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Impact of abiotic factors on population fluctuation of whitefly (*Bemisia tabaci*) and its natural enemies in cotton agroecosystem

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ABSTRACT

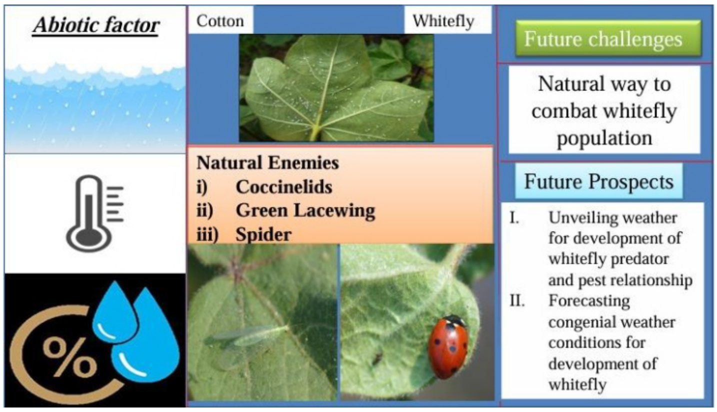
Aim: *Whitefly a phloem-feeding insect, is economically more important because it causes reduction in yield of cotton. Various weather parameters also affect its population. Natural enemies of pests play a significant role in cotton ecosystem. Proper identification of change in the whitefly population and its natural enemies population along with change in weather conditions is most important for Integrated Pest Management.*

Methodology: *So, to study the population dynamics of whitefly and its natural enemies in cotton and their relation with weather parameters an experiment was conducted at the Research Farm, Cotton Section, Department of Genetics and Plant Breeding, CCSHAU, Hisar during kharif 2017 and 2018. To diminish the magnitude of data and to transform variables into principal components (PC), Principal component analysis (PCA) was done to describe the nature and amount of the interaction between diverse variables.*

Results: *It has been observed that the incidence of whiteflies started from 24th SMW and attained a peak during 34th SMW (Fourth week of August). Whitefly population exhibited highly significant positive correlation with morning relative humidity (r = 0.709**) while a significant negative with maximum temperature (r = -0.535*). Predators population viz.,Chrysoperla, coccinellids, and spiders population also attained their maximum population in the month of August and exhibited highly significant positive correlation (r = 0.863*, r = 0.723* and r = 0.611*), respectively with whitefly population and reported positive density-dependent response. It has been found that PC1 and PC2 confined 41.3 and 34 per cent of variability in the data, respectively.*

Interpretation: *The present study focused on the population fluctuation of whiteflies and its natural enemies in cotton and also their correlation with weather parameters and also the relationship between whiteflies and its natural enemies.*

Keywords: *Bemisia tabaci, Chrysoperla, Coccinellids, Correlation, Cotton, Population fluctuation, Predators, Spiders, Weather parameters.*



Introduction

Cotton, *Gossypium spp.* (Family Malvaceae), is one of the most commercially important fiber crops in the world. As an annual crop, it is grown in both tropical and warm temperate regions.

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It plays a major role in manufacturing of textiles, additionally it also produces seeds with a potential multi product base such as hulls, oil, lint and food for animals [1]. It has been reported that in India, nearly 5.8 million people grow cotton while 40-50 million people directly and indirectly get employed from cotton industry [2].

Although India grows 41 per cent of the world's cotton (133.50 lakh hectare) but a low productivity (487 kg/ha) is a dampener to the economy of the Indian farmers [3]. The lower productivity attributed mainly to the damage by various insect-pests cause 10-40 per cent losses [4] that is further accentuated by the lint quality deterioration. Adoption of Bt cotton that completely altered the cotton landscape as well as pest scenario in the country. Initially, the incidence of bollworms decreased drastically while the occurrence of sucking insect pests increased [5] [6]. Among sucking insect pests, whitefly, *Bemisiatabaci*(Gennadius), a phloem feeding insect, is economically more important because it causes 50 per cent decrease in boll yield [7]. It is a destructive pest of many horticultural, vegetable, ornamental and agricultural crops in tropical and subtropical countries of the world [8]. It is a polyphagous pest which feeds on greater than 900 different host plants. Damage by this pest is caused by two ways, firstly, by loss of cell sap due to which vitality of plants reduced.

Secondly due to secretion of honeydew, on which sooty mould develops, which interfere with photosynthesis and ultimately quality of harvested produce reduces. It also transmits cotton leaf curl virus in cotton [9].

