The Pharma Innovation Journal 2022; 11(7): 1506-1512

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(7): 1506-1512

www.thepharmajournal.com
Received: 07-05-2022
Accepted: 16-06-2022

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Population dynamics of mealybug, *Phenacoccus solenopsis* Tinsley and its natural enemies on *Bt* cotton

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Abstract
The present investigations on population dynamics of mealybug, *Phenacoccus solenopsis* Tinsley and its natural enemies on *Bt* cotton was carried out at Main Cotton Research Station, Navsari Agricultural University, Surat, Gujarat during *Kharif*, 2020-21 and 2021-22. Mealybug incidence initiated during 34th SMW and found gradually increasing after cessation of rain and reached to peak in 52th SMW. The intensity of infestation within total plants and infested plants were found to range from 0.00 to 10.00 and 0.00 to 37.50 percent, respectively showing maximum intensity at the end of the crop period under untreated condition during the both year. With respect to weather parameters, morning relative humidity, evening relative humidity, average relative humidity, rainfall and rainy days showed significant negative correlation while sunshine hour had positive association with mealybug incidence. Thus, an almost similar result was noticed with respect to incidence of mealybug in relation to weather parameters during both the years. The activity of *A. bambawalei* was active from 35th or 36th SMW to 2nd or 4th SMW. Parasitizing activity was higher during December and January months during the both the years. The activity of parasitiod was found to coincide with the population build-up of mealybug and there was significant positive correlation between parasitiod and mealybug populations. The activity of parasitoid showed significant negative correlations with minimum temperature, average temperature, morning humidity, evening humidity, average relative humidity and rainy days and positive correlation with sunshine hour. The activity of coccinellids was observed from 30th or 32nd SMW to 2nd or 4th SMW during 2020-22. The incidence of coccinellids coincided with mealybug population build up and the association was found significant. Minimum temperature, morning and evening relative humidity and rainy days adversely affected the coccinellids population. The sunshine hour's favours the population build-up of coccinellids by showing significant positive relationship during the both years. The activity of Chrysoperla was not influenced by mealybug population and the activity was noticed mainly with aphids. The sunshine hours favours the population build-up of Chrysoperla by showing significant positive relationship during the both years.

Keywords: Cotton, mealybug, natural enemies, correlation

Introduction
Cotton (*Gossypium hirsutum* Linnaeus), is the "King of fibre" popularly known as "White gold", an important cash crop in India. Cotton belongs to the family "Malvaceae" and genus "Gossypium". It is popularly known as "Friendly fibre" because in India, cotton crop contributes about 80 per cent of the raw material to textile industry in the country providing livelihood for more than 100 million people, through production, processing, trading and marketing (Rakesh and Kathane, 1989) [20]. World total cotton production was recorded 118.45 million bales from the 32.25 million hectares of total cultivated area and 800 kg/hectare productivity in 2021-22. According to Cotton Advisory Board, the production of cotton was 362.18 lakh bales from the 120.69 lakh hectares of cultivated area and 510.15 kg/hectare productivity in India during 2020-21. Gujarat is the largest cotton producing state with 80.96 lakh bales of the total production of the country from approximately 22.57 lakh hectares with 609.80 kg/hectare productivity during 2020-21. (Anon., 2021) [1]. The mealybug, *Phenaccocus solenopsis* Tinsley was hitherto not familiar or its identity was not established which caused significant economic damage in Pakistan and India (Muhammad, 2007 and Jhala *et al*., 2008) [9, 14]. Earlier, minor pest pink mealybug, *Maconellicoccus hirsutus* (Green) was reported in outbreak form on desi and hybrid cotton in Kutch district of Gujarat state way back in 1997 (Muralidharan and Badaya, 2000) [15]. *Phenaccocus solenopsis* is believed to be introduced in India for the first time in Gujarat via Pakistan during 2006 and spread to the different cotton growing states of the India rapidly (Nagrare *et al*., 2009) [16] which created havoc in middle and south Gujarat in 2006 and almost entire Gujarat in 2007. Invasiveness, rapid spread,

potential to cause economic damage and biological advantages of *P. solenopsis* drew the attention of several researchers with their focus on preliminary researchable issues like survey of mealybug species and its natural enemies, reasons for their outbreak, biology and management aspects. In spite of regular occurrence of *P. solenopsis* in the last few years, there is a paucity of information on population dynamics and efficiency/potential of natural enemies under South Gujarat condition. Hence, to develop insect pest management programme for specific agro-ecosystem, detailed study on these aspects is highly essential. To fill this lacunae and an insight into the whole mealybug cotton complex the present study was undertaken.

