of sucking pests, leafhoppers, whitefly, thrips and aphids inverse

Table 6. Correlation coefficient (=r) of abiotic factors and natural enemies population on cotton during crop season 2010-2011.

Factors	Correlation coefficient (=r) for natural enemies population											
	HS 6				*Ganganagar Ageti*				RCH 134 Bt			
	Spiders	*Chrysoperla*	Coccinelids	Others[#]	Spiders	*Chrysoperla*	Coccinelids	Others[#]	Spiders	*Chrysoperla*	Coccinelids	Others[#]
Rainfall	−0.038[NS]	0.031[NS]	−0.008[NS]	−0.000[NS]	−0.173[NS]	−0.080[NS]	−0.027[NS]	−0.127[NS]	−0.042[NS]	0.157[NS]	−0.040[NS]	0.158[NS]
Temp Max.	−0.109[NS]	−0.265[*]	−0.147[NS]	−0.220[NS]	0.174[NS]	0.415[**]	0.521[**]	0.221[NS]	−0.310[*]	−0.286[*]	0.224[NS]	−0.318[*]
Temp. Min	−0.424[**]	−0.369[**]	0.035[NS]	−0.366[**]	−0.142[NS]	0.270[*]	0.383[**]	−0.012[NS]	−0.229[NS]	−0.064[NS]	0.207[NS]	−0.129[NS]
RH Morn	0.125[NS]	0.345[**]	0.113[NS]	0.243[NS]	−0.276[*]	−0.540[**]	−0.578[**]	−0.351[**]	0.194[NS]	0.086[NS]	−0.162[NS]	0.155[NS]
RH Even	−0.476[**]	−0.268[*]	−0.176[NS]	−0.410[**]	−0.543[**]	−0.370[**]	−0.436[**]	−0.551[**]	−0.105[NS]	−0.151[NS]	−0.127[NS]	−0.087[NS]

[*]Significant at 5% (p = 0.05), [**]Significant at 1% (p = 0.01), [NS]Non-significant, [#]Dragonflies, damselflies, yellow wasp etc.

relationship with all the weather parameters exception case of aphids being non-significant with evening RH. Mirid bugs population did not show any correlation with the weather parameters studied.

Correlations for the natural enemies during crop season 2010-2011 in relation to abiotic factors were non-significant with most of the parameters in hybrids HS 6, Ganaganagar Ageti and RCH 134 *Bt* except negative correlations between spiders and evening RH, *Coccinellid* & *Chrysoperla* with morning RH. *Coccinellids* had significantly positive correlation with maximum temperature only in hybrid Ganganagar Ageti. During the crop season 2009-2010, none of the weather parameters was found to have any correlation in case of H 1117 and RCH 134 *Bt*. Negative correlation of green lace wing with all abiotic factors [16] and lady bird beetle showed significantly positive correlation with sunshine hours and significantly negative correlation with minimum temperature and relative humidity [17].

The comparison of natural bio-agents in cotton hybrids under study (**Table 8** & **Table 9**) revealed that overall mean population of natural enemies were higher in *Bt* cotton hybrid as compared to non-*Bt*. The present scenario corroborates the findings of [13] report that 25 percent increase in natural enemies of pests in *Bt* cotton fields and observed higher number of natural enemies such as wasps (Vespoidea), aphids consuming flies (*Syrphus* spp.) and ladybirds (*Hippodamia* spp.) than in non-*Bt* fields [12]. Natural enemies, viz. spiders, predatory bugs (*Geocoris* spp.), green lace wing (*Chrysoperla* spp.) and Coccinellids (*Coccinella* spp.) were significantly higher in *Bt* hybrids than non-*Bt* hybrids [11].

Table 7. Correlation coefficient (=r) of abiotic factors and natural enemies population on cotton during crop season 2009-2010.

Factors	Correlation coefficient (=r) for natural enemies population							
	H 1117				RCH 134 Bt			
	Spiders	*Chrysoperla*	Coccinellids	Others[#]	Spiders	*Chrysoperla*	Coccinellids	Others[#]
Rainfall	−0.040^{NS}	−0.326**	−0.034^{NS}	−0.161^{NS}	−0.222^{NS}	−0.279*	0.036^{NS}	−0.232^{NS}
Temp Max.	−0.148^{NS}	−0.090^{NS}	−0.250^{NS}	−0.207^{NS}	−0.174^{NS}	−0.245^{NS}	−0.154^{NS}	−0.220^{NS}
Temp. Min	0.131^{NS}	0.160^{NS}	0.036^{NS}	0.134^{NS}	−0.226^{NS}	−0.203^{NS}	0.301*	−0.161^{NS}
RH Morn	0.165^{NS}	0.056^{NS}	0.216^{NS}	0.188^{NS}	0.022^{NS}	0.269*	0.147^{NS}	0.145^{NS}
RH Even	0.162^{NS}	0.109^{NS}	0.265*	0.224^{NS}	−0.259^{NS}	−.095^{NS}	0.323*	−0.133^{NS}

*Significant at 5% (p = 0.05), **Significant at 1% (p = 0.01), ^{NS}Non-significant, $^{\#}$Dragonflies, damselflies, yellow wasp etc.

Table 8. Population of natural enemies in *Bt* and non-*Bt* genotypes of cotton, 2009-2010.

Genotypes	Mean population of natural enemies (Spiders, *Coccinellids*, *Chrysoperla* sp. and others[#]) per plant																			Mean
	Standard weeks																			
	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	
RCH 134 Bt	0.03	0.0	0.09	0.19	0.39	1.31	0.7	1.12	1.1	1.0	1.0	0.81	0.99	1.04	0.94	0.85	0.9	0.81	0.7	0.73
H 1117	0.0	0.14	0.11	0.18	0.32	0.86	0.59	0.72	0.92	0.94	1.4	0.74	0.65	0.49	0.46	0.48	0.26	0.31	0.4	0.52
S.Em±	0.02	0.01	0.03	0.01	0.01	0.02	0.01	0.02	0.03	0.02	0.02	0.03	0.02	0.01	0.02	0.03	0.02	0.01	0.01	
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

Figures in parentheses are √ n + 1 transformation; $^{\#}$Dragonflies, damselflies, yellow wasp etc.; NS, Non-significant.

Table 9. Population of natural enemies in *Bt* and non-*Bt* genotypes of cotton, 2010-2011.

Genotypes	Mean population of natural enemies (Spiders, *Coccinellids*, *Chrysoperla* sp. and others[#]) per plant																			Mean
	Standard weeks																			
	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	
RCH 134 Bt	0.24	0.12	0.61	0.59	0.44	0.30	0.46	0.0	0.06	0.05	0.12	0.41	0.44	1.03	0.89	0.74	0.10	0.59	0.0	0.45
Ganganagar ageti	0.49	2.23	0.33	0.31	0.49	0.46	0.77	0.06	0.04	0.06	0.03	0.31	0.61	1.38	0.68	0.61	0.92	0.37	0.31	0.55
HS 6	0.37	0.18	0.44	0.46	0.59	0.56	0.61	0.08	0.05	0.05	0.03	0.29	0.31	1.53	0.61	0.46	1.22	0.43	0.46	0.37
S. Em±	0.05	0.02	0.04	0.07	0.04	0.05	0.04	0.07	0.06	0.07	0.07	0.06	0.03	0.05	0.07	0.04	0.02	0.06	0.07	
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	

Figures in parentheses are √ n + 1 transformation; [#]Dragonflies, damselflies, yellow wasp etc.; NS, Non-significant.

5. Conclusion

In conclusion, the present results confirm that use of *Bt* cotton in lieu of conventional could positively impact non-target and beneficial organisms by preserving their host populations [18]-[20].

References

[1] Anupam, B. (2010) Cotton Statistics at a Glance. Directorate of Cotton Development Ministry of Agriculture, Government of India, Mumbai, 148.

[2] http://www.mcxindia.com

[3] Anonymous (2012) Annual Report 2012-13. All India Coordinated Cotton Improvement Project. Indian Council of Agricultural Research, Project Coordinator (Cotton Improvement), Central Institute for Cotton Research, Coimbatore.

