Indian Journal of Agricultural Sciences **84** (5): 572–8, May 2014/Article

Population dynamics of insect pests and some of their natural enemies and their correlation with weather parameters on Bt cotton

D V MUCHHADIYA[1], D A SARADAVA[2] and B B KABARIA[3]

College of Agriculture, Navsari Agricultural University, Bharuch, Gujarat 392 012

Received: 23 January 2012; Revised accepted: 10 March 2014

ABSTRACT

The study was conducted at different villages of Rajkot district (Gujarat) to know the population dynamics and correlation of pests and their natural enemies on Bt cotton from 2008 to 2011. It revealed that sucking pests such as jassid, white fly, thrips, and aphid were found damaging the Bt cotton throughout the season however their peak activity was found on 39th SMW (3.50/3 leaves), 47th SMW (3.48/3 leaves), 38th SMW (2.94/3 leaves) and 51st SMW (27.23%), respectively. Mealy bug appeared from 33rd S M W and reached its peak on 50th SMW (1.95 grades). The peak period of bollworms, heliothis, spotted bollworm, pink bollworm and leaf eating caterpillar were 41st SMW (0.11/pl.), 39th SMW (0.08/pl.), 51st SMW (0.26/pl.) and 41st SMW (0.18/pl.), respectively. In natural enemies chrysopid was found higher in number than spiders and coccinellids throughout the season. The peak periods of the coccinellids, chrysopid and spiders were found on 42nd SMW (0.51/pl.), 45th SMW (3.01/pl.) and 32nd SMW (1.13/pl.), respectively. Correlation amongst sucking pests showed that jassid, whitefly, aphid and mealy bug population showed significant positive correlation with sunshine hours and significant negative association with rainfall whereas thrips showed significant negative correlation with sunshine hours. Amongst bollworms, heliothis, spotted bollworm and leaf eating caterpillar showed significant negative correlation with rainfall whereas spotted bollworm and spodoptera showed significant positive correlation with sunshine hours. Pink bollworm showed significant negative correlation with maximum and minimum temperature and morning and evening relative humidity. In natural enemies, chrysopid and coccinellid showed significant negative correlation with rainfall whereas spiders showed significant positive association with rainfall however chrysopid showed significant positive correlation with sunshine hours.

Key words: Bt Cotton, Correlation, Insect pests, Natural enemies, Population dynamics

Cotton accounts for 40% of the total global fibre production and is the most important fibre in the world. India is a major player with world cotton market in terms of area and production. India is the second largest cotton producer, consumer and exporter in the world. India has an area 121.70 lakh ha with a production of 353 lakh bales and productivity of 493 kg/ha lint. Gujarat has an area 29.62 lakh ha area with a production of 120 lakh bales and productivity of 689 kg/ha lint during year 2011-12.In Gujarat, the major cotton producing districts, viz. Rajkot, Bhavnagar, Vadodara, Amreli, Mehsana, Bharuch and Surendranagar, produce about 85 per cent of the total cotton production in the state. Rajkot district has the largest area under the cotton (3.65 lakh ha) with the production of 18.10 lakh bales and productivity of 843 kg/ha lint during year 2011-12 in Gujarat (Kabaria *et al.* 2013). With introduction of Bt cotton technology farmers of Saurashtra region are getting good production but still there are some issues in the Bt cotton to be deal with. The sucking pests and diseases such as grey mildew and leaf reddening are the major constraints in Bt cotton production. Therefore, the present study has been conducted to monitor the insect pests and natural enemies activity in Bt cotton under natural conditions on farmers field at different locations of the district so that the major problems pertaining the insect pests and diseases in Bt cotton can be identified and management strategies can be prepared.

MATERIALS AND METHODS

A study was conducted on pest surveillance, activities of natural enemies and other key issue such as grey mildew and reddening and their correlation with weather parameters in Bt cotton on farmers field during year 2008-09, 2009-10, 2010-11 and 2011-12. Five talukas of the Rajkot district were selected on the basis of the cotton growing area and four villages per talukas were selected, i.e. total twenty villages were selected and two farmers' field per village to record the data at weekly interval between 6:30-8:30 AM starting from the 4th week of July to 4th week of December each year. Two fields per village were selected in opposite