Material and Methods

The present study was taken up at Main Cotton Research Station, Navsari Agricultural University, Surat during *Kharif* 2020-21 and 2021-22. The population dynamics of mealybug and its natural enemies were recorded on *Bt* cotton (G.Cot.Hy.8 BG II). Population counts of mealy bugs (crawler (nymph) and adult stages) were recorded from 5 cm apical twig of twenty tagged plants from five spot starting from 30 days after sowing till the crop maturity at weekly interval and expressed as average number of mealybug from 5 cm shoot/twig. Observations were also recorded to assess the severity of infestation. For this purpose, each plant in the net plots was categorized in the 0-4 scale as under.

Scale	Infestation level
0	: Healthy (No mealy bug on any of the plant parts)
1	: Initiation of crawlers in any part of the plant or about 1-10 mealy bugs scattered on the plant
2	: Half stem and few branches infested or One branch infested heavily with mealy bugs
3	: More than 50 per cent of the branch infested or two or more branches infested heavily with mealy bugs, up to 50% plant affected
4	: Whole plant/ complete plant affected/infested

Based on above categorization of plants in net plots of each treatment, the per cent infested plants were estimated by counting healthy (0 scale) and infested plants (1 to 4 scales). The severity of infestations in the net plots was also estimated for total plats and infested plants under the net plots. For the purpose, the intensity of infestation within total plants was estimated by sum of number of plants in each scale divided by total category of scale and total number of plants in net plots. The intensity of infestation within infested plants (per net plot) was also estimated by sum of number of plants in each scale divided by category of scale in infestation and number of infested plants in net plots. The number of mummified mealybug assuming the parasitization was also recorded on 20 shoot or twigs from five spots and the per cent parasitism was worked out by counting total number of healthy and mummified mealybug. At peak parasitism, such 100 infested shoots/twig was brought to the laboratory and a per cent successful emergence of parasitiod was estimated. Observations on other natural enemies *viz.,* coccinellids (grab and adult) and chrysoperla (grab) were recorded on 20 tagged plants from 5 spots randomly selected plants and expressed as average number plant.

Results and Discussion

Incidence of mealybug

The data on incidence of mealybug (2020-21) presented in Table 1 revealed that the incidence initiated during 34th standard week *i.e*., third week of August (3.90/5cm apical twig) and found gradually increasing after cessation of rain and reached to peak (110.20/5cm twig) in 52nd standard week *i.e*., last week of December. Thereafter, the population found to decrease. Out of 100 tagged plants, the mealybug was found to gradually spreading to plants after cessation of reached and the maximum infested plants were noticed at crop maturity/harvest during 2nd week of January (35% infested plants) under untreated condition. The intensity of infestation within total plants and infested plants were found to range from 0.00 to 9.20 and 0.00 to 32.86 per cent, respectively showing maximum intensity at the end of the crop period under untreated condition. The correlation between mealybug and different weather parameter revealed that maximum temperature, minimum temperature and average temperature showed negative association, but was found not significant. Whereas, morning relative humidity, evening relative humidity, average relative humidity and rainy days showed highly significant negative association and rainfall too showed significant negative association with mealybug population. The bright sunshine hour had positive correlation with mealybug incidence (Table 3).

Table 1: Incidence of mealybug and its natural enemies during *Kharif*, 2020-21.