Worldwide, in controlling the population of insect pests, natural enemies had massive importance [10]. In cotton ecosystem, the natural enemies of pests play a significant role. Across the India, against whitefly, a number of natural enemies from different groups have been recorded [11] [12] [13], [14].

Studies on population fluctuations in relation to biotic and abiotic factors are very important for proper understanding of pest ecology in key agricultural crops. By doing this fragile connection in the life cycle of insect-pest can be known, which eventually, help in developing efficient pest management strategies [15]. Existing weather parameters in an area affects whitefly and also its natural enemies. It has been reported that favourable environmental conditions play a major role in build-up of insect-pests and natural enemies. A proper identification of change in whitefly population and its natural enemies population along with change in weather conditions is most important for Integrated Pest Management (IPM). This will give an idea about the peak activity period of the pest which may be useful in developing pest management strategy. So keeping in view the importance of the crop and losses caused to it by insect-pest, the present research aimed to study the impact of abiotic factors on the population fluctuation of whiteflies and its natural enemies.

Materials and Methods

Experimental site: The field experiment was conducted at the Research farm, Cotton Section, Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar, (29.14° North latitude and 75.70° East longitude with an altitude of 215 m above mean sea level), Hisar. An experiment was conducted for two years during *kharif* 2017 and 2018. The *Bt*cotton variety, RCH-650 BG-II was sown in an area of 400 m^2 with a spacing of 67.5 cm between the rows and 60 cm between the plants in the month of May, during both years. To raise healthy crop all the practices were done as per the recommendation of Package of Practices of *Kharif* crops of CCSHAU, Hisar [16], except for the plant protection measures.

Seasonal incidence of whitefly

Observations on population of whiteflies were initiated 20 days after sowing (DAS) and continued till harvest of crop. Data on adults of whitefly were recorded from 20 randomly selected plants on 3 leaves per plant representing the top, middle and bottom canopy of the plant. Data were recorded early in the morning at weekly intervals. Later, the population was averaged to per leaf.

Seasonal incidence of natural enemies

Observations on the population of natural enemies (Chrysoperla, coccinellids and spiders) were initiated 20 days after sowing (DAS) and continued till harvest of crop. Data on eggs and larvae of chrysocolla, grubs and adults of coccinellids and adults of spiders were recorded from 20 randomly selected plants. Data were recorded early in the morning at weekly intervals. Later, the population was averaged to per plant.

Meteorological data: The data of weather parameters *viz*., maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, rainfall, wind speed and sunshine hours during experimental years 2017 and 2018 were obtained from the Meteorological Observatory of the Department of Agricultural Meteorology, CCSHAU, Hisar. Data under different heads were pooled for both seasons, *Kharif* 2017 and 2018.

Principal component analysis: To reduce the dimensions of data by using PCA a multivariate analysis was performed and the variables were transformed into principal components (PC) to describe the nature and level of the interaction between diverse variables. Principal components are the newly generated variables constructed as linear combinations of the initial variables. These new variables (i.e., principal components) are uncorrelated and most of the information within the original variables is squeezed or condensed into the first components (PCI and PC2). The significance of each variable explained by the remoteness among each vector component *i.e.* smaller the distance more significant is the relation. The length of the vector explains the variance due to that vector *i.e.* longer the length of the vector, the more is the deviation caused by the vector.

Statistical analysis: Correlation coefficient and multiple linear regression of different abiotic factors with whitefly and its natural enemies were worked out by using the OPSTAT software (http:// 192.168.2.174/opstat/default.asp) *i.e.* online platform for on-campus user. Principal Component Analysis (PCA) were plotted by using the R software [17].

RESULTS AND DISCUSSION

A. Population dynamics of whitefly on cotton: Whitefly adults started appearing from the 24th SMW (second week of June) and continued throughout the remaining crop season till second week of October corresponding to 41st SMW (Table 1). From an initial lower population (0.51 adults/leaf, 24th SMW), a gradual increase was witnessed that peaked (23.54 adults/leaf) during 34th SMW (fourth week of August) and declined steadily during later stages of crop growth to end with a moderate level of 4.65 during 41st SMW. Studies are in conformity with those of [18] for initiation of whitefly in the month of June. Many studies from the different pan Indian locations also confirmed whitefly appearance in mid-June and highest population in the month of August [19] [20] [21] [22] [23].

