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Spatial distribution of whitefly, *Bemisia tabaci* (Gennadius) on transgenic cotton (*Gossypium hirsutum* L.) in weeded and non-weeded agro-ecosystem in Sirsa district, Haryana state

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Abstract
Present study was carried out during *Kharif* 2018 to know the changes in population of whitefly adults as well as nymphs in weedy and non-weedy habitats. The transgenic hybrid cotton variety RCH 650 was sown in first fortnight of May, 2018 with a spacing of 100×45 cm and replicated four times in both non-weedy and weedy habitats. Mean adult population (adults/leaf) peaked twice during the study *i.e.* in 29th (8.01 and 8.82/ leaf) and 35th SMW (8.96 and 10.89 / leaf) whereas, whitefly nymphs peaked in 34th SMW (20.12 and 23.21/leaf) in non-weedy and weedy habitat respectively. White fly population (nymphs and adult) presented a non-significant positive correlation with temperature and relative humidity. Adult population in non-weedy habitat was significantly negatively correlated with rainfall (r = -0.502) and wind speed (r = -0.515) whereas nymphal population showed non-significant negative correlation. Regression analysis revealed that influence of weather parameters was high and significant on whitefly adults (R^2=0.86) and nymphal (R^2=0.57) population.

Keywords: Abiotic factors, cotton, insect-pest, population dynamics, whitefly

Introduction
Cotton, (*Gossypium hirsutum)* is known by various names such as "King of Fiber" and “the white gold”. China, India, USA, Pakistan and Brazil are the most important cotton producing countries of world. Cotton crop occupies 10.5 million ha in India with production of 35.10 million bales and average yield of 568 kg/ha [2]. In Haryana, cotton crop is mainly grown in five districts *viz.*, Sirsa, Fatehabad, Hisar, Jind and Bhiwani covering 4.98 lakh hectares with a production of 20.00 lakh bales with an average yield of 683 kg/ha [2].

Cotton crop is unable to express it’s full potential because of biotic and abiotic stresses encountered during its life cycle. Various biotic constraints appear to be very important, of which the ravages caused by insect-pest assume greater importance. Approximately, 184 insect-pests have been so far reported on cotton in India which causes upto 80 per cent loss to the yield [17]. Major sucking insect-pests of cotton are leafhopper, *Amrasca biguttula biguttula* (Ishida); whitefly, *Bemisia tabaci* (Gennadius); mealy bug, *Phenacoccus solenopsis* (Tinsley); Thrips, *Thrips tabaci* (Lindeman) and aphid, *Aphis gossypii* (Glover). After the introduction of *Bt* cotton hybrids, a substantial change in insect-pest complex has occurred and transgenic cotton played important role in the management of the bollworm population only [8, 15], but that led to an exponential rise in population of sucking pests especially *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) is a major threat to the *Bt* cotton grown throughout the country. It is most notorious pest in tropical and subtropical agriculture and is quite devastating on cotton, brinjal, okra, tomato and several ornamental plants [16]. Cotton leaf curl virus (CLCV) transmitted by *B. tabaci* is also very serious problem throughout the cotton belt in India. As weather parameters have been proved to be the major factors in pest development in the experiments conducted by many researchers. The relationship between the ecological factors and the population build-up of whitefly has been studied by many researchers at different locations [19, 9, 5, 4]. The present investigations were carried out to understand the abiotic factors affecting the buildup of whitefly in traditional cotton growing district in Haryana state.

Materials and Methods
The transgenic hybrid cotton variety RCH 650 was sown on 13th May, 2018 with a spacing of 100×45 cm for the experimental studies during *Kharif*, 2018.The experiment was replicated four times in both non-weedy and weedy habitats. All the other cultural practices were adopted as per the recommendation of “Package of Practices of *Kharif* crops” of CCS Haryana Agricultural University, Hisar [3]. Weeds were removed from weeded plots to make them weed free and weeds were not removed from non-weeded plots.

Observations recorded
The observation on population of adults and nymphs started approximately after 40 days of sowing of crop and were recorded from 27th to 43rd SMW (July to October) by observing undersides of three fully formed leaves, one each from the upper, middle and lower canopy of each five randomly selected plants from each plot. All the observations were recorded early in the morning, so that the adults do not fly away on disturbance. Further a hand mirror was placed at the underside of leaves and counting of whiteflies was undertaken. The nymphal population of whitefly was counted by using the hand lens of 10X zoom. Both the whitefly adult and nymphal population was averaged and expressed as number of adults or nymph per leaf.

Statistical analyses
The data on population dynamics of whitefly nymphs and adults was subjected to correlation and regression analysis with data on weather parameters like temperature (maximum, minimum and average temperature), relative humidity (morning, evening and average relative humidity), wind speed and rainfall using Online Agriculture Data Analysis Tool (OPSTAT) and Statistical Package for the Social Sciences (SPSS). The weather data were obtained from Automatic Weather Station, Central Institute of Cotton Research, Sirsa.

Results and discussion
The data on population of whitefly, *B. tabaci* adults and nymphs were recorded at weekly intervals on *Bt* cotton hybrid RCH 650 during *Kharif* 2018 from 27th SMW to 43rd SMW under non-weedy and weedy habitats.

Population dynamics of whitefly, *B. tabaci* adults
The pest population in weedy (W) habitat was higher than on non-weedy (NW) habitats during the most period of observations in season (Fig 1 and Table 1). The adult population in both the habitats was recorded low in first week of July (27th SMW) with a population density of 0.86 and 0.78 adults per leaf in non-weedy and weedy plots, respectively. The population of the insect increased with the advancement of crop growth and reached to 1.27 and 2.22 adults per leaf in 28th SMW in non-weedy and weedy habitats, respectively. The population of whitefly adult crossed the ET two times from 27th SMW to 43rd SMW during crop season (Fig. 1). First peak was observed during vegetative growth period of cotton crop in 29th SMW with population density of 8.01 and 8.82 adults per leaf in non-weedy and weedