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Seasonal abundance of sucking pests and natural enemies in *Bt* cotton ecosystem and their correlation with abiotic factors

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Abstract
The field study was conducted at CCS HAU, Cotton Research Station, Sirsa during *Kharif* 2019 to study the seasonal abundance of sucking pests in *Bt* cotton and to assess the impact of abiotic (weather variables) and biotic factors (natural enemies) on their population build-up. The population abundance of sucking pests *viz.*, leafhopper, *Amrasca biguttula biguttula* (Ishida); thrips, *Thrips tabaci* Lindemann and whitefly, *Bemisia tabaci* (Gennadius) was recorded at weekly intervals using the standard methods of observation. Beat-basket method of observation was followed for recording the population of natural enemies *viz.*, green lace wing, *Chrysoperla zastrowi sillemi*; lady bird beetle, *Coccinella septempunctata*; spiders and yellow wasps, *Vespa* spp. The number of sucking pests was found fluctuating during course of study and their active period was observed during 25th to 42nd SMW however the population of thrips was disappeared after 36th SMW. Leafhoppers and whitefly were found in significant positive correlation with relative humidity while significantly positive association of thrips was observed with rainfall. Natural enemies were found active during entire study period. They were negatively correlated with population build-up of thrips; meanwhile positive correlation was found with leafhopper and whiteflies; however negative correlation of green lace wings was recorded with whiteflies' population. Green lace wings were observed at peak during 30th and 40th SMW whereas maximum abundance of lady bird beetle was recorded in 30th and 42nd SMW. The population of natural enemies was negatively correlated with temperature while green lace wings and lady bird beetle was positively correlated with morning relative humidity and rainfall. Activity of spiders and yellow wasps was highest during 39th SMW and their negative correlation was observed with rainfall though the positive correlation was established with morning relative humidity.

Keywords: Cotton, correlation, natural enemies, sucking pests and weather parameters

Introduction
Cotton, *Gossypium* spp. is the important genetically modified crop which is cultivated throughout the tropical and sub-tropical areas of world on large scale. In India, the cotton is grown on 129.57 lakh hectares area with a production of 371 lakh bales and productivity of 486.76 Kg/ha (Anonymous, 2021) [1]. The production of cotton in India is severely hampered by 162 species of insect-pests accounting for 10-30 per cent losses (Anonymous, 2014) [2]. Leafhopper, *A. biguttula biguttula* (Ishida); whitefly, *B. tabaci* (Gennadius); thrips, *T. tabaci* Lindemann; aphid, *Aphis gossypii* Glover and mealybug, *Phenacoccus solenopsis* Tinsley are major insect-pests which cause damage to crop by sucking sap (Shera *et al*., 2013) [30]. Weather parameters are major abiotic components which affect the population abundance of sucking pests (Jeyakumar *et al*., 2008; Shera *et al*., 2013) [14, 30]. For keeping the population of insect-pest below economic threshold level, biological control can be used as the most reliable and environment friendly method of pest management (Bale *et al*., 2008; Kumar *et al*., 2016) [6, 18]. Natural enemies are the agents of biological control which keep the population of insect-pests below economic threshold level by feeding on them thereby protecting the crop from the damage done by pests. *Coccinella septempunctata*, *Cheilomenes sexmaculata*, *Chrysoperla zastrowi sillemi*, *Encarsia lutea*, *Vespa spp.* and spiders have been observed as potential natural enemies of insect-pest in cotton ecosystem (Kedar *et al*., 2014; Kumar *et al*., 2016; Patel and Radadia, 2018) [15, 18, 24]. Seasonal variation of meteorological factors affects the activity and abundance of natural enemies ultimately influencing their predatory activities (Dhaka and Pareek, 2007; Rawal *et al*., 2017) [11, 26]. Keeping this in view, the current study was conducted to assess the relationship between population of natural enemies in cotton agro-ecosystem and weather parameters.

