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Population dynamics of natural enemies on *bt* / non *bt* cotton and their correlation with weather parameters

Roomi Rawal[1]*, K. K. Dahiya[1], Roshan Lal[1] and Adesh Kumar[2]

[1]Department of Entomology, CCS Haryana Agricultural University, Hisar-125001 (Haryana), INDIA
[2]Punjab Agricultural University, Fruit Research Station, Jallowal- Lesriwal, Jalandhar-144303 (Punjab), INDIA
*Corresponding author. E-mail: roomi.rawal78@gmail.com

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Abstract: The field study was carried out at Research Farm of cotton section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar, India to determine the effect of environmental factors and seven cotton genotypes (*Bt* and non *Bt*) on three natural enemies namely chrysoperla, coccinellids beetle and spiders. Natural enemies remained active throughout the crop season (with two peaks) with little differences among them. Chrysoperla and coccinellids both were remained active from 25th to 40th SMW (June to October, 2014) while spiders were active from 25th to 41st. It was observed that highest population of Chrysoperla (1.17 eggs/plant) and spiders (1.59 adult/plant) was observed on *Bt* cotton cultivar namely RCH-134 and JK-1947 respectively. However, coccinellids preferred non *Bt* genotype (HHH-223) for their population build-up. Chrysoperla and coccinellids population was significantly negatively correlated with maximum temperature (r = -0.527 at 5% and r = -0.626 at 1% respectively); positively correlated with RHm, RHe; negatively correlated with minimum temperature and wind speed without significance.While, spiders population showed negative correlation with all weather parameters except sunshine hours. It was observed that population of the natural enemies fluctuated under different environmental conditions during cotton season.

Keywords: Cotton, Natural enemies, Population dynamics, Weather parameters

INTRODUCTION

Cotton, *Gossypium hirsutum* L. (Family Malvaceae), is important commercially fiber crop in the world and grown in both tropical and warm temperate regions. Cotton production in India is severely hampered by 162 species of insect-pests, these attack on crop from sowing to maturity, which cause up to 10-30 per cent loss with Rs. 260000 million per year (Anonymous, 2014). Vast group of cotton pests is separated in two groups bollworms and sucking pests. Among sucking pests, aphid, *Aphis gossypii* (Glover), leafhoppers, *Amrasca biguttula biguttula* (Ishida), thrips, *Thrips tabaci* (Lind.) and whitefly, *Bemisia tabaci* (Genn.) have major importance. These sucking pests infect the crop at all the growth stages and responsible for indirect yield losses. A reduction of 22.85 per cent in seed cotton yield due to sucking pests (*Aphis gossypii*, *Amrasca biguttula biguttula, Thrips tabaci* and *Bemisia tabaci*) has been reported by Satpute *et al.* (1990).

Biological control has considered a reliable and long term solution of the insect pest problems due to self-perpetuating nature and environment friendly tactic (Bale *et al*., 2008). However, gradually more intensive farming strongly influences the population dynamics of insect natural enemies. *Bt* cotton is cultivated extensively and preferred by farmers due to higher production potential, less dependence on insecticides and targeted control of specific lepidopterous pests (Arshad and Suhail, 2011; Arshad *et al*., 2015). Population of natural enemies might be reduced due to high expression level of *Bt* genes because pest population reduced 100%, which is important for natural enemies survival (Schuler, 2000). The ultimate aim of this study is to estimate the population dynamics of natural enemies on different cotton cultivars (*Bt* and non *Bt* cotton) and role of environment to fluctuate the population of natural enemies.

MATERIALS AND METHODS

In this study, we evaluated the effect of environment and cotton germplasm on natural enemies' population under natural condition. The experiment was conducted at Cotton Research Farm, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University Hisar, India, during the cotton seasons 2014. Experiment was laid out in a randomized block design (RBD) with three replications. The cotton crop grown followed by package and practices and under unsprayed condition (Anonymous, 2008). Seven genotypes were grown in the field with plot size 5.4m x 4.5m, the row to-row and plant-to-plant distance was 67.5 cm and 60 cm, respectively (Anonymous, 2008). Among the genotypes, five were with *Bt* gene con-

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struct *viz.* Bio Seed-6588, NECH-6, JK-1947, SP-7007 and RCH-134. Two genotypes namely HHH-223 and H-1236 belonged to non *Bt* cotton.