[1]Assistant Professor, Department of Entomology (e mail: muchhadiyadipak@gmail.com), [2]Training Associate (e mail: kvkrajkot@gmail.com), [3] Programme Coordinator (e mail: kvkrajkot@gmail.com), KVK, Junagadh Agricultural University, Targhadia, Rajkot 360 003

direction to get the picture of entire village. For getting the information of pest status of entire village common growing variety of the Bt cotton in the village was selected for study. Every year two new farmers field were selected and some of the old villages were replaced by new villages of the same taluka. So far total 36 villages were covered from year 2008-09 to 2011-12. Ten field scouts were recruited and trained to collect the data and each field scouts were given two villages. The data was collected from 20 randomly selected plants/field. Farmers' methods of plant protections and agronomic practices were followed. The data of jassid (nymphs), *Amarsca biguttula biguttula* (Ishida); whitefly (adults), *Bemisia tabaci* (Gennadius) *;* and thrips , *Thrips tabaci* Lindeman were recorded from three randomly selected leaves from top, middle and bottom per plant. The aphid, *Aphis gossypii* Glover incidence was calculated in per cent infested plants by observing the aphids on terminal shoots. Mealy bug, *Phenoccous solenopsis* Tinsley was recorded in grade system, i.e. 0-4 grade where 0 for no mealy bug population, 1 for scattered mealy bug appearance, 2 for full infestation on any one branch of plant, 3 for full infestation on more than one branch/half portion of the plant and 4 for heavy infestation on whole plant. The larva of bollworms such as heliothis, *Helicoverpa armigera* (Hübner); spotted bollworm, *Earias vittella* (Fabricius); pink bollworm, *Pectinophora gossypiella* (Saunders) and leaf eating caterpillar, *Sopodptera litura* (Fabricius) were recorded in number per plant. Amongst the natural enemies, the coccinellid's grub+adult were recorded in number per plant, in chrysopid, *Chrysoperla zastrowi sellimi* (Esben-Petersen) the green coloured eggs were recorded in number per plant and number of spiders per plant were recorded. The villages selected for study were Khorana, Kotharia, Khokhaddad, Magharvada, Rafala, Manharpur, Bedla, Gomta, Pipaliya, Bhojpara, Patidad, Gundala, Charakhadi, Atkot, Panchavda, Kalasar, Lilapur, Kharachiya, Jungavd, Kanesara, Barvada(Jas), Kothi, Kundani, Lakhavad, Ambardi, Shivrajpur, Savdi, Hadmatia, Chhatar, Ganeshpar, Samadhiyala, Chandrapur, Kankot, Kherva, Arnitimba and Tithwa of Rajkot district.

RESULTS AND DISCUSSION

Population Dynamics and correlation of insect pests of Bt Cotton with weather parameters Amrasca biguttula biguttula

The pest population (Table 1) started building up from 4th week of July 2.24/3 leaves and reached peak 4.28/3 leaves on 4th week of September and declined thereafter during year 2008-09. During year 2009-10, the pest population started from 4th week of July (2.92/3 leaves) and reached highest 4.92/3 leaves on 3rd week of September and pest population declined thereafter however the population was present throughout the season lower than its peak point. During year 2010-11, the pest activity started from 4th week of July and increased gradually till 2nd week of December, i.e. highest (4.07/3 leaves) and then decreased in subsequent weeks. During year 2011-12, the pest population started building up from 4th week of July and reached its peak on 1st week of August (2.65/3 leaves) and then population declined gradually till 1st week of September and than pest population increased till 3rd week of November and decreased thereafter. The average data of four years shows that, the pest population started from 4th week of July and increased gradually and reached its peak on 4th week of September (3.50/3 leaves) and then pest population decreased than its peak point in the subsequent weeks. Ashfaq *et al*.(2010) also observed the maximum population of jassids during 2nd and 3rd week of September (2.73 and 2.24 per leaf). Sana *et al.*(2011) recorded the activity of *A. biguttula biguttula* throughout the cotton growth period which support the present investigation.

Correlation with weather parameters showed that jassid population (Table 3) found significant positive correlation with sunshine hours (r=0.516) and significant negative correlation with rainfall (r=-0.672). Ashfaq *et al*.(2010) also observed negative effect of rainfall on jassid population on cotton which supports the present work.

Bemisia tabaci

The density of *B. tabaci* started from 4th week of July and increased gradually in subsequent weeks and reached highest (4.22/3 leaves) on 4th week of September (Table 1), the pest population decreased gradually thereafter during year 2008-09. During year 2009-10, the pest density started from 4th week of July and increased gradually till 4th week of September (4.03/3 leaves) and population decreased thereafter, however the abrupt population rise was recorded on 3rd week of November, i.e. 5.08/3leaves, which was the highest pest activity. During year 2010-11, the population started from 4th week of July and increased gradually and maximum activity 3.80/3 leaves was recorded on 3rd week of October and population decreased thereafter. During year 2011-12, the pest activity started from 4th week of July and it decreased till 2nd week of September. The population started increasing thereafter and reached peak 3.10/3 leaves in the 2nd week of December. The average data of four years indicates that the pest population started from 4th week of July reached its peak 3.48/3 leaves in the 3rd week of November. Sana *et al.*(2011) observed the activity of *B. tabaci* throughout the cotton growth period which support the present investigation.