Correlation of whitefly with weather parameters: Whitefly population (Table 2) exhibited significant negative correlation ($r = -0.535^{*}$) with maximum temperature and significant positive with morning relative humidity ($r = 0.709^{**}$). These results are in conformity with various authors [18] [24] [25]

Principal component analysis: It has been noted that PC1 and PC2 confined 41.3 and 34% of the variability in data, respectively (Fig. 1a). This figure explains that weather parameters which are positively correlated with whitefly *viz*., morning relative humidity, evening relative humidity and sun shine hours are situated on the same side of the quadrats while negatively related variables *i.e.,* maximum temperature, minimum temperature, wind speed and rainfall are located on the contrary quadrats. In the case of whitefly and predators, PCA explains that PC1 and PC2 are responsible for 74.1 and 19.9 % of the variability in data, respectively (Fig. 1b). This figure also explains that positively correlated variables *viz.,* coccinellids, chrysoperla and spiders population are positioned on same side of axis of whitefly.

Regression analysis

The multiple regression analysis, indicated that weather parameters (maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, wind speed, total rainfall and sunshine hours) were responsible for 78 per cent variability in whitefly population (R2 = 0.78) (regression equation Y1) (Table 3). Results are in line with [26] who reported that all the weather parameters exerted a 64.90 and 79.50 per cent impact on whitefly adult population. It has been reported that abiotic factors collectively contributed 68 per cent variability in whitefly adult population, which supports present finding [27]. However morning relative humidity and maximum temperature both were the most significant weather parameters, together contributed 55 per cent variability (Table 4) and individually they contributed 50 and 29 per cent variability (R2 = 0.50, 0.29) in whitefly population, respectively (Fig. 2a & 2b).

B. Population dynamics of *Chrysoperlazastrowiisilemmi* on cotton: It is a effective predator on a number of soft bodied insects like whiteflies, thrips and aphids. It has been reported that the commencement of the predator occurred on the crop during 25th SMW and remained active throughout the period of study *i.e*. from 25th to 41st SMW (*i.e.* June to October) (Table 1). Population increased sustainably along with population of whitefly and attained its peak during same SMW as of whitefly as in 34th SMW (fourth week of August) (1.67 eggs and larvae/plant). Same finding were given by [28] [29], who reported that maximum population of chrysoperla were observed in month of August and September.

Correlation and Regression analysis with weather parameters: Chrysoperla population exhibited significant negative correlation ($r = -0.553^{*}$) with maximum temperature while significant positive with morning relative humidity ($r = 0.765^{**}$) and evening relative humidity ($r = 0.626^{**}$) (Table 2). Principle component analysis showed that PC1 and PC2 confined 39.3 and 37.4 per cent of the variability in the data, respectively (Fig. 1c).Same observations were recorded by [13] [30].

Weather parameters accounted 73 per cent variability in the population of chrysoperlaover the whole interval of crop (R2 = 0.73) (Regression equation Y2) (Table 3) and 64 per cent of this was contributed by morning and evening relative humidity (R2 = 0.64) (Table 4).Out of which 58 per cent were contributed only by the morning relative humidity (R2 = 0.58) (Fig. 2d), 30 per cent by maximum temperature and 39 per cent were given by evening relative humidity (Fig. 2c & 2e).

C. Population dynamics of coccinellids on cotton: Similar to chrysoperla, coccinellids were recorded initially during 25th SMW (0.10 grubs and adults per plant). The population increased gradually and reached at its peak during the fourth week of August (34th SMW) (2.33 grubs and adults per plant) (Table 1). Results are in conformation with [21] [28], [31] who reported that the population of coccinella appeared in June and peaked in month of August. Subsequently, the population started decline steadily, which may be due to a decline in prey density and reached to its minimum during 41st SMW (0.32 grubs and adults per plant) (Table 1).

Correlation and Regression analysis with weather parameters: Populations of coccinellids showed a significant positive correlation with morning relative humidity ($r = 0.616^{**}$) and evening relative humidity ($r = 0.697^{**}$). Results are in line with [13] [32] [33], who reported that coccinellids population showed significant positive correlation with morning and evening relative humidity.

Principle component analysis showed that PC1 and PC2 confined 39.4 and 36.5 per cent of the variability in the data, respectively (Fig. 1d).Multiple regression equations suggests that all the weather parameters were responsible for 81 per cent variability in the population (R2 = 0.81) (Regression equation Y3) (Table 3). Out of which morning and evening relative humidity were mainly accountable for changes in coccinellids population, contributed together 56 percent variability (R2 = 0.56), of which, individually were responsible for 37 and 48 per cent variability (R2 = 0.37) (Fig. 2f & 2g).