Observation: Population of natural enemies were initiated at 20 days after of sowing the crop and continued till maturity of crop by following the beat-bucket method developed by Knutson and Wilson (1999). In this method, cotton plants shacked inside a white plastic bucket of 10 inches deep. The top 10 inches of cotton plant was placed inside the bucket and five separate, rapid jerks were given from side to side and predators were counted in the bottom of the bucket. Data was observed early in the morning at weekly intervals, of five randomly selected plants in each replication of each treatment for counting the natural enemies population. Meteorological data was collected from the Department of Agricultural Meteorology, Chaudhary Charan Singh Haryana Agricultural University, Hisar to correlate the population of natural enemies with the weather parameters. The data recorded during the field experiment was got computed for analysis of variance by using method published by Panse and Sukhatme (1995).

RESULTS AND DISCUSSION

Chrysoperla zastrowi sillemi

Population of *Chrysoperla zastrowi sillemi* on different cotton genotype: *C. zastrowi sillemi* (Esben-Peterson) is a potential predator against variety of soft bodied insects. It is used in biological control programme widely acknowledged (Geetha and Swamiappan 1998; Maher *et al.* 1983; Mannan *et al.* 1995; Souliotis 1999). Overall mean values for the population of *C. zastrowi sillemi* on different genotypes of cotton being tested is shown in the Table 1. The maximum average eggs population of *C. zastrowi sillemi* was found on two *Bt* genotypes namely RCH-134 (1.17 eggs /plant) and BIOSEED-6588 (1.04 eggs/ plant). The minimum eggs population was 0.71 eggs/ plant on NECH-6 and other have 0.85, 0.84, 0.84 and 0.74 eggs/plant, on JK-1947, SP-7007, HHH-223 and H-1236 respectively. Wan *et al.* (2002) support the present study that the population dynamics of predators *Chrysoperla spp.* were higher in numbers (49) while, it was reduced 5.8% in conventional cotton fields. However, Hegde *et al.* (2004) observed no difference in the population of *Chrysoperla* and coccinellids between *Bt,* non-*Bt* and local hybrids of cotton.

Population movement of *C. zastrowi sillemi* throughout the year: The results on intermittent fluctuation of *C. zastrowi sillemi* on cotton are presented in Table 1. Data indicates that the natural enemy remained active on the crop throughout the period of study *i.e.* from 25th to 40th standard meteorological weeks (SMW) (*i.e.* June to October, 2014). Population increased slowly and reached to its peak in 29th SMW

Table 1. Population of *Chrysoperla zastrowi sillemi* in *Bt* and non-*Bt* cotton genotypes during *kharif* 2014.

Genotypes	Mean population of *Chrysoperla zastrowi sillemi* during different periods of observation (eggs/plant) Standard Meteorological Weeks																Mean
	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	
BIOSEED-6588	0.16 (1.07)	0.20 (1.09)	0.37 (1.17)	0.40 (1.18)	1.30 (1.51)	1.07 (1.44)	1.08 (1.44)	0.95 (1.39)	0.98 (1.41)	1.97 (1.72)	1.22 (1.49)	1.09 (1.44)	0.87 (1.36)	1.83 (1.68)	2.17 (1.78)	0.97 (1.39)	1.04
NECH-6	0.07 (1.04)	0.12 (1.06)	0.63 (1.29)	0.67 (1.25)	1.50 (1.58)	0.81 (1.34)	0.56 (1.25)	0.88 (1.37)	0.60 (1.26)	0.50 (1.22)	0.88 (1.37)	0.42 (1.18)	0.43 (1.19)	1.25 (1.49)	1.32 (1.52)	0.80 (1.34)	0.71
JK-1947	0.13 (1.06)	0.19 (1.09)	0.54 (1.26)	0.80 (1.34)	1.49 (1.57)	0.53 (1.23)	1.05 (1.43)	0.82 (1.34)	0.53 (1.23)	0.80 (1.34)	1.33 (1.52)	0.86 (1.35)	0.65 (1.28)	1.26 (1.50)	1.44 (1.56)	1.24 (1.49)	0.85
SP-7007	0.12 (1.05)	0.19 (1.09)	0.17 (1.08)	0.60 (1.24)	1.51 (1.58)	1.13 (1.46)	1.12 (1.45)	1.02 (1.42)	0.98 (1.41)	1.40 (1.55)	1.54 (1.60)	0.52 (1.23)	0.32 (1.15)	1.03 (1.43)	1.21 (1.48)	0.65 (1.28)	0.84
RCH-134	0.20 (1.09)	0.35 (1.16)	0.60 (1.26)	0.40 (1.18)	1.96 (1.72)	2.36 (1.83)	0.78 (1.33)	1.02 (1.42)	1.63 (1.62)	0.57 (1.25)	1.53 (1.59)	1.42 (1.55)	1.43 (1.56)	1.43 (1.56)	2.17 (1.78)	0.93 (1.36)	1.17
HHH-223	0.12 (1.06)	0.40 (1.18)	0.20 (1.09)	0.73 (1.31)	1.55 (1.59)	0.93 (1.38)	1.12 (1.45)	1.12 (1.45)	0.72 (1.31)	0.93 (1.38)	0.87 (1.37)	0.97 (1.40)	0.65 (1.28)	1.12 (1.46)	1.30 (1.53)	0.75 (1.32)	0.84
H-1236	0.07 (1.04)	0.24 (1.11)	0.17 (1.08)	0.70 (1.29)	1.59 (1.61)	0.47 (1.21)	0.53 (1.23)	0.88 (1.38)	0.85 (1.35)	0.98 (1.40)	0.64 (1.28)	0.84 (1.36)	0.98 (1.40)	0.99 (1.41)	1.08 (1.43)	0.77 (1.33)	0.74
Mean	0.12	0.24	0.38	0.61	1.56	1.04	0.89	0.96	0.90	1.02	1.14	0.87	0.76	1.27	1.53	0.87	0.89
SE(m)±	(0.05)	(0.07)	(0.05)	(0.11)	(0.08)	(0.10)	(0.05)	(0.07)	(0.07)	(0.06)	(0.06)	(0.08)	(0.05)	(0.05)	(0.07)	(0.11)	
CD(P=0.05)	(N.S.)	(N.S.)	(0.17)	(N.S.)	(N.S.)	(0.23)	(0.18)	(N.S.)	(0.21)	(0.21)	(0.17)	(N.S.)	(0.16)	(0.16)	(0.19)	(N.S.)	

*Figures in parentheses are √n+1 transformed values

Table 2. Population of Coccinellids in *Bt* and non- *Bt* cotton genotypes during *kharif* 2014 .