Materials and Methods

The study was conducted at CCS HAU, Cotton Research Station, Sirsa (Haryana) during *Kharif* 2019 on *Bt* cotton hybrid RCH 650. The sowing was done on 8th May 2019 and all the cultural practices for raising the crop were followed as per the recommendation of "Package of practices for *Kharif* crops" of CCS Haryana Agricultural University, Hisar (Anonymous, 2017) [3].

The experiment was laid using randomized block design (RBD) with three replications. The population of sucking pests and natural enemies was recorded at weekly intervals, from 25th SMW to 42nd SMW on five plants which were selected at random from each replication and tagged. Number of sucking pests was recorded on three leaves per plant, representing the top, middle and lower canopy of plant while the population of natural enemies was recorded by using the beat basket method of observation. The population of yellow wasp, *Vespa* spp. was observed by recording the number of wasps visiting the randomly selected five plants per two minutes in each replication. Correlation analysis of data was worked out using Online Statistical Software Package for Agricultural Research Workers (OPSTAT) (Sheoran *et al.*, 1998) [29]

Results and Discussion

Seasonal abundance of sucking pests and their correlation with abiotic factors

Leafhopper, Amrasca biguttula biguttula (Ishida)

During the study, the population of leafhopper was observed at peak in third week of July (29th SMW) and in third week of August (33rd SMW) as per Table 1, that coincides with Sharma *et al.* (2004) who recorded the highest population of leafhopper in July in cotton ecosystem. In similar line, Jeyakumar *et al.* (2008) [14] observed maximum population of leafhopper in 30th and 33rd SMW in Sirsa (Haryana), while in Punjab, Shera *et al.* (2013) [30] found peak abundance of leafhopper in 29th SMW in cotton crop. As per the observation made in current study, leafhoppers were found in highly significant positive correlation with morning and evening relative humidity whereas significant positive correlation was observed with rainfall (Table 2). However, non-significant negative correlation of leafhopper was observed with maximum and minimum temperature.

These outcomes are favoured by Arif *et al.* (2006) [4] who reported positive correlation of leafhopper with relative humidity. Shera *et al.* (2013) [30] too found positive correlation of leafhopper with relative humidity and rainfall in cotton. Furthermore, non-significant negative correlation was pointed out between leafhopper and maximum temperature. The conclusion are in line with Dahiya *et al.* (2018) [10] who recorded negative correlation of leafhopper with maximum temperature in cotton and positive correlation was with rainfall and relative humidity in Haryana region.

Thrips, Thrips tabaci Lindemann

The peak abundance of thrips was found in 28th SMW (second week of July) during the experiment (Fig. 1); though Shera *et al.* (2013) [30] concluded maximum abundance of thrips in 25th SMW in Punjab conditions. The aggregated findings made during study revealed non-significant positive or negative association of thrips with weather parameters regardless of rainfall which showed significant positive correlation with thrips as per Table 2. The results obtained are admired by Arif *et al.* (2006) [4] who found non-significant positive correlation of thrips with temperature, relative humidity and rainfall in cotton. The findings are favoured by Bala *et al.* (2019) [5] too in whose findings positive correlation was observed between thrips and meteorological parameters *viz.*, maximum temperature, minimum temperature and rainfall in *Bt* cotton crop in West Bengal area.