D. Population dynamics of spiders on cotton: Spiders are generalist predators which mostly feed on sucking insect pests. Initially population of spiders were reported from 25th SMW and remained active throughout the whole crop duration 41st SMW (Table 1). The population increased slowly from 25th SMW (0.14 adults per plant) and reached to peak during the 35th SMW (2.64 adults per plant). Afterward, it declined as the population of whitefly started declined. It has been reported that the incidence of spiders occurred from June and attained its peak in month of August and remained throughout the crop season [13], which supports present finding. Also reported that peak population of spiders in month of August [29].

Correlation and Regression analysis with weather parameters: Spiders population reported a significant negative correlation with maximum temperature ($r = -0.506^{*}$) while a significant positive with morning relative humidity ($r = 0.681^{**}$) (Table 2). Principle component analysis explains that PC1 and PC2 confined 42.6 and 33.2 per cent of the variability in the data, respectively (Fig. 2e). It was reported that maximum temperature harmed the population of spiders [13]. It was found that maximum temperature had a negative and relative humidity had a positive impact on spiders [34]. Multiple regression analysis, indicated that there was 65% variability (R2 = 0.65) in spiders population due to various weather parameters (regression equation Y3) (Table 3). Out of which 50 per cent variability were due to morning relative humidity and maximum temperature (R2 = 0.50) (Table 4) while 34 per cent were due to maximum temperature (Fig. 2h).

E. Population of natural enemies in relation to whitefly*:* As the population of whitefly increased, the natural enemies population also increased. After attaining the peak as the population decreased, simultaneously the population of natural enemies also decreased, showing a positive correlation (Table 1). Population of chrysoperla, coccinellids and spiders exhibited highly significant and positive correlation with the population of whitefly r = 0.863*, r = 0.723**, r = 0.611**, respectively (Table 5). It was reported that predatory lady bird beetle had a positive significant relation with whitefly population (r = 0.97) on okra crop [33]. It was too reported that lady bird beetle had a positive relation with whitefly on Indian bean [35]. Linear regression equation of chrysoperla, coccinellids and spiders with whitefly revealed that whitefly population accounted 74, 52 and 37 per cent (R2 = 0.74, 0.52, 0.37) variability in chrysoperla, coccinellids and spiders population, respectively (Fig. 3a, 3b, 3c) and results are in confirmation with [36] who reported that chrysoperla showed significant correlation with whitefly population accounted 55 per cent variability.

Table 1: Population dynamics of whitefly and its predators on cotton (Pooled of Kharif 2017 and 2018)

SMW*	Whitefly (adults/leaf)	*Chrysoperla zastrowii sillemi* (eggs and larvae/plant)	Coccinellids (grubs and adults/plant)	Spiders (adults/plant)	MAX TEMP (°C)	MIN TEMP (°C)	RH (M) (%)	RH (E) (%)	AVG WS KM/H	BRI SUN HRS	RAIN FALL (mm)
24	0.51	0.00	0.00	0.00	39.73	26.98	67.86	42.79	9.84	4.95	10.35
25	1.54	0.12	0.10	0.14	36.67	25.51	74.07	47.64	6.07	6.85	63.15
26	3.54	0.45	0.56	0.76	34.80	26.65	84.93	70.93	7.04	4.86	92.95
27	6.65	0.65	0.61	1.11	35.85	26.82	83.29	59.57	6.64	6.71	25.75
28	8.18	0.43	0.88	1.19	36.92	27.90	82.57	60.29	6.21	6.79	7.10
29	9.23	0.93	1.32	1.32	34.40	26.43	92.71	75.86	5.81	5.54	30.00
30	12.49	1.03	1.56	0.75	33.56	26.65	93.07	78.57	6.20	4.80	47.50
31	14.32	0.89	1.23	0.93	34.69	26.24	86.21	63.50	6.90	4.96	4.75
32	17.45	0.94	1.64	0.73	36.08	27.04	83.00	59.79	6.64	5.29	1.90
33	20.32	1.21	1.94	0.95	34.22	26.16	88.57	67.14	5.69	6.27	25.65
34	23.54	1.67	2.33	0.89	35.31	26.75	91.43	66.57	5.56	6.39	13.05
35	21.01	1.14	1.64	2.64	34.29	26.24	90.64	73.57	6.54	5.49	17.70
36	19.32	0.86	1.30	1.86	34.34	25.39	91.21	66.57	4.98	5.45	29.80
37	20.01	0.74	0.65	1.43	34.78	24.48	88.86	60.93	4.61	7.74	14.60
38	21.88	1.12	0.82	1.59	34.61	22.63	90.14	56.50	4.11	6.46	22.30
39	10.54	0.85	0.63	1.65	32.84	22.25	91.43	54.93	3.65	5.85	16.00
40	5.21	0.48	0.43	1.43	35.54	19.66	85.07	34.07	2.88	8.05	0.00
41	4.65	0.31	0.32	1.10	33.91	16.99	87.29	36.43	3.15	6.81	0.00