Genotypes	Mean population of Coccinellids during different periods of observation (adults/plant) Standard Meteorological Weeks																
	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	Mean
BIOSEED-6588	0.14	0.25	2.48	1.25	0.48	0.93	1.43	2.21	1.86	0.27	1.42	1.90	1.40	2.97	2.43	0.74	1.38
	(1.07)	(1.11)	(1.85)	(1.49)	(1.21)	(1.34)	(1.53)	(1.77)	(1.67)	(1.13)	(1.55)	(1.68)	(1.53)	(1.98)	(1.85)	(1.32)	
NECH-6	0.13	0.42	2.37	1.15	0.21	0.70	1.20	1.24	1.17	0.53	2.27	1.40	1.70	1.13	1.47	0.84	1.12
	(1.06)	(1.18)	(1.83)	(1.46)	(1.10)	(1.29)	(1.48)	(1.48)	(1.45)	(1.23)	(1.80)	(1.52)	(1.61)	(1.45)	(1.57)	(1.36)	
JK-1947	0.00	0.46	3.57	0.72	0.35	0.48	0.98	1.08	1.76	0.40	1.44	1.65	1.22	1.99	1.92	0.96	1.19
	(1.00)	(1.21)	(2.13)	(1.31)	(1.16)	(1.21)	(1.40)	(1.43)	(1.64)	(1.18)	(1.56)	(1.62)	(1.48)	(1.71)	(1.71)	(1.40)	
SP-7007	0.13	0.25	1.24	0.30	0.57	0.30	0.62	0.82	0.93	0.71	2.10	1.88	2.05	2.11	1.84	0.96	1.05
	(1.06)	(1.11)	(1.50)	(1.14)	(1.24)	(1.13)	(1.27)	(1.35)	(1.38)	(1.30)	(1.77)	(1.69)	(1.74)	(1.75)	(1.68)	(1.39)	
RCH-134	0.15	0.68	2.24	0.82	0.18	1.40	1.90	2.16	1.74	0.40	2.09	1.52	1.58	1.54	1.34	0.60	1.25
	(1.07)	(1.29)	(1.80)	(1.35)	(1.08)	(1.52)	(1.70)	(1.78)	(1.65)	(1.21)	(1.75)	(1.57)	(1.59)	(1.59)	(1.53)	(1.26)	
HHH-223	0.98	0.38	4.02	2.48	0.37	1.50	2.00	2.60	1.18	0.80	2.85	2.20	2.16	4.12	3.20	1.77	2.06
	(1.38)	(1.17)	(2.24)	(1.86)	(1.16)	(1.55)	(1.73)	(1.89)	(1.47)	(1.34)	(1.96)	(1.78)	(1.78)	(2.26)	(2.05)	(1.66)	
H-1236	0.07	0.43	0.98	0.38	0.26	1.70	2.79	1.43	1.56	0.27	1.69	1.90	0.97	1.32	1.05	0.53	1.08
	(1.08)	(1.19)	(1.41)	(1.17)	(1.12)	(1.62)	(1.95)	(1.55)	(1.59)	(1.13)	(1.63)	(1.70)	(1.39)	(1.52)	(1.43)	(1.24)	
Mean	0.23	0.41	2.41	1.01	0.35	1.00	1.56	1.65	1.46	0.48	1.98	1.78	1.58	2.17	1.89	0.91	1.31
SE(m)±	(0.08)	(0.08)	(0.08)	(0.07)	(0.07)	(0.12)	(0.09)	(0.08)	(0.10)	(0.04)	(0.08)	(0.14)	(0.13)	(0.14)	(0.04)	(0.07)	
CD(P=0.05)	(N.S.)	(N.S.)	(0.26)	(0.23)	(N.S.)	(N.S.)	(0.27)	(0.26)	(N.S.)	(0.14)	(0.23)	(N.S.)	(N.S.)	(0.44)	(0.13)	(0.23)	

*Figures in parentheses are √n+1 transformed values.

Table 3. Population of spiders in *Bt* and non- *Bt* cotton genotypes during *kharif* 2014.