SMW	Month	Mealybug population/ 5 cm shoot	Infested plant (%)	% Intensity within total plant	% Intensity within infested plant	% Parasitism	Coccinellids/ plant	Green lacewing/ plant
32	August (06th August to 02nd September)	0.00	0.00	0.00	0.00	0.00	1.20	0.80
33		0.00	0.00	0.00	0.00	0.00	1.50	1.10
34		3.90	2.00	0.40	25.00	0.00	1.80	1.35
35		6.50	2.00	0.40	25.00	0.00	2.45	1.05
36	September (03rd September to 30th September)	8.80	5.00	1.00	25.00	6.55	2.60	2.35
37		10.20	6.00	1.40	29.17	7.01	2.45	2.30
38		13.50	7.00	1.40	25.00	6.88	2.55	2.40
39		19.60	11.00	2.20	25.00	6.88	2.50	2.20
40	October (1st October to 4th November)	20.70	12.00	2.60	27.08	6.95	2.50	2.50
41		25.10	14.00	3.00	26.79	7.70	2.65	2.55
42		29.58	13.00	2.80	26.92	8.12	2.70	2.65
43		36.00	12.00	2.60	27.08	9.05	2.85	1.85
44		49.40	18.00	3.80	26.39	8.80	2.80	1.70
45	November (5th November to 2	52.40	20.00	4.20	26.25	8.76	2.80	1.50
46		55.80	21.00	4.40	26.19	9.10	2.80	1.55

47	December)	80.50	24.00	5.60	29.17	10.03	3.05	0.85
48		97.20	25.00	5.60	28.00	11.54	3.40	1.20
49	December (3rd December to 31st December)	100.30	27.00	7.20	33.33	12.87	3.70	1.15
50		103.50	30.00	7.40	30.83	13.55	3.85	0.80
51		107.80	32.00	8.20	32.03	13.90	3.90	0.75
52		110.20	33.00	8.80	33.33	14.10	4.05	0.60
01	January (1st January to 14th January)	100.95	34.00	9.00	33.09	15.42	4.00	0.45
02		97.20	35.00	9.20	32.86	18.26	4.15	0.30
Av.	-	49.09	16.65	3.97	25.80	8.50	2.88	1.48

During *Kharif*, 2021-22, the incidence initiated during 34th standard week *i.e.*, third week of August (3.70/5cm apical twig) and found gradually increasing after cessation of rain and reached to peak (109.30/5cm twig) in 52th standard week *i.e.*, last week of December. Thereafter, the population found to decrease (Table 2). Thus, the same trend was noticed during both the years. Out of 100 tagged plants, the mealybug was found to gradually spreading to plants after cessation of reached and the maximum infested plants were noticed at crop maturity/harvest during 2nd and 4th week of January (37% infested plants) under untreated condition. The intensity of infestation within total plants and infested plants were found to range from 0.00 to 10.00 and 0.00 to 37.50 per cent, respectively showing maximum intensity at the end of the crop period under untreated condition. The correlation studies revealed that maximum temperature, minimum temperature and average temperature showed negative correlations, but was found not significant. Whereas, morning relative humidity, evening relative humidity, average relative humidity and rainy days showed highly significant negative correlations with mealybug population and the correlation with rainfall was found significant negative. The bright sunshine hour had positive association with mealybug incidence. Thus, an almost similar result was noticed with respect to incidence of mealybug in relation to weather parameters during both the years (Table 3).

Table 2: Incidence of mealybug and its natural enemies during *Kharif*, 2021-22.