Correlation with weather parameters showed that *B. tabaci* (Table 3) found significant positive correlation with sunshine hours (r=0.796) and significantly negative correlation with rainfall (r=-0.560). Bashir *et al.* (2001) also found negative correlation of rainfall with whitefly population.

Thrips tabaci

The data of *T. tabaci* during year 2008-09 shows that it started from 4th week of July and gradually increased thereafter and reached peak on 3rd week of September 3.24/ 3 leaves and than it decreased (Table 1). During year 2009-

Table 1 Mean density of pests on Bt cotton in different villages of Rajkot district (2008-2011)

Pest	Year	Standard Meteorological Week																					
		31 July	32 Aug.	33 Aug.	34 Aug.	35 Aug.	36 Sep.	37 Sep.	38 Sep.	39 Sep.	40 Oct.	41 Oct.	42 Oct.	43 Oct.	44 Oct.	45 Nov.	46 Nov.	47 Nov.	48 Nov.	49 Dec.	50 Dec.	51 Dec.	52 Dec.
Amrasca biguttula biguttula (no./3 leaves)	2008-09	2.24	2.15	3.10	3.20	2.10	2.24	2.35	3.37	4.28	4.24	4.26	3.15	2.50	3.26	3.79	4.15	4.24	3.70	1.15	0.50	0.26	1.50
	2009-10	2.92	1.15	0.80	1.24	2.37	2.24	2.15	4.92	4.04	3.41	2.20	3.70	3.21	3.53	3.29	2.81	3.27	4.14	2.79	3.05	3.28	3.83
	2010-11	0.22	1.24	1.75	1.99	2.44	3.05	3.65	3.35	3.46	3.27	3.01	3.37	3.51	3.21	3.02	3.25	3.37	3.28	3.09	4.07	2.82	2.50
	2011-12	0.47	2.65	0.94	1.51	1.95	1.09	1.89	2.32	2.23	2.62	2.34	2.64	2.43	2.43	2.50	2.11	2.17	1.54	1.28	1.10	1.22	1.30
	Average	1.46	1.80	1.65	1.99	2.22	2.16	2.51	3.49	3.50	3.39	2.95	3.22	2.91	3.11	3.15	3.08	3.26	3.17	2.08	2.18	1.90	2.28
Bemisia tabaci (no./3 leaves)	2008-09	0.50	0.40	1.10	1.25	2.90	2.30	3.24	3.10	4.22	4.20	4.21	3.50	3.50	3.21	2.50	2.79	2.80	3.78	2.10	1.20	1.50	2.10
	2009-10	1.24	1.50	1.20	1.83	1.80	2.10	3.80	3.91	4.03	3.35	3.21	3.63	3.73	3.67	3.59	3.19	5.08	4.03	3.05	3.76	2.95	4.63
	2010-11	0.50	0.90	0.99	1.83	2.57	2.83	3.00	3.18	2.86	3.08	3.68	3.80	3.67	3.78	2.47	3.67	3.75	3.30	3.11	2.65	3.00	2.17
	2011-12	1.10	0.30	0.24	0.06	0.62	0.42	0.82	1.23	1.06	1.33	1.53	1.79	2.34	2.22	2.41	2.10	2.28	2.62	2.90	3.10	2.44	2.67
	Average	0.84	0.78	0.88	1.24	1.97	1.91	2.72	2.86	3.04	2.99	3.16	3.18	3.31	3.22	2.74	2.94	3.48	3.43	2.79	2.68	2.47	2.89
Thrips tabaci (no./3 leaves)	2008-09	2.10	1.56	0.80	2.80	2.38	2.14	3.10	3.24	3.10	2.01	2.10	2.22	1.05	1.20	0.50	1.10	0.60	1.20	1.23	1.56	2.00	1.55
	2009-10	3.55	3.10	4.20	2.56	3.22	3.78	3.80	3.34	2.76	1.71	2.05	1.89	1.91	2.00	1.81	1.78	2.28	2.34	2.13	2.21	1.90	1.57