Genotypes	Mean population of spiders during different periods of observation (adults/plant) Standard Meteorological Weeks																	
	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	Mean
BIOSEED-6588	0.25	0.80	1.90	1.67	1.44	0.54	0.73	0.67	1.27	0.78	3.10	0.88	1.47	1.45	1.84	2.32	1.76	1.35
	(1.12)	(1.34)	(1.70)	(1.62)	(1.56)	(1.24)	(1.31)	(1.29)	(1.51)	(1.33)	(1.54)	(1.37)	(1.57)	(1.56)	(1.68)	(1.82)	(1.66)	
NECH-6	0.20	0.67	0.46	0.95	0.89	1.11	0.93	1.13	0.46	1.47	2.90	0.66	1.43	1.89	1.87	2.41	1.79	1.25
	(1.09)	(1.28)	(1.21)	(1.40)	(1.37)	(1.45)	(1.39)	(1.46)	(1.21)	(1.56)	(1.37)	(1.28)	(1.56)	(1.70)	(1.69)	(1.84)	(1.65)	
JK-1947	0.09	0.76	1.60	2.00	2.20	0.98	1.07	0.80	0.67	0.60	3.90	0.65	1.89	2.63	1.60	2.90	2.80	1.59
	(1.04)	(1.32)	(1.61)	(1.73)	(1.78)	(1.39)	(1.44)	(1.34)	(1.29)	(1.26)	(1.78)	(1.28)	(1.70)	(1.86)	(1.61)	(1.98)	(1.94)	
SP-7007	0.13	0.56	0.88	1.00	0.99	0.34	1.07	0.87	0.67	1.25	1.90	0.97	1.00	0.79	1.47	1.86	1.87	1.04
	(1.06)	(1.25)	(1.37)	(1.39)	(1.41)	(1.15)	(1.43)	(1.37)	(1.29)	(1.50)	(1.40)	(1.40)	(1.41)	(1.34)	(1.57)	(1.69)	(1.68)	
RCH-134	0.08	0.98	1.70	0.97	1.1	0.44	0.94	1.27	0.80	0.80	2.40	0.65	2.13	2.44	1.87	2.54	0.76	1.27
	(1.03)	(1.40)	(1.64)	(1.41)	(1.43)	(1.21)	(1.39)	(1.50)	(1.34)	(1.34)	(1.44)	(1.28)	(1.77)	(1.85)	(1.69)	(1.88)	(1.32)	
HHH-223	0.13	0.67	0.77	0.93	0.99	0.45	0.88	0.80	0.87	0.87	2.50	0.10	1.43	1.44	1.87	2.11	1.65	1.08
	(1.06)	(1.29)	(1.33)	(1.39)	(1.41)	(1.20)	(1.38)	(1.34)	(1.34)	(1.37)	(1.41)	(1.01)	(1.60)	(1.56)	(1.69)	(1.76)	(1.63)	
H-1236	0.07	0.30	0.44	0.79	0.89	1.30	0.87	0.73	0.46	0.46	1.80	1.87	2.08	0.55	1.97	1.84	0.66	1.06
	(1.03)	(1.14)	(1.20)	(1.32)	(1.37)	(1.51)	(1.36)	(1.31)	(1.21)	(1.21)	(1.37)	(1.69)	(1.75)	(1.25)	(1.72)	(1.68)	(1.29)	
Mean	0.14	0.68	1.11	1.19	1.21	0.74	0.93	0.90	0.74	0.89	2.64	0.81	1.63	1.72	1.73	2.28	1.61	1.23
SE(m)±	(0.04)	(0.07)	(0.06)	(0.12)	(0.08)	(0.05)	(0.07)	(0.07)	(0.06)	(0.06)	(0.13)	(0.07)	(0.10)	(0.05)	(0.12)	(0.05)	(0.10)	
CD(P=0.05)	(N.S.)	(N.S.)	(0.20)	(N.S.)	(0.24)	(0.17)	(N.S.)	(N.S.)	(0.18)	(0.17)	(N.S.)	(0.22)	(N.S.)	(0.17)	(0.37)	(0.16)	(0.30)	

*Figures in parentheses are √n+1 transformed values

Table 4. Correlation of chrysoperla, coccinellids and spiders population with weather parameters.