SMW	Month	Mealybug population/ 5 cm shoot	Infested plant (%)	% Intensity within total plant	% Intensity within infested plant	% Parasitism	Coccinellids/ plant	Green lacewing/ plant
30	July (23rd July to 5th August)	0.00	0.00	0.00	0.00	0.00	0.50	0.30
31		0.00	0.00	0.00	0.00	0.00	0.65	0.46
32	August (06th August to 02nd September)	0.00	0.00	0.00	0.00	0.00	0.80	0.90
33		0.00	0.00	0.00	0.00	0.00	1.05	1.10
34		3.70	4.00	1.20	32.14	0.00	1.90	1.25
35		4.50	4.00	1.20	37.50	5.85	2.70	1.30
36	September (03rd September to 30th September)	9.50	7.00	1.80	33.33	6.44	2.90	1.60
37		10.30	8.00	2.40	30.77	7.91	3.00	2.10
38		14.30	9.00	2.40	32.14	8.39	3.05	2.25
39		17.10	13.00	3.20	32.81	6.74	2.45	2.30
40	October (1st October to 4th November)	18.20	14.00	3.60	33.33	7.15	2.60	2.60
41		25.60	16.00	4.20	32.14	7.83	2.85	2.70
42		31.85	15.00	4.00	30.00	8.27	2.90	2.40
43		38.00	14.00	3.60	30.68	7.13	2.50	2.15
44		47.00	20.00	4.80	30.43	8.27	2.90	2.00
45	November (5th November to 2 December)	52.90	22.00	5.40	32.69	8.62	2.95	1.10
46		55.80	23.00	5.60	30.56	9.15	3.10	1.55
47		99.20	26.00	6.80	34.48	10.03	3.40	1.00
48		99.50	27.00	6.60	32.03	10.62	3.60	0.90
49	December (3rd December to 31st December)	102.40	29.00	8.00	33.09	11.42	3.80	0.85
50		105.30	32.00	8.20	35.71	14.74	3.85	0.70
51		107.45	34.00	9.00	34.72	13.83	4.00	0.25
52		109.30	35.00	10.00	33.78	14.74	4.05	0.00
01	January (1st January to 28th January)	104.80	36.00	10.00	37.50	18.86	3.90	0.00
02		99.25	37.00	10.00	37.50	22.49	4.20	0.00
03		95.24	33.00	8.40	31.82	22.90	4.65	0.00
04		88.40	37.00	9.60	32.43	24.24	4.75	0.00
Av.	-	49.61	18.33	4.81	28.21	9.47	2.93	1.18

Table 3: Effect of weather parameter on mealybug incidence and its natural enemies.

Sr. No.	Factor	2020-21 (N=23)				2021-22 (N=27)			
		Mealybug	Parasitism (%)	LBB	Green lacewing	Mealybug	Parasitism (%)	LBB	Green lacewing
Abiotic factor									
X1	Max. Temp.(°C)	-0.147	-0.028	-0.123	-0.239	-0.325	-0.165	-0.343	-0.06
X2	Min. Temp. (°C)	-0.400	-0.799**	-0.833**	-0.480**	-0.340	-0.610**	-0.777**	-0.552**

X3	Av. Temp. (°C)	-0.344	-0.691**	-0.752**	-0.542**	-0.376	-0.578**	-0.720**	-0.507**
X4	Morning humidity (%)	-0.565**	-0.426*	-0.551**	-0.532**	-0.674**	-0.440*	-0.583**	-0.594**
X5	Evening humidity (%)	-0.845**	-0.738**	-0.511*	-0.579**	-0.531**	-0.598**	-0.437*	-0.505**
X6	Av. RH (%)	-0.815**	-0.718**	-0.615**	-0.633**	-0.739**	-0.603**	-0.476*	-0.629**
X7	Sunshine hours	0.558**	0.620**	0.519*	0.126	0.531**	0.714**	0.457*	0.367
X8	Rainfall (mm)	-0.513*	-0.693**	-0.412	-0.07	-0.486**	-0.496**	-0.178	-0.006
X9	Rainy days	-0.609**	-0.777**	-0.407**	-0.418*	-0.739**	-0.565**	-0.528**	-0.394*
Biotic factor									
P1	Parasitoid (*A. bambawalei*)	0.904**	-	-	-	0.870**	-	-	-
P2	Coccinellids	0.926**	-	-	-	0.834**	-	-	-
P3	Green lacewing	-0.638**	-	-	-	-0.693**	-	-	-

Correlation coefficient table value: (df= 21, 0.05 - 0.413; 0.01 - 0.526); Correlation coefficient table value: (df= 25, 0.05 - 0.381; 0.01 - 0.487)
* Significant at 5%; ** Significant at 1%