[4] Hargreaves, H. (1984) List of Recorded Cotton Insects of World. Commonwealth Institute of Entomology, London, 50.

[5] Dhawan, A.K. (2000) Cotton Pest Scenario in India: Current Status of Insecticides and Future Perspectives. *Agrolook*, **1**, 9-26.

[6] Sundramurthy and Chitra (1992) Integrated Pest Management in Cotton. *Indian Journal of Plant Protection*, **20**, 1-17.

[7] Benedict, J.H. and Altman, D.W. (2001) Commercialization of Transgenic Cotton Expressing Insecticidal Crystal Protein. *Genetic Improvement of Cotton*: *Emerging Technologies*, Oxf. & IBH Pub Co. Pvt. Ltd., New Delhi, 137-201.

[8] Aumaitre, A. (2004) Safety Assessment and Feeding Value for Pigs, Poultry and Ruminant Animals of Pest Protected (Bt) Plants and Herbicide Tolerant (Glyphosate, Glufosinate) Plants: Interpretation of Experimental Results Observed Worldwide on GM Plants. *Italian Journal of Animal Science*, **3**, 107-121. http://dx.doi.org/10.4081/ijas.2004.107

[9] Klaus, A. (2009) Human and Health-Rebuttal to a Review of Dona and Arvanitoyannis 2009, Part One. European Fedeartion of Biotechnology.

[10] Summy, K.R., Ranlston, J.R., Spurgeon, D. and Vargas, J. (1996) An Analysis of the Beetworm Outbreak on Cotton in the Lower Rio Grande Valley of Texas. *Proceedings of the Beltwide Cotton Conference*, Nashville, 9-12 January 1996, 837-841.

[11] Aggarwal, N., Brar, D.S. and Buttar, G.S. (2007) Evaluation of *Bt* and Non-*Bt* Version of Two Cotton Hybrids under Different Spacings against Sucking Insects-Pests and Natural Enemies. *Journal of Cotton Research and Development*, **21**, 106-110.

[12] Sun C.G., Xu J., Zhang Q.W., Feng H.B., Wang, F., Song, R., Sun, C.G., Xu, J., Zhang, Q.W., Feng, H.B., Wang, G. and Song, R. (2002) Effect of Transgenic *Bt* Cotton on Population of Cotton Pests and Their Natural Enemies in Xinjiang. *Chinese Journal of Biological Control*, **18**, 106-110.

[13] Buranakanonda, A. (1999) *Bt* Cotton Is Potential Economic Savior of Chineses Province. Bangkok Post, 6.

[14] Anonymous (2010) Package of Practices for Kharif Crops. Directorate of Publications, CCS Haryana *Agric. Univ.*, Hisar, Institute for Cotton Research, Coimbatore, 177.

[15] Panse, V.G. and Sukhatme, P.V. (1995) Statistical Methods for Agricultural Workers. ICAR, New Delhi.

[16] Purohit, D. and Smith, R.H. (1997) An Extension Entomologist's 1996 Observations of Bollgard (Bt) Technology.

Proceedings of the Beltwide Cotton Conference, National Cotton Council, Memphis, 856-858.

[17] Gosalwad, S.S., Kamble, S.K., Wadnerkar, D.W. and Awaz, H.B. (2009) Population Dynamics of Major Insect-Pests of Cotton and Their Natural Enemies. *Journal of Cotton Research and Development*, **23**, 117-125.

[18] Head, G., Freeman, B., Mina, B., Moar, W., Ruberso, J. and Turnipseed, S. (2001) Natural Enemy Abundance in Commercial Bollgard and Conventional Cotton Fields. *Proceedings of the Beltwide Cotton Conference*, Memphis, 796-798.

[19] Smith, R.H. (1997) An Extension Entomologist's 1996 Observations of Bollgard (Bt) Technology. *Proceedings of the Beltwide Cotton Conference*, National Cotton Council, Memphis, 856-858.

[20] Xia, J.Y., Cui, J.J., Ma, L.H., Dong, S.X. and Cui, X.F. (1999) The Role of Transgenic *Bt* Cotton in Integrated Insect Pest Management. *Acta Gossypii Sinica*, **11**, 57-64.