Weather parameters	**Correlation coefficient (r value)**		
	C. zastrowi sillemi	**Coccinellids**	**Spiders**
Temperature max. (ºC)	-0.527*	-0.626**	-0.136
Temperature min. (ºC)	-0.408	-0.389	-0.394
Morning RH (%)	0.521*	0.547*	-0.041
Evening RH (%)	0.274	0.466	-0.225
Sunshine (hrs)	0.291	0.022	0.063
Rainfall (mm)	0.046	0.147	-0.214
Wind speed (Km/hr)	-0.372	-0.142	-0.440

*Significant at 5% ** Significant at 1%

(1.56 eggs/plant) and second peak was observed during 39th SMW (1.53 eggs/plant).The present finding are in line with the findings of Kedar (2014) who also found two closely related peaks on cotton, one on 31st and second was on 40th SMW with 1.4 and 1.6 chrysopids/plant respectively. Gosalwad *et al.* (2009) also reported that the maximum population of *Chrysoperla* was recorded during the fourth week of September, with a mean population of 3.8 predators per plant. Purohit *et al.* (2006) also supported that maximum population of *Chrysoperla* (6.20 predators/cotton plant during the year 2004) on fourth week of September.

Coccinellids

Population of coccinellids on different cotton genotype: Coccinellids ladybird beetle is the farmer's friend that protect crop from aphids, mealybugs, scale-insects, whiteflies, thrips, leafhoppers, mites etc. Overall mean values for the population of coccinellids being tested is shown in the (Table 2). Amongst the genotypes, maximum mean population was observed on HHH-223 (non *Bt* genotype), it was 2.06 adults/plant followed by *Bt* genotype BIOSEED-6588 (1.38 adults/plant), RCH-134 (1.25 adults/plant), JK-1947 (1.19 adults/plant), NECH-6 (1.12 adults/plant) and non *Bt* H-1236 genotype (1.08 adults/plant). Minimum mean population of coccinellids was observed in SP-7007 (1.05 adults /plant). Rajanikantha (2004) observed no difference in predatory population in MECH-184 *Bt,* non *Bt* and NHH-44 hybrids. Similarly, Udikeri (2003) reported that the incidence of coccinellids, *Chrysoperla* and syrphids did not vary significantly on RCH-2*Bt* and non *Bt* hybrids. However, Aggarwal *et al*. (2007) studied the response of two *Bt* hybrids (RCH-134 and RCH-317) and two non-*Bt* hybrids (RCH-134 and RCH-317) to natural enemies, it was observed that the population of spiders (2.09/plant), coccinellids (0.43/plant), green lacewing (0.67/plant) and predatory bugs (0.65/plant) being highest in RCH-134 *Bt* cotton and lowest (1.33/plant), (0.35/plant), (0.32/plant) and (0.32/plant) in RCH-317 non-*Bt* cotton.

Population movement of coccinellids throughout the year: The present study revealed that coccinellids predator appeared in the month of June and remained throughout the crop season (Table-2). The population was reached two times at their peak level, first during the 27th and second during the 38th SMW. First peak was during the first week of July and second was during third week of September with number of 2.41 and 2.17 adults per plant respectively. Purohit *et al*. (2006) present similar result earlier, they observed that population increased (4.66/plant) gradually and reached to its peak in September. Kedar (2014) also support that investigation, who reported two peaks of coccinellids population.

Spiders

Population of spiders on different cotton genotype: Mean population of spiders showed varying reaction on different genotypes. Maximum mean population of spiders was recorded on *Bt* genotypes as compared to non *Bt* genotypes. The highest adults per plant was observed on JK-1947 (1.59 adults/plant) followed by BIOSEED-6588 (1.35 adults/plant), RCH-134 (1.27 adults/plant), NECH-6 (1.25 adults/plant), HHH-223 (1.08 adults/plant), H-1236 (1.06 adults/plant), while minimum mean population was recorded in SP-7007 (1.04 adults/plant) (Table-3). Aggarwal *et al.* (2007) also support the result, they observed that natural enemies population *viz*. spiders, predatory bugs (*Geocoris* spp.), green lace wing (*Chrysopa* spp.) and coccinellids (C*occinella* spp.) was significantly higher in *Bt* hybrids than non *Bt* hybrids. However, Kengegowda (2003) observed no difference with respect to predator population of *Chrysoperla,* coccinellids, anthocorids and spiders appeared more or less same in *Bt*, non *Bt* and NHH-44 hybrids under unprotected conditions at Raichur, Karnataka. Many authors also widely acknowledged reaction *Bt* and non *Bt* genotypes on natural enemies population *viz.* Coccinellides, Chrysoperla and spiders (Udikeri 2003 ;Prasad and Rao 2008; Dhillon and Sharma 2013). Rajanikantha (2004) also observed that no difference in predatory population in MECH-184 *Bt*, non *Bt* and NHH-44 hybrids.