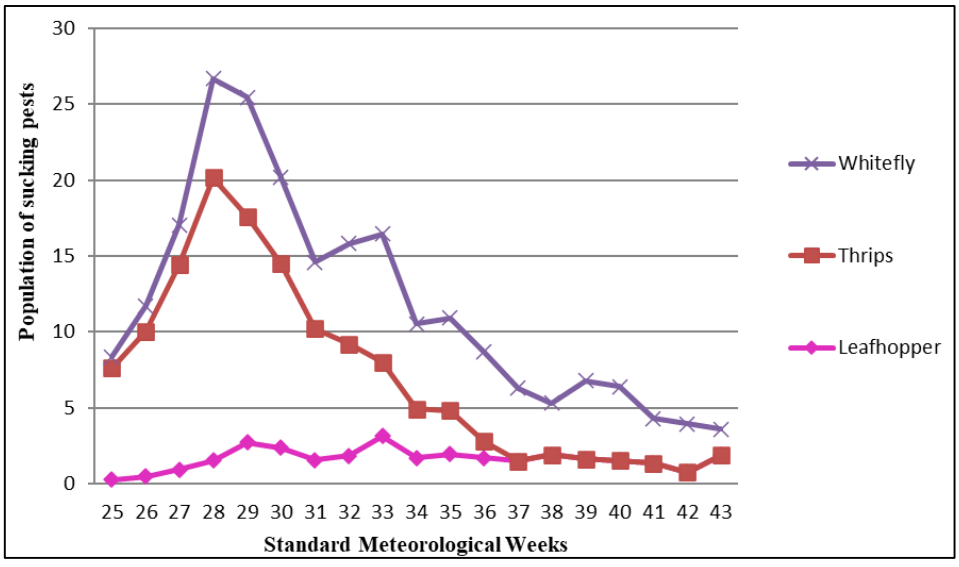

Fig 1: Seasonal abundance of sucking pests in *Bt* cotton

Table 1: Weather parameters and seasonal abundance of sucking pests and natural enemies

SMW	Temp (ºC)		R.H. (%)		Total rainfall (mm)	Population per plant						
	Max.	Min.	Morning	Evening		Green lacewing	Spiders	Ladybird beetle	Yellow wasp	Leafhopper	Thrips	Whitefly
25	37.6	26.2	69.3	45.4	14.0	0.20	0.23	0.14	0.00	0.27	7.34	0.74
26	39.6	26.9	61.3	40.6	0.0	0.34	0.67	0.34	0.00	0.47	9.57	1.67
27	38.4	27.1	68.0	47.4	12.5	0.60	1.74	0.60	0.00	0.94	13.47	2.64
28	36.5	26.2	70.9	57.6	8.40	0.40	2.54	0.27	0.07	1.54	18.64	6.49

29	33.1	21.9	82.5	65.0	66.8	1.94	1.87	0.80	0.14	2.72	14.87	7.85
30	33.2	22.0	83.2	67.4	92.7	2.34	1.27	1.34	0.14	2.38	12.11	5.69
31	34.7	22.9	80.3	64.7	0.0	0.74	2.67	0.94	0.07	1.56	8.64	4.41
32	36.8	24.6	71.4	55.7	5.20	1.07	2.34	0.67	0.27	1.85	7.35	6.63
33	34.1	21.9	79.1	66.3	39.5	1.67	2.94	0.87	0.27	3.14	4.87	8.45
34	35.8	27.1	70.9	58.5	0.0	1.40	3.74	0.27	0.27	1.72	3.21	5.61
35	36.1	27.3	77.1	60	0.0	1.54	3.07	0.74	0.34	1.94	2.87	6.09
36	36.1	27.0	79.3	58.3	0.0	1.40	2.67	0.54	0.34	1.72	1.07	5.89
37	36.9	27.4	78.5	54.0	0.0	1.80	2.27	0.87	0.27	1.49	0.0	4.81
38	34.6	25.1	77.6	57.2	0.0	1.47	3.67	0.67	0.47	1.92	0.0	3.38
39	33.5	22.1	75.1	57.8	0.0	2.14	4.27	0.27	0.87	1.63	0.0	5.16
40	31.7	21.0	83.9	56.7	0.0	2.47	3.54	0.87	0.47	1.54	0.0	4.85
41	32.9	19.5	71.1	43.0	0.0	1.60	3.14	1.14	0.54	1.34	0.0	2.94
42	32.5	19.9	72.6	41.0	1.20	0.94	1.94	1.47	0.74	0.74	0.0	3.21
43	32.0	17.2	79.1	38.1	0.0	0.27	2.32	1.27	0.47	1.87	0.0	1.72

Whitefly, *Bemisia tabaci* (Gennadius)