Thus, an almost similar result was noticed with respect to incidence of mealybug in relation to weather parameters during both the years. Dhawan *et al.* (2009) [5] recorded mealybug incidence from 30th standard week with peak in 34th standard week and found positive correlation of per cent field infestation, number of infested rows with temperature, whereas negative correlation with relative humidity and rainfall. Hanchinal *et al.* (2010) [7] found that mealy bug infestation started appearing in the month of September, gradually increased as crop growth advanced with peak in 7th standard week and showed negative correlations with minimum temperature, rainfall, rainy days and relative humidity (morning and evening). Kedar *et al.* (2011) [12] recorded peak population during mid-August to the third week of September and found significant negative correlation with rainfall and no impact of temperature and relative humidity on population build up. Singh and Kumar (2012) [24] observed peak population in the month of October and found positive correlation with higher temperature. Muchhadiya *et al.* (2014) [13] found that the mealy bug appeared from 2nd week of August with peak on 2nd week of December (at KVK, Rajkot) showing negative correlation with minimum temperature, relative humidity (morning and evening) and rainfall. Babu and Meghwal (2014) [3] observed peak during the 42nd standard week which continued up to the 50th standard week. The dry condition contributed to the higher incidence and the population was found to increase with the increase in sunshine hours. Pawar *et al.* (2017) [19] recorded incidence of mealy bug from the 38th standard week (September) till January-February at MCRS, Surat. They also found gradual increase of average grade and severity from the 48th to 6th standard week with a simultaneous increase in the population of mealy bug. Further, they noticed that the activity was positively influenced by sunshine hours and negatively by temperature (minimum and maximum), relative humidity (morning and evening), rainfall and rainy days. Shah *et al*. (2015) [23] found maximum population of mealybug during September 2nd fortnight and stated that the temperature played important role on mealy bug population. Zahi and Farag (2017) [26] noted that the infestation of *P. solenopsis* started in early June on two months old cotton plants at Giza, Egypt observing peak population during first two weeks of September. Badgujar *et al.* (2018) [4] reported that the incidence of mealy bugs was started from 32nd standard week with a peak during 46th standard week during 2008-09 and in 39th standard week during 2009-2010. Harde *et al.* (2018) [8] reported the peak during 5th week of September (10% infestation) in 2009-10 and during 3rd week of October (9% infestation) in 2010-11 and later it decreased gradually at the end of season. Thus, the mealybug dynamics mostly depended on weather parameter especially rainfall and humidity and varieties or hybrids. Thus, the incidences of mealybugs in the present experiments are more or less in accordance with dynamics studied in Gujarat and Maharashtra (Hanchinal *et al.*, 2010, Muchhadiya *et al.*, 2014, Babu and Meghwal, 2014 and Pawar *et al.*, 2017) [3, 7, 13, 19]. In contrast to reports of Dhawan *et al.* (2009) [5], Kedar *et al.* (2011) [12], Singh and Kumar (2012) [24], Shah *et al*. (2015) [23], Zahi and Farag (2017) [26], Badgujar *et al.* (2018) [4] and Harde *et al.* (2018) [8], the present finding differed which might be due to different location, germination time and climatic condition.