	2010-11	1.24	2.10	0.89	2.36	2.11	2.06	1.99	2.01	1.71	1.71	1.80	1.71	1.87	1.57	1.10	1.64	1.73	1.46	1.54	0.68	1.36	0.11
	2011-12	0.60	2.97	0.84	2.61	2.31	1.23	2.35	3.17	3.55	3.48	3.29	2.57	2.30	2.34	1.90	1.44	1.24	1.06	0.77	0.80	1.20	0.80
	Average	1.87	2.43	1.68	2.58	2.51	2.30	2.81	2.94	2.78	2.23	2.31	2.10	1.78	1.78	1.33	1.49	1.46	1.52	1.42	1.31	1.62	1.01
Plants infested by *Aphis gossypii* (%)	2008-09	3.00	2.00	1.20	1.20	2.10	1.15	1.10	1.20	1.10	1.20	0.00	0.00	0.00	19.00	2.30	1.79	2.10	1.50	30.21	21.25	20.10	10.10
	2009-10	2.00	1.00	1.20	1.10	1.20	2.30	3.60	0.00	0.20	0.50	2.15	2.12	1.12	2.30	2.30	1.56	1.23	2.30	13.10	20.10	25.10	23.10
	2010-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00	20.00	21.00	18.00	12.20	15.40	12.30	16.00	21.00	45.50	31.20	23.30
	2011-12	0.00	0.00	0.00	0.00	0.00	8.10	3.56	9.80	9.80	8.80	10.10	12.10	12.10	32.10	45.50	35.40	21.40	20.40	20.10	20.40	32.50	23.60
	Average	1.25	0.75	0.60	0.58	0.83	2.89	2.07	2.75	2.78	2.63	6.81	8.56	8.56	17.85	15.58	13.54	9.26	10.05	21.10	26.81	27.23	20.03
Phenococcus solenopsis incidence (0-4 grade)	2008-09	0.00	0.00	0.00	1.20	1.56	1.29	1.25	1.10	2.56	2.79	2.21	2.20	2.24	2.20	3.71	3.24	3.78	3.24	3.10	3.30	2.31	2.24
	2009-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.22	0.12	0.20	0.20	0.25	0.60	1.24	1.15	2.15	2.10	3.80	2.10	2.10
	2010-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.22	0.10	0.23	0.01	0.30	0.45	0.55	1.12	0.00	0.20	0.21	0.00	0.00
	2011-12	0.00	0.00	0.56	0.21	0.23	0.12	1.12	1.15	0.12	0.56	0.48	0.78	0.09	0.80	0.23	0.26	0.47	0.20	0.23	0.50	1.24	2.80
	Average	0.00	0.00	0.14	0.35	0.45	0.35	0.59	0.56	0.75	0.95	0.73	0.85	0.64	0.89	1.25	1.32	1.63	1.40	1.41	1.95	1.41	1.79
Helicoverpa armigera Larva/plant	2008-09	0.00	0.00	0.08	0.07	0.04	0.00	0.00	0.00	0.00	0.25	0.19	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2009-10	0.00	0.00	0.08	0.06	0.05	0.00	0.00	0.02	0.26	0.09	0.17	0.10	0.14	0.13	0.10	0.10	0.16	0.07	0.10	0.14	0.07	0.09
	2010-11	0.00	0.00	0.04	0.10	0.07	0.07	0.06	0.08	0.07	0.07	0.09	0.08	0.08	0.08	0.04	0.08	0.08	0.08	0.06	0.03	0.07	0.01
	2011-12	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average	0.00	0.00	0.05	0.06	0.04	0.02	0.02	0.04	0.09	0.10	0.11	0.07	0.06	0.05	0.04	0.05	0.06	0.04	0.04	0.04	0.04	0.03
Earias vittella Larva/plant	2008-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2009-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.04	0.09	0.07	0.09	0.11	0.05	0.09	0.08	0.10	0.06	0.06	0.08	0.08

Contd.