Whitefly population was found at peak in 30th (last week of July) and 33rd SMW (third week of August) as shown in Fig. 1, which is in confirmation with Jeyakumar *et al.* (2008) [14] who observed maximum abundance of whitefly in cotton in 31st and 33rdSMW at farmers' field in Sirsa district of Haryana. Janu and Dahiya (2017) [13] reported peak population of whitefly in cotton fields in 34th SMW, however Shera *et al.* (2013) [30] observed maximum number of whitefly in 30th SMW in cotton. Rolania *et al.* (2018) [27] also stated population of whitefly at economic threshold level in 33rd SMW in cotton ecosystem which is in line with the outcomes of present study.

Negative correlation of whitefly was observed with maximum temperature while positive correlation was established with other weather factors *viz.*, minimum temperature, rainfall, morning and evening relative humidity as given in Table 2, which is in consonance with the results of study conducted by Arif *et al.* (2006) [4] according to whom, significant positive correlation of whitefly was existed with temperature, highly significant positive correlation was observed with relative humidity and non-significant positive correlation was found with rainfall in cotton field. In findings of Shera *et al.* (2013) [30] positive correlation of whitefly was seen with minimum temperature, morning and evening relative humidity in cotton. Rolania *et al.* (2018) [27] described substantial negative correlation of whitefly with maximum temperature and extremely significant positive relationship with minimum temperature and evening relative humidity on cotton hybrid HS-6, however non-significant positive correlation was observed with rainfall.

Table 2: Correlation cofficient between sucking pests and weather parameters

Sucking Pests	Temp (OC)		R. H. (%)		Total Rainfall (mm)
	Max.	Min.	Morning	Evening	
Leafhopper	-0.459	-0.261	0.696**	0.738**	0.537*
Thrips	0.385	0.274	-0.202	0.268	0.524*
Whitefly	-0.191	0.064	0.486*	0.826**	0.410

*significant at 5% level of significance **significant at 1% level of significance

Seasonal abundance of natural enemies and their correlation with abiotic factors

Ladybird beetle, *Coccinella septempunctata*

Ladybird beetle, *Coccinella septempunctata* which is an important predator in cotton agro-ecosystem, was present in the field throughout the study period *i.e.*, from 25th to 43rd SMW as given in Table 1. Its peak activity was observed during the 30th SMW (last week of July) and 42nd SMW (third week of October). The findings are in consonance with Bhattacharyya (2017) who observed peak activity of ladybird beetle in 41st SMW. Significant positive correlation of ladybird beetle was observed with morning relative humidity while rainfall was found in non-significant positive correlation with it as shown in Table 3, which is in agreement with Harde *et al.* (2020) [12] as they observed significant positive correlation of ladybird beetle population with morning relative humidity and non-significant positive correlation with rainfall. In present experiment, highly significant negative correlation of ladybird beetle was found with maximum and minimum temperature which is in confirmation with the findings of Rawal *et al.* (2017) [26] who revealed negative correlation of ladybird beetle with maximum and minimum temperature.

Green lacewing, *Chrysoperla zastrowi sillemi*

The population of green lacewing was active in field throughout the study period and its peak number was observed for first time during 30th SMW (last week of July), while second peak was recorded during 40th SMW (first week of October) as tabulated in Fig. 2 which is in affirmation with Kedar (2014) [15] who reported maximum population of *C. zastrowi sillemi* in 31st and 40th SMW in cotton. Rawal *et al.* (2017) [26] also found two peaks in population of green lacewing *i.e.*, first peak in 29th SMW and another peak in 39th SMW. Green lacewing population exhibited highly significant positive correlation with morning and evening relative humidity; however non-significant positive correlation was appeared with rainfall as provided in Table 3. Significant negative correlation was observed with maximum temperature and non-significant negative correlation was found with minimum temperature which lies in accordance with Shukla (2014) [31] who reported highly significant negative correlation of *Chrysoperla* with minimum temperature and non-significant positive correlation was observed with rainfall. Similarly, Harde *et al.* (2020) [12] recorded significant positive correlation of green lacewing with rainfall, morning and evening relative humidity in cotton.