Population movement of spiders throughout the year: The results on periodic fluctuation of spiders on cotton are presented in (Table 3). The population of spiders was recorded in the 25th SMW *i.e.* third week of June and remained active throughout the crop season. Two peaks of spiders population were recorded throughout the crop season. First on 35th SMW (Last week of August) with an average 2.64 adults per plant. Second peak in spiders population was recorded on 40th SMW *i.e.* first week of October with an average

2.28 adults per plant. Muchhadiya *et al*. (2014) reported that the peak period of spider's population was observed on the 4th week of July to the 2nd week of September with the highest population on 1st week of August on cotton plant. This slight variation in natural enemy's population build up may be due to difference in sowing time.

Role of abiotic factors in population fluctuation of natural enemies: Weather has played important role in natural enemies population fluctuations. The results regarding the correlation between abiotic factors and population of *C. zastrowi sillemi*, coccinellids and Spiders are given in (Table 4). The population of *C. zastrowi sillemi* and *coccinellids* showed significantly negative correlation (r = -0.527 at 5% and r = -0.626 at 1% respectively) with maximum temperature, while spiders showed non significant negative correlation (r = -0.136). However, all natural enemies demonstrate non significant negative correlation with minimum temperature; wind speed and positive non significant correlation with sunshine. Chakraborty and Korat (2013) support the finding; they reported that maximum temperature showed significant negative correlation (r = -0.391 at 5%) on coccinellids population and positive with morning relative humidity and sunshine hours. Purohit *et al.* (2006) reported significant negative correlation (r = -0.480 at 5% level) with maximum temperature and positive with morning relative humidity in case of coccinellids. Gosalwad *et al.* (2009) also reported that maximum temperature showed negative correlation on coccinellids population (r = -0.055). Similary, Muchhadiya *et al*. (2014) support the statement regarding spiders. It was observed that rainfall has non significant positive correlation with *C. zastrowi sillemi* ; coccinellids and negative correlation with spiders. Similarly, Gosalwad *et al.* (2009) also reported that rainfall had no significant effects. However, Muchhadiya *et al*. (2014) reported significant positive correlation with rainfall (r = 0.465 at 5%) and negative with sunshine (r = -0.597 at 1%). Many authors reported that meteorological parameters (temperature, humidity, rainfall, sunshine and wind speed) play an important role in the population fluctuation of natural enemies (Kavitha *et al.* 2003; Purohit *et al.* 2006; Chakraborty and Korat 2013). Relative humidity during morning time has significant positive correlation with population of *C. zastrowi sillemi* (r = 0.521 at 5%) and coccinellids (r = 0.547 at 5%) while evening humidity present non significant positive correlation (r = 0.274) and (r = 0.466) respectively. It was also observed that humidity play negative role in spider's population development.

Conclusion

In present study natural enemies remained active throughout the crop season. The highest population of Chrysoperla (1.17 eggs/plant) and spiders (1.59 adults/plant) was observed on *Bt* cotton namely RCH-134 and JK-1947 respectively. However, coccinellids preferred non *Bt* genotype (HHH-223) for their population build-up (2.06 adults/plant). Chrysoperla and coccinellids population was significantly negatively correlated (r = -0.527 at 5% and r = -0.626 at 1% respectively) with maximum temperature and positively correlated with RHm, RHe and negatively correlated with minimum temperature and wind speed. Spiders population showed negative correlation with majority of weather parameters. In this study it was also observed that *Bt* genotype don't have any effect on growth of natural enemies while coccinellids population little effective.

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