Table 1 *Continued*

Pest	Year	Standard Meteorological Week																						
		31 July	32 Aug.	33 Aug.	34 Aug.	35 Aug.	36 Sep.	37 Sep.	38 Sep.	39 Sep.	40 Oct.	41 Oct.	42 Oct.	43 Oct.	44 Oct.	45 Nov.	46 Nov.	47 Nov.	48 Nov.	49 Dec.	50 Dec.	51 Dec.	52 Dec.
	2010-11	0.00	0.00	0.01	0.07	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.06	0.06	0.06	0.03	0.05	0.05	0.05	0.04	0.03	0.04	0.01
	2011-12	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00
	Average	0.00	0.00	0.00	0.02	0.01	0.01	0.01	0.01	0.08	0.03	0.03	0.03	0.04	0.05	0.02	0.04	0.04	0.04	0.03	0.03	0.03	0.02
Pectinophora	2008-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.06
gossypiella	2009-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.03	0.01
Larva/plant	2010-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.02	0.00	0.05	0.00
	2011-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.08	0.90	0.50
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.02	0.03	0.26	0.14
Spodoptera.	2008-09	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.30	0.07	0.01	0.01	0.01	0.20	0.10	0.10	0.02	0.02	0.01	0.10
litura	2009-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.28	0.06	0.33	0.08	0.13	0.13	0.11	0.13	0.34	0.16	0.17	0.20	0.11	0.15
Larva/plant	2010-11	0.00	0.00	0.02	0.06	0.06	0.06	0.05	0.08	0.07	0.07	0.08	0.09	0.17	0.10	0.08	0.09	0.10	0.08	0.07	0.04	0.06	0.01
	2011-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
	Average	0.00	0.05	0.01	0.02	0.02	0.02	0.01	0.07	0.09	0.05	0.18	0.06	0.08	0.06	0.05	0.11	0.14	0.09	0.07	0.07	0.05	0.07

10, the pest activity started from 4th week of July and reached its peak (4.20/3 leaves) in 2nd week of August and population decreased thereafter. During year 2010-11, the pest activity started from 4th week of July and highest population was recorded on 3rd week of August (2.36/3 leaves) and population decreased thereafter. During year 2011-12, the pest started building up from 4th week of July and increased gradually in subsequent weeks and reached highest population 3.55/3 leaves on 4th week September and it decreased thereafter. The average data of four years indicate that pest population started from 4th week of July and reached its peak 2.94/3 leaves on 3rd week of September and then decreased in subsequent weeks.

Thrips population showed (Table 3) significant positive correlation with maximum (r=0.635) and minimum temperature (r=0.632) and morning (r=0.708) and evening relative humidity (r=0.688) whereas significant negative correlation with sunshine hours (r=-0.533). Shivana *et al.* (2009) observed positive correlation of the maximum temperature with population of cotton thrips.

Aphis gossypii

The data on per cent plants infested by *A. gossypii* during year 2008-09 indicates that pest population started from 4th week of July and reached peak 30.21 per cent on 1st week of December (Table 1). During year 2009-10, the population was recorded from 4th week of July to 4th week of December but peak period was observed during 3rd week of December, i.e. 25.10 per cent plants. During year 2010-11, the pest incidence started from 2nd week of October and reached peak 45.50 per cent in the 2nd week of December. During year 2011-12, the pest appeared from 1st week of September and reached peak 45.50 per cent on 1st week of November and population started declined thereafter. The average data of four years indicate that the pest population appeared from 4th week of July and found throughout the year however its peak period was observed during 3rd week of December, i.e. 27.23 per cent. Hanumantharaya *et al.* (2008) and Godhani *et al.* (2009) found population of *A. gosypii* throughout the cotton growth period which support the present investigation.

Aphid population showed (Table 3) significant positive correlation with sunshine hours (r=0.756) and significant negative correlation with minimum temperature (r=-0.761), morning (r=-0.943) and evening relative humidity (r=-0.787) and rainfall (r=-0.554). Prasad *et al*. (2008) also observed the significant negative association of aphid population with minimum temperature, relative humidity at morning and evening and rainfall.

Phenococcus solenopsis

During year 2008-09, the mealy bug population appeared from 3rd week of August and increased thereafter and reached peak 3.78 grades on 3rd week of November (Table 1). During year 2009-10, the pest appeared from 4th week of September and increased thereafter and reached peak 3.80 grades on 2nd week of December. Again during

Table 2 Mean densities of natural enemies on Bt cotton in different villages of Rajkot district (2008-2011)