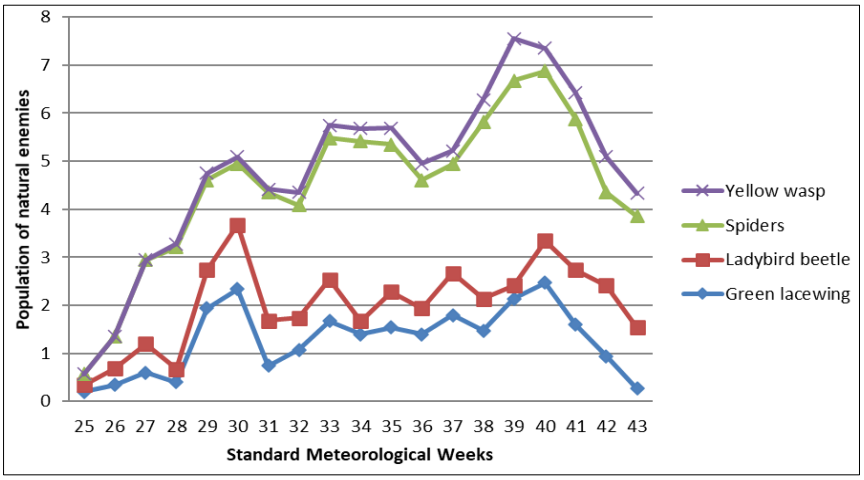

Fig 2: Seasonal abundance of natural enemies in *Bt* cotton

Spiders

In present findings, the population of spiders was found highest in last week of September (39th SMW) as presented in Table 1, that is in confirmation with Nemade *et al.* (2015) [22] who inference peak population of spiders during 38th SMW in cotton. The findings are in association also with Harde *et al.* (2020) [12] who reported peak abundance of spiders in 39th SMW. Non-significant negative correlation was found between spiders and weather factors *i.e.*, maximum temperature, minimum temperature and rainfall whereas; non-significant positive correlation was prevalent with morning and evening relative humidity (Table 3) which was evident in study of Laxman *et al.* (2016) [19] who revealed negative relationship of spiders with maximum temperature and rainfall, meanwhile positive correlation was found with morning and evening relative humidity. Boda and Ilyas (2017) [9] observed non-significant negative correlation of spiders with minimum temperature and rainfall in cotton.

Table 3: Correlation cofficient between natural enemies and weather parameters

Natural Enemies	Temp (OC)		R. H. (%)		Total Rainfall (mm)
	Max.	Min.	Morning	Evening	
Green lacewing	-0.519*	-0.193	0.647**	0.593**	0.378
Ladybird beetle	-0.660**	-0.701**	0.490*	-0.076	0.284
Spiders	-0.441	-0.155	0.344	0.343	-0.358
Yellow wasp	-0.645**	-0.527*	0.230	-0.163	-0.320

*significant at 5% level of significance **significant at 1% level of significance

Yellow Wasps, *Vespa* spp.

Maximum abundance of yellow wasp, *Vespa* spp. was found in 39th SMW *i.e.*, last week of September (Fig. 2), which is supported by Sharma *et al.* (1979) [28] and Kumar *et al.* (1998) [17] who noticed highest population of *V. auraria* during September month. Rasool *et al.* (2017) [25] too revealed the peak population of *V. orientalis*, *V. tropica* and *V. velutina* during September month. *Vespa* spp. were found in highly significant negative relationship with maximum temperature and in significant negative correlation with minimum temperature as tabulated in Table 3. However, non-significant positive correlation of spiders was set up with morning relative humidity and non-significant negative correlation with evening relative humidity as well as with rainfall. Painkra *et al.* (2015) [23] recorded negative correlation of wasps with maximum temperature and minimum temperature although, positive association was observed with morning relative humidity. Negi *et al.* (2018) [21] also revealed positive correlation of yellow wasp with relative humidity.