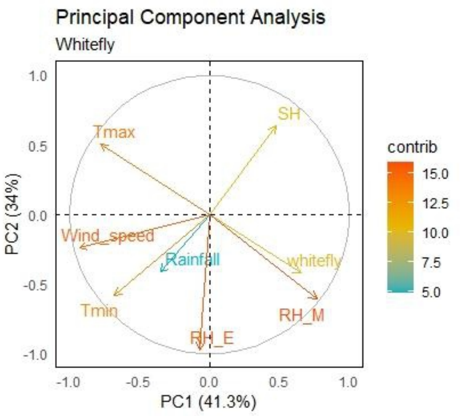
**SMW= Standard Meteorological Week*

Table 2: Correlation of whitefly, chrysoperla, coccinellids and spiders population with weather parameters

	Correlation coefficient (r value)			
	Whitefly	***C. zastrowi sillemi***	**Coccinellids**	**Spiders**
Temperature max. (ºC)	-0.535*	-0.553*	-0.387^{NS}	-0.506*
Temperature min. (ºC)	-0.043^{NS}	0.210^{NS}	0.411^{NS}	-0.239^{NS}
Morning RH (%)	0.709**	0.765**	0.616**	0.681**
Evening RH (%)	0.363^{NS}	0.626**	0.697**	0.260^{NS}
Sunshine (hrs)	-0.402^{NS}	-0.197^{NS}	0.032^{NS}	-0.349^{NS}
Rainfall (mm)	0.089^{NS}	-0.142^{NS}	-0.291^{NS}	0.156^{NS}
Wind speed (km/hr)	-0.368^{NS}	-0.147^{NS}	-0.124^{NS}	-0.250^{NS}

**Significant at P=0.05%; **Significant at P=0.01%*

1a



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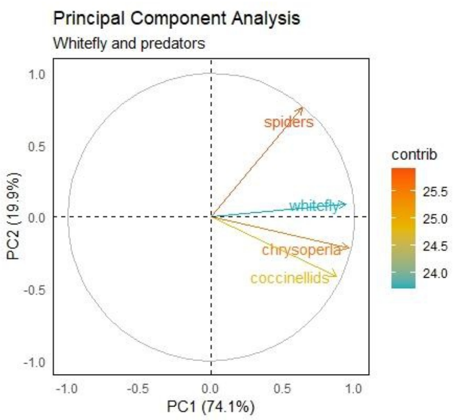

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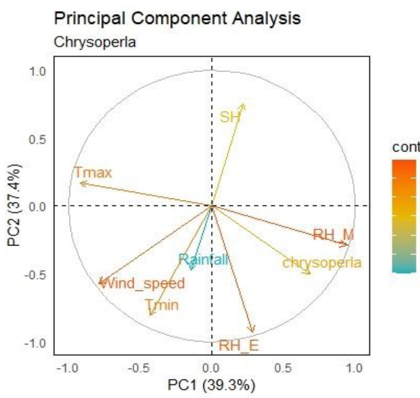

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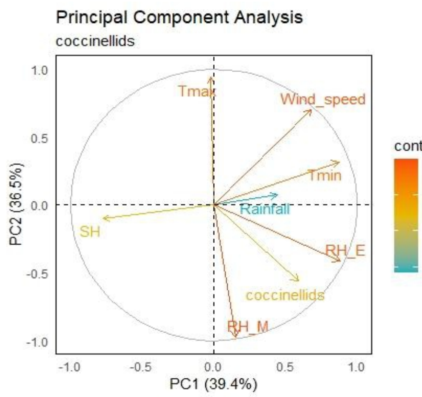

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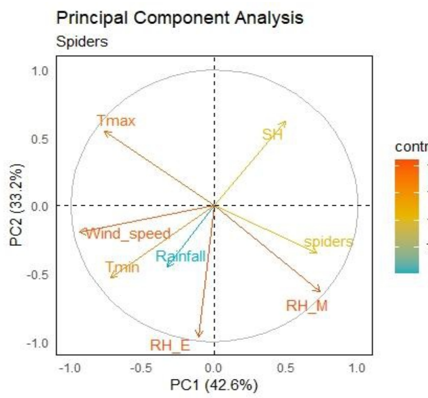


Fig. 1: Loading plots of whitefly population with weather parameters (a) whitefly population with predators (b), Chrysoperla population with weather parameters (c) Coccinellids population with weather parameters (d) and Spider population with weather parameters (e).