Incidence of parasitoid, *A. bambawalei*

During the *Kharif,* 2020-21, the data revealed that *A. bambawalei* was active from 36th standard week *i.e.,* first week of October (6.55% parasitism) to 2th standard week *i.e.*, second week of January (18.26% parasitism). Parasitizing activity was higher during December and January months (12.87 to 18.26% parasitism) which coincided with the higher population of mealybug (Table 1). The parasitoid activity was noticed once mealybug population was started to increase and the correlation between parasitism per cent and mealybug population showed highly significant positive correlation which indicated naturally coincided activities of parasitoids with the population buildup of the mealybug especially under unsprayed/untreated condition. The activity of parasitoid showed significant negative correlations with minimum temperature, average temperature, evening humidity, average relative humidity, rainfall, rainy days, and morning humidity. Only the sunshine hour showed significant positive correlation with parasitoid population (Table 3). The data on per cent parasitism as observed during different periods of 2021-22 are presented in Table 2. The data revealed that *A. bambawalei* was active from 35th standard week *i.e.,* fourth week of august (5.85% parasitism) to 4th standard week *i.e.,* fourth week of January (24.24% parasitism). Parasitoid activity was higher during December and January months (11.42 to 24.24% parasitism) which coincided with the higher population of mealybug. Similarly, as previous year, the parasitoid activity showed highly significant positive correlation with mealybug population which indicated naturally coincided activities of parasitoids with the population buildup of the mealybug especially under unsprayed/untreated condition. The correlations with weather parameters also showed almost similar trends as observed in the previous year where all studied weather parameters showed negative correlations except sunshine hour (Table 3).
The present investigation is in accordance with the reports of

Hanchinal *et al.* (2010) [7], the activity of parasitoids was started during 44th meteorological week and later on increased gradually to reach peak during 7th to 9th meteorological weeks and they found highest parasitism (20.65%) during 7th meteorological week coinciding with the higher population of mealybug. Patel *et al.* (2010) [17] observed 17.16 to 48.82 per cent parasitism of *A. bambawalei* in farmer's field in Anand and Baroda districts during *Kharif* 2009 with peak activity during mid-August to mid-September. Vijaya *et al.* (2010) [25] observed 28.65 to 58.97 per cent mean parasitisation of mealybug with peak activity during September. Singh and Kumar (2012) [24] stated that the activity of parasitoids started during 43rd standard week and later gradually gained peak during 6th to 8th meteorological week at Vadodara, Gujarat. Pawar *et al.* (2017b) [19] found parasitoid to be active from 41st standard week *i.e.*, second week of October (2.53% parasitism) to 8th standard week *i.e.*, fourth week of February (33.71% parasitism) and observed higher activity during January and February months (10.31 to 33.71% parasitism) coinciding with the higher population of mealybug positively influenced by sunshine hours and negatively by minimum temperature, relative humidity (morning and evening), rainfall and rainy days. The all above reports more or less conformity with the present reports. The present result is a little more or less than all the above information might be due to different location, germination time and climatic conditions.

Incidence of predators, coccinellids and chrysoperla

The data on incidence of predators, coccinellids and Chrysoperla presented in Table 1 showed that the population of predators was low during initial period of the crop. Higher activity of coccinellids was noticed during the higher incidence of the mealybug during 47th standard week *i.e.*, third week of November to 2nd standard week *i.e.*, second week of January. The peak populations of coccinellids (Av. 4.15/plant). Higher activity of Chrysoperla was noticed during 36th standard week *i.e.*, first week of September to 42nd standard week *i.e.*, third week of October. The peak populations of Chrysoperla (Av. 2.65/plant). Amongst predators, activity of coccinellids was noticed with increasing population of mealybug and the correlation between population of coccinellids and mealybug showed highly significant positive correlation, while the Chrysoperla population showed highly significant negative correlations with mealybug population indicating it's less impact on mealybug control which might be due to favoring aphid incidence. The correlations between coccinellids and different weather parameter revealed maximum temperature and rainfall had negative association, but found no significant, whereas, minimum temperature, average temperature, morning relative humidity, average relative humidity and rainy days showed highly significant negative correlations with coccinellids population. The evening humidity showed significant negative correlation whereas sunshine hour showed significant positive correlation with coccinellids population. The results on correlation between Chrysoperla larvae and different weather parameter revealed maximum temperature and rainfall showed non-significant negative correlation, whereas, minimum temperature, average temperature, morning relative humidity, evening humidity and average relative humidity showed highly significant negative correlations. The rainy days showed significant negative correlation while sunshine hour showed significant positive correlation with larvae population of Chrysoperla (Table 3).