Relationship between population abundance of sucking pests and their natural enemies

Natural enemies are the important tool in integrated pest management programme. They feed on insect pests and protect the crop from adverse impacts caused by them. Same conclusion can be revealed from present study. In the experiments conducted, a moderate positive correlation was observed between populations of ladybird beetle and sucking pests *viz.*, leafhopper and whitefly (Table 4) which is according to the inference made by Nemade *et al.* (2015) [22] who observed highly significant positive correlation between Coccinellids and leafhopper in cotton in Maharashtra. Similarly, Nagar *et al.* (2017) [20] recorded positive correlation of ladybird beetle with population of leafhopper and whitefly in Jobner (Rajasthan). Kumar *et al.* (2016) [18] too come up with same conclusion of constructive relationship of Coccinellids with leafhopper and whitefly on cotton in Haryana conditions.

Table 4: Correlation cofficient between natural enemies and sucking pests

Natural Enemies	Sucking Pests		
	Whitefly (adults)	Leafhopper	Thrips
Green lacewing	0.559*	0.570*	-0.299
Ladybird beetle	-0.001	0.277	-0.258
Spiders	0.401	0.423	0.503*
Yellow wasp	0.010	0.091	-0.761**

*significant at 5% level of significance **significant at 1% level of significance

During the research presented, green lacewing was found to have highly significant positive correlation with *A. biguttula biguttula* and of *B. tabaci* in cotton ecosystem as given in Table 4. The findings are favoured by Patel and Radadia (2018) [24] who concluded highly significant positive correlation between *Chrysoperla* and *A. biguttula biguttula* in cotton crop in Gujrat. In Buldana (Maharashtra), *Chrysopa* spp. were found in non-significant positive relationship with *A. biguttula biguttula* in cotton fields (Nemade *et al.*, 2015) [22]. Similarly, Basit *et al.* (2016) [7] observed that *Chrysoperla* was positively correlated with *B. tabaci*.

Spiders can act as potential bio-control agent of major insect-pests in cotton that ultimately play a decisive role in the pest management in cotton crop as cited by Dhaka and Pareek (2007) [11]. In current experiment, non-significant positive correlation of spiders was found with leafhopper (Table 4), whitefly and thrips. Nemade *et al.* (2015) [22] recorded significant positive correlation between spiders and leafhopper in cotton in Maharashtra conditions. In opinion of Kumar *et al.* (2016) [18] positive association exist between spiders and thrips in cotton. Simultaneously, Patel and Radadia (2018) [24] observed positive correlation of spiders with *A. biguttula biguttula* in cotton in Gujrat area. The findings made by Basit *et al.* (2016) [7] support present results and as they described that spider were in significant positive correlation with *Empoasca* spp. in sunflower. Moreover, Khuhro *et al.* (2012) [16] observed spiders as potential biological control agent of thrips and whitefly in a number of field crops in Sindh region.

A moderate positive correlation was evident between yellow wasps and sucking pests in present study as evident from Table 4, this inference is in line with Kumar *et al.* (2016) [18] who reported yellow wasp as potential natural enemy of major sucking pests in cotton ecosystem.

Conclusion

Sucking pests are potential pests in ecosystem which cause huge economical loss cotton crop. Their abundance is influenced by seasonal variation of meteorological factors. It can be concluded from the presented work that first fortnight of July and second fortnight of August have more favourable conditions for population build-up. Among abiotic factors, minimum temperature, relative humidity and rainfall have positive relation with population build-up of sucking pests while maximum temperature is quite unfavourable for them.

The population of natural enemies also gets fluctuated due to seasonal variation of weather parameters. In this experiment, higher abundance of natural enemies was observed from last week of July to third week of October. Relative humidity and rainfall were observed as the major factors which exert positive impact on the population of natural enemies. Meanwhile green lace wing, spiders and yellow wasps were established as potential natural enemies which affect the population abundance of sucking pests in cotton ecosystem.

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