Table 3: Multiple regression analysis between whitefly, chrysoperla, coccinellids and spiders with weather parameters on cotton

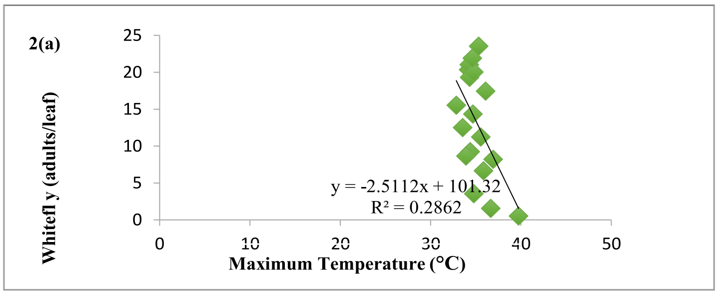
	Multiple linear regression equations	R2
Whitefly	Y1 = -16.243 – 1.095 X1 + 1.562 X2 + 0.482 X3 + 0.016 X4 – 2.320 X5 + 0.286 X6 - 0.125 X7	0.78
C. zastrowisillemi	Y2 = -11.393 – 0.042 X1 + 0.169 X2 + 0.131 X3 - 0.051 X4 + 0.167 X5 + 0.027 X6 + 0.012 X7	0.73
Coccinellids	Y3 = -15.14 + 0.085 X1 + 0.161 X2 + 0.127 X3 - 0.032 X4 + 0.151 X5 - 0.110 X6 - 0.011 X7	0.81
Spiders	Y4 = 2.739 + 0.055 X1 - 0.159 X2 - 0.032 X3 + 0.067 X4 – 0.171 X5 + 0.075 X6 - 0.010 X7	0.65

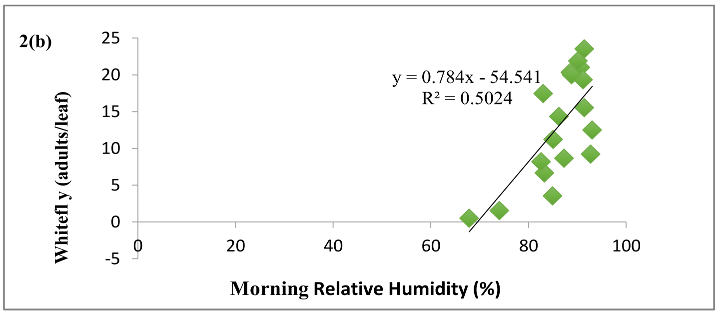
X1 = Maximum Temperature, X2 = Minimum Temperature, X3 = Relative humidity (morning), X4 = Relative humidity (evening), X5 = Wind speed, X6 = Sun shine hours, X7 = Rainfall (mm)

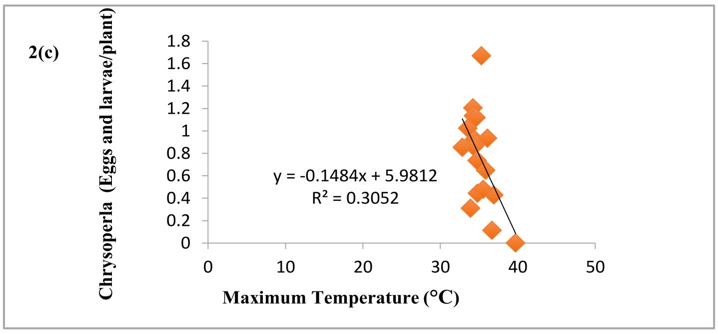
Table 4: Step wise multiple linear regression showing the contribution of major weather parameters in variability of whitefly, chrysoperla, coccinellids and spiders