The data on incidence of different predators presented in Table 2 showed that the population of predators was low during initial period of the crop. Higher activity of coccinellids was noticed during the higher incidence of the mealybug during 46th standard week *i.e.*, second week of November to 4th standard week *i.e.*, fourth week of January. The peak populations of coccinellids (Av. 4.75/plant). Higher activity of Chrysoperla was noticed during 37th standard week *i.e.*, second week of September to 42nd standard week *i.e.*, third week of October. The peak populations of Chrysoperla (Av. 2.40/plant). Among predators, activity of coccinellids and Chrysoperla showed similar trends as previous year showing positive effect of coccinellids and ineffectiveness of Chrysoperla. The correlations of populations of coccinellids and Chrysoperla with weather parameter revealed more or less similar trends as observed in the previous year (Table 3). Several workers studied the occurrence or dynamics of the predator at different locations and varieties. Gosalwad *et al.* (2009) [6] found maximum population of coccinellids in 2nd week of September (2004) and November (2005) whereas, Chrysoperla (*Chrysopa spp.*) population was maximum in the 2nd week of October during both the year at Parbhani (MH). Ashfaq *et al.* (2011) [2] observed *C. septempunctata* to be appeared on cotton on 30th June and disappeared in the subsequent weeks but appeared again on 20th July. Its density gradually increased in the subsequent weeks and peak was observed on 10th August. Kataria and Kumar (2015) [10] found maximum population of coccinellids during 3rd and 4th week of November during *kharif* seasons of cotton (2008-2011) at Vadodara, Gujarat. Patel and Radadia (2017) [19] recorded a higher population of coccinellids during later crop stage with its peak (1.34/plant) in 48th standard week whereas Chrysoperla was observed during 37th standard week (0.04/plant) to 2nd standard week (0.48/plant) in 2015-16. Further, they recorded higher population of coccinellids in the later crop stage from 49th to 1st standard week (December and January). Whereas, Chrysoperla from 36th standard week (0.04/ plant) till 51st standard week (0.10/plant) with a peak population in 40th standard week (0.36/ plant) in 2016-17 at Bharuch (Gujarat). Pawar *et al.* (2017b) [19] reported that the peak populations of coccinellids (Av. 13.35/plant) and green lacewing (Av. 4.45/plant) were recorded in 1st standard week *i.e.*, first week of January 2011, that correlation of predators population *viz.*, coccinellids showed positive correlations with sunshine hour. While, significant and negative correlations observed for coccinellids with minimum temperature, relative humidity (morning & evening) and rainy days. Rawal *et al.* (2017) [22] reported that natural enemies remained active throughout the crop season (with two peaks) with little differences among them at CCS, Haryana. Chrysoperla (*C. zastrowi*) and coccinellids both were remained active from 25th to 40th standard week. They found highest population of Chrysoperla (1.17 eggs/plant) on RCH-135 BG II. However, coccinellids preferred non *Bt* genotype (HHH-223) for their population build-up. Chrysoperla and coccinellids population was significantly negatively correlated with maximum temperature; negatively correlated with minimum temperature. Kedar *et al.* (2018) [11] at CCS Haryana revealed that the population of coccinellids reached peak twice during 29th and 41st standard week in 2011-12. During 2012-13 coccinellids population reached its peak during 30th and 42nd standard week. The correlation studies with the minimum

temperature showed highly significant negative correlation. Ramzan *et al.* (2019) [21] noted the activity of natural enemies throughout the study period with maximum activity of chrysoperla (*Chrysoperla* spp.) and coccinellids (*Coccinella spp*.) in June and September, respectively in Cotton at Multan (Pakistan). They found negative correlation of chrysoperla and coccinellids with rainfall. Thus, the present investigation is in accordance with the reports of Patel and Radadia (2017) [19], and Pawar *et al*. (2017) [19] However, Ashfaq *et al.* (2011) [2], Kataria and Kumar (2015) [10], Rawal *et al.* (2017) [22], Kedar *et al.* (2018) [11] and Ramzan *et al.* (2019) [21] are not tally with present findings might be due to different location, germination time and climatic condition.

Acknowledgement
The authors are thankful to Navsari Agricultural University, Navsari for providing facilities during research work.

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