Natural enemies	Year	Standard Meteorological Week																				
		31 July	32 Aug.	33 Aug.	34 Aug.	35 Aug.	36 Sep.	37 Sep.	38 Sep.	39 Sep.	40 Oct.	41 Oct.	42 Oct.	43 Oct.	44 Oct.	45 Nov.	46 Nov.	47 Nov.	48 Nov.	49 Dec.	50 Dec.	51 Dec.	52 Dec.
Coccinellid/ plant	2008-09	0.20	0.10	0.26	0.35	0.36	0.20	0.10	0.40	0.60	0.29	0.50	0.78	0.50	0.40	0.36	0.25	0.26	0.29	0.30	0.10	0.20	0.20
	2009-10	0.10	0.05	0.23	0.56	0.50	0.10	0.20	0.07	0.71	0.67	0.94	0.77	0.69	0.91	0.27	0.65	0.39	0.24	0.49	0.46	0.31	0.30
	2010-11	0.10	0.05	0.04	0.27	0.48	0.53	0.35	0.40	0.45	0.39	0.31	0.34	0.42	0.42	0.35	0.42	0.59	0.41	0.39	0.20	0.52	0.03
	2011-12	0.23	0.08	0.03	0.03	0.01	0.05	0.04	0.11	0.16	0.12	0.20	0.14	0.15	0.14	0.13	0.16	0.12	0.12	0.17	0.10	0.26	0.05
	Average	0.16	0.07	0.14	0.30	0.34	0.22	0.17	0.25	0.48	0.37	0.49	0.51	0.44	0.47	0.28	0.37	0.34	0.27	0.34	0.22	0.32	0.15
Chrysopid egg/plant	2008-09	0.09	1.20	1.30	1.05	1.20	2.10	0.80	0.90	2.53	3.21	4.56	6.58	7.21	3.50	8.10	2.30	2.40	2.10	3.25	3.48	3.21	2.10
	2009-10	0.20	0.10	1.02	1.05	1.20	1.11	1.20	7.53	3.72	2.62	2.68	2.74	2.49	3.06	2.75	2.43	2.97	3.43	2.25	3.16	3.85	4.20
	2010-11	0.00	0.20	1.34	1.04	1.15	1.06	0.95	1.36	1.11	1.22	1.12	1.14	1.45	1.31	1.09	1.32	1.45	1.94	1.76	1.95	1.57	2.58
	2011-12	0.08	0.38	0.09	0.05	0.00	0.12	0.03	0.09	0.14	0.08	0.08	0.10	0.10	0.11	0.10	0.11	0.09	0.07	0.11	1.50	1.20	1.29
	Average	0.09	0.47	0.94	0.80	0.89	1.10	0.75	2.47	1.88	1.78	2.11	2.64	2.81	2.00	3.01	1.54	1.73	1.89	1.84	2.52	2.46	2.54
Spider/plant	2008-09	0.20	1.20	0.30	0.50	0.60	0.75	0.30	0.20	0.10	0.22	0.29	0.31	0.32	0.25	0.29	0.50	0.26	0.40	0.40	0.26	0.21	0.29
	2009-10	2.10	3.11	0.50	3.50	2.10	1.20	2.10	0.24	0.59	0.44	0.96	0.39	0.43	0.46	0.40	0.34	0.23	0.45	0.33	0.44	0.66	0.50
	2010-11	0.06	0.06	0.52	0.38	0.43	0.41	0.34	0.42	0.50	0.60	0.38	0.45	0.48	0.48	0.48	0.46	0.44	0.46	0.43	0.44	0.64	0.43
	2011-12	0.15	0.14	0.06	0.04	0.05	0.11	0.06	0.14	0.18	0.18	0.20	0.26	0.28	0.29	0.27	0.28	0.33	0.32	0.30	1.24	1.25	1.29
	Average	0.63	1.13	0.35	1.11	0.80	0.62	0.70	0.25	0.34	0.36	0.46	0.35	0.38	0.37	0.36	0.40	0.32	0.41	0.37	0.60	0.69	0.63

year 2010-11, the pest appeared from 4th week of September however reached its peak 1.12 grades on 3rd week of November. During year 2011-12, the pest appeared from 2nd week of August and remained present in more or less throughout the season however its peak was observed on 4th week of December, i e 2.80 grades. The average data of four years shows that pest appeared from 2nd week of August and reached its peak 1.95 grades on 2nd week of December. Vennila *et al*. (2010) also recorded the severity of *P. solenopsis* during month of November, which supports the present investigation.

P. solenopsis showed (Table 3) significant positive association sunshine hours (r=0.855) and significant negative association with maximum (r= -0.633) and minimum temperature (r=-0.700), morning (r= -0.803) and evening relative humidity (r= -0.774) and rainfall (r=-0.546). Dhavan *et al.* (2009) also reported negative impact of humidity and rainfall on mealy bug population in Bt cotton.

Bollworm complex

The average mean data of four years reveal that amongst bollworms, the *H. armigera* larva was found between 0.02 to 0.11 per plant, the *E. vittella* was found between 0.01 to 0.08 per plant, the *P. gossypiella* larva was found from 3rd week of November to 4th week of December in a range of 0.01 to 0.26 per plant and *S. litura* larva appeared from 1st week of August and reached its peak 0.18 per plant on 2nd week of October and found throughout season below its peak point in subsequent weeks (Table 1).