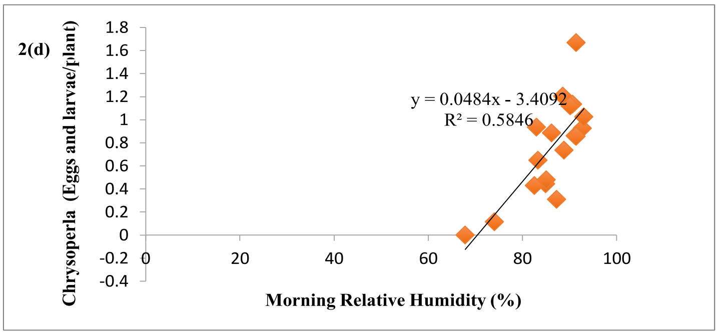
	Step-wise multiple linear regression equations	R2
Whitefly	Y1 = -54.541 + 0.784 X3	0.50
	Y1 = -179.419 + 2.341 X1 + 1.277 X3	0.55
C. zastrowi sillemi	Y2 = -3.409 + 0.048 X3	0.58
	Y2 = -3.094 + 0.038 X3 + 0.009 X4	0.64
	Y2 = -11.185 + 0.150 X1 + 0.175 X3 + 0.007 X4	0.70
Coccinellids	Y3 = - 4.282 + 0.061 X3	0. 37
	Y3 = -3.041 + 0.033 X3 + 0.027 X4	0.56
Spiders	Y4 = -4.325 + 0.063 X3	0.40
	Y4 = -6.861 + 0.047 X1 + 0.073 X3	0.46

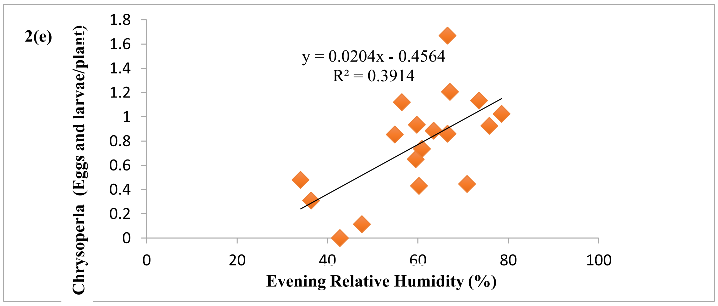
X1 = Maximum Temperature, X2 = Minimum Temperature, X3 = Relative humidity (morning), X4 = Relative humidity (evening), X5 = Wind speed, X6 = Sun shine hours, X7 = Rainfall (mm)