Amongst bollworms (Table 3), *H. armigera* showed significant negative correlation with rainfall (r=0.542). *E. vittella* showed significant negative correlation with rainfall (r=0.610) and positive significant correlation with sunshine hours (r=0.602). *S. litura* also showed significant negative correlation with rainfall (r=0.631) and positive correlation with sunshine hours (r=0.619). *P. gossypiella* showed significant negative correlation with maximum (r=0.803) and minimum temperature (r=0.758) and morning (r=0.649) and evening relative humidity (r=0.701).

Population dynamics and correlation of natural enemies with weather factors on Bt cotton

The average mean data of four years reveal that coccinellid (grub + adult) population was found throughout season from 4th week of July to 4th week of December between 0.07 to 0.51 per plant, the peak period of coccinellid 0.51 per plant was observed on 3rd week of October. Chrysopid eggs (green coloured) were found higher in number throughout the season comparing to coccinellid and spider (Table 2). The peak period of chrysopid (3.01 per plant) was observed in the 1st week of November and it decreased thereafter. The spider population was also observed throughout the season between 0.25 to 1.13 per plant. The peak of spider population was observed in the 1st week of August (1.13 per plant). Sana *et al.*(2011) reported the highest activity of coccinellid and spider during August month which is comparable with this investigation as both

Table 3 Correlation of insect pests and some of their natural enemies on Bt cotton with weather parameters

Name	Temperature (°C)		Relative humidity (%)		Sunshine	Rainfall
	Max.	Min.	Morning	Evening	hours	mm
Amrasca biguttula biguttula (no./3 leaves)	–0.120	0.308	–0.012	0.129	0.516*	–0.672**
Bemisia tabaci (no./3 leaves)	–0.228	–0.138	–0.412	–0.279	0.796**	–0.560*
Thrips tabaci (no./3 leaves)	0.635**	0.632**	0.708**	0.688**	–0.533*	0.292
Plants infested by *Aphis gossypii* (%)	–0.407	–0.761**	–0.943**	–0.787**	0.756**	–0.554*
Phenococcus solenopsis incidence (0-4 grade)	–0.633**	–0.700**	–0.803**	–0.774**	0.855**	–0.546*
Helicoverpa armigera Larva/plant	0.155	0.268	0.009	0.080	0.341	–0.542*
Earias vittella Larva/plant	–0.233	–0.078	–0.409	–0.324	0.602**	–0.610**
Pectinophora gossypiella Larva/plant	–0.803**	–0.758**	–0.649**	–0.701**	0.384	–0.200
Spodoptera. litura Larva/plant	–0.342	–0.073	–0.248	–0.193	0.619**	–0.631**
Coccinellid/plant	0.111	0.275	–0.178	–0.062	0.378	–0.537*
Chrysopid egg/plant	0.055	–0.309	–0.580**	–0.455*	0.822**	–0.693**
Spider/plant	0.111	–0.064	0.178	0.108	–0.597**	0.465*

*Significant at 0.05 level (r=0.44), ** significant at 0.01 level (r=0.561)

of these natural enemies were recorded during this month in present research.

Coccinellid showed (Table 3) significant negative correlation with rainfall (r=0.537). Chrysopid showed significant positive correlation with sunshine hours (r=0.822) and significant negative correlation with rainfall (r=0.693) and morning (r=0.580) & evening relative humidity (r=0.455). Spiders showed significant negative correlation with sunshine hours (r=0.597) and significant positive correlation with rainfall (r=0.465). Dhaka and Pareek (2007) reported negative significant effect of maximum and minimum temperature on chrysopid population and positive effect of maximum and minimum temperature on spider population.