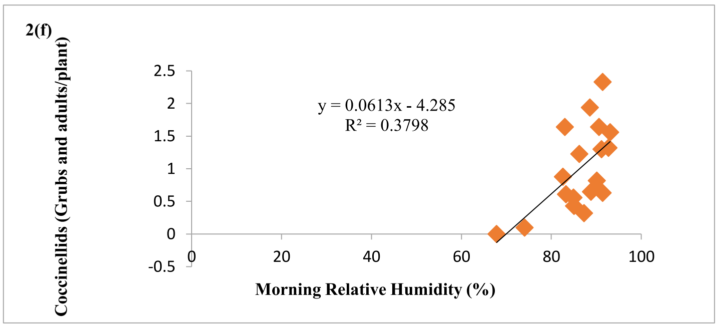


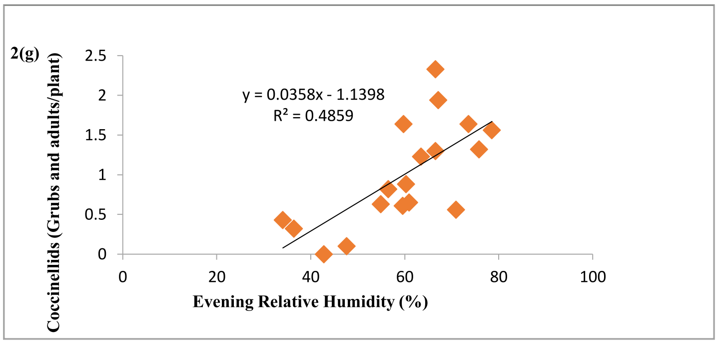


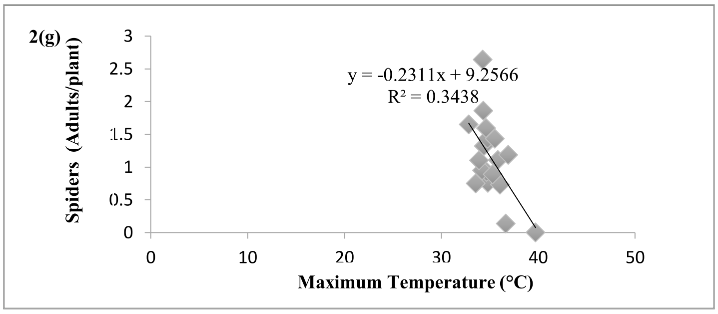












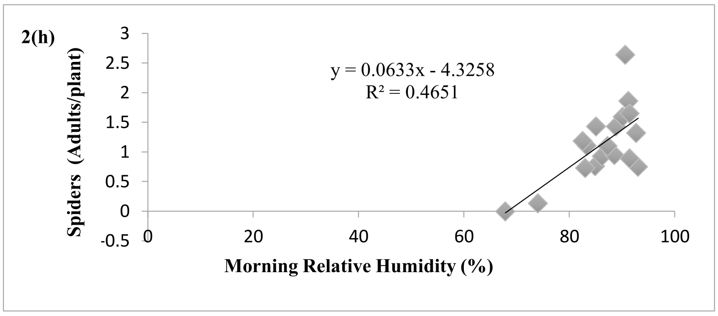


Fig. 2: Linear regression line plots of whitefly population with maximum temperature (2a), whitefly population with morning relative Humidity (2b), Chrysoperla population with maximum temperature (2c), Chrysoperla population with morning relative Humidity (2d), Chrysoperla population with evening relative Humidity (2e), Coccinellids population with morning relative humidity (2f) Coccinellids population with evening relative humidity (2g) Spiders population with maximum temperature (2h), Spiders population with morning relative Humidity (2i),

Table 5: Correlation coefficient between whitefly and natural enemies (Pooled)

Predators	r
C. zastrowisillemi	0.863**
Coccinellids	0.723**
Spiders	0.611**

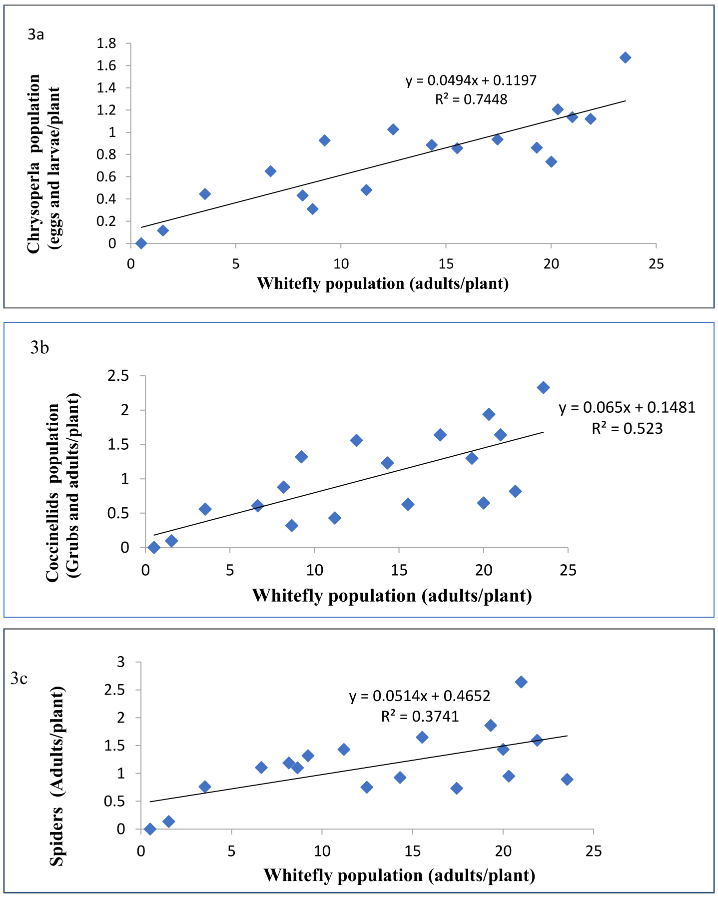


Fig. 3: Linear regression line plots of whitefly with Chrysoperla (3a), Coccinellids (3b), and Spiders (3c)

CONCLUSION

The present study mainly focused on the population fluctuation of whiteflies and its natural enemies (chrysocolla, coccinellids and spiders) throughout the crop season and also their relation with different weather parameters. Additionally, the relationship between whitefly and its natural enemies. Natural enemies showed a highly significant positive association with whitefly, showing a positive density-dependent response. Proper understanding of population fluctuation of whiteflies along with biotic and abiotic factors may enhance the improvement for management of pest. Development of IPM program including the natural enemies with other management practices minimize the dependence on pesticides.

Abbreviation

SMW: Standard Meteorological Week

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Scope of the study: A population fluctuation study of whitefly (*Bemisia tabaci*), considering weather parameters, intentions to understand how factors such as moisture, temperature, rainfall and humidity effect whitefly populations, helping to predict the pest outbreaks and develop effective management tactics.

Conlict of Interest: The authors claim no conlicts of interest in publishing this manuscript.

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