The present study shows that sucking pests are the major problem of Bt cotton. The sucking pests like aphid, jassid, whitefly and thrips were found damaging the cotton crop throughout the growth period of Bt cotton. *A.biguttula biguttula* incidence was observed from 4th week of July and reached peak during 4th week of September, *B. tabaci* was observed from 4th week of July and its activity peaked in 3rd week of November, *T.tabaci* was observed from 4th week of July and reached its peak during 3rd week of September and *A. gossypii* population was observed from 4th week of July and reached peak 3rd week of December. Mealy bug, *P. solenopsis* appeared from 2nd week of August and reached its peak on 2nd week of December. Among bollworms, in general the population of *P. gossypiella* was high as compared to *H.armigera, E. vittella* and *S. litura* being active from August to December. Among natural enemies, the chrysopid , *C.z. sellimi* was found higher than spiders and coccinellids. The coccinellids were found between 0.07 to 0.51 per plant throughout the season, the chrysopid eggs were also found throughout the season however their peak period 3.01 per plant was observed on 1st week of November and the peak of spider population was observed on 1st week of August 1.13 per plant. The Correlation with weather factors showed that jassid population found significant positive correlation with sunshine hours and significant negative correlation with rainfall. *B. tabaci* found significant positive correlation with sunshine hours and significantly negative correlation with rainfall. Thrips population showed significant positive correlation with maximum and minimum temperature and morning and evening relative humidity whereas significant negative correlation with sunshine hours. Aphid population showed significant positive correlation with sunshine hours and significant negative correlation with minimum temperature, morning and evening relative humidity and rainfall. *P. solenopsis* showed significant positive association sunshine hours and significant negative association with maximum and minimum temperature, morning and evening relative humidity and rainfall. Amongst bollworms, *H. armigera* showed significant negative correlation with rainfall. *E. vittella* also showed significant negative correlation with rainfall and positive significant correlation with sunshine hours. *S. litura* also showed significant negative correlation with rainfall and positive correlation with sunshine hours. *P. gossypiella* showed significant negative correlation with maximum and minimum temperature and morning and evening relative humidity. Coccinellid showed significant negative correlation with rainfall. Chrysopid found significant positive correlation with sunshine hours and significant negative correlation with rainfall and morning and evening relative humidity. Spiders showed significant negative correlation with sunshine hours and significant positive correlation with rainfall.

REFERENCES

Ashfaq M, Muhammad Noor Ul Ane, Khuram Zia, Abida Nasreen and Mansoor –Ul-Hasan.2010.The correlation of abiotic factors and physico-morphic characteristic (*Bacillus thuringiensis*) transgenic cotton with white fly, *Bemisia tabaci* (Homoptera:Aleyrodidae) and jassid, *Amrasca devastans* (Homoptera: Jassidae) populations. *African Journal of*

Agricultural Research **5**(22) : 3 102–7.

Bashir M H, Afzal M, Sabri M A and Raza A B M. 2001. Relationship between sucking insect pests and physic-morphic plant characters towards resistance/susceptibility in some new genotypes of cotton. *Pakistan Entomology* **23**(1-2) : 75–8.

Dhaka, Shish Ram and Pareek, Bhanwar Lal. 2007.Seasonal incidence of natural enemies of key insect pests of cotton and their relationship with weather parameters. *Journal of Plant Protection Research* **47** (4) : 417–23.

Dhavan A K, Karnaldeep S A and Sarika S. 2009. Distribution of mealy bug, *Phenococcus solenopsis* Tinsley in cotton with relation to weather factors in south-western districts of Punjab. *Journal of Entomological Research* **33**(1) : 59–63.

Godhani P H, Patel R M, Jani J J, Yadav D N, Korat D M and Patel B H.2009.Impact of habitat manipulation on insect pests and their natural enemies in hybrid cotton. *Karnataka Journal of Agricultural Science* **22**(1) : 104–7.

Hanumantharaya L, Goud K B and Naik L K.2008.Use of green lacewing, *Chrysoperla carnea* (Stephens) and neem seed kernel extract for management of insect pests on cotton. *Karnataka Journal of Agricultural Science* **21**(1) : 41–4.

Kabaria B B, Saradava D A and Muchhadiya D V. 2013. A Decade of Bt cotton-Socio-economic impact of Bt cotton in Rajkot district (Gujarat). Krishi Vigyan Kendra, Junagadh Agricultural University, Targhadia, Rajkot.

Prasad N V V S D, Rao N H P. and Mahalakshmi M S 2008. Population dynamics of major sucking pests infesting cotton and their relation to weather parameters. *Journal of Cotton Research and Development* **22** (1) : 85–90.

Shivanna B K, Nagaraja D N, Manjunatha M. and Naik M I. 2009. Seasonal incidence of sucking pests on transgenic Bt cotton and correlation with weather factors. *Karnataka Journal of Agricultural Science* **22**(3): 666–7.

Sana Ashfaq, Imtiaz Ali Khan, Muhammad Saeed, Ahmad Ur Rahman Saljoqi, Farkhanda Manzoor, Kamran Sohail, Komal Habib and Amna Sadozai.2011. Population dynamics of insect pests of cotton and their natural enemies. *Sarhad Journal of Agriculture* **27**(2) : 521–3.

Venilla S, Ramamurthy V V, Deshmukh A, Pinjarkar D B, Agarwal M, Pagar P C, Prasad Y G, Prabhakar M, Kranthi K R and Bambawale O M.2010. *A treatise on mealybugs of central Indian cotton production system*. Technical Bulletin no. 24, National Centre for Intergrated Pest Management, New Delhi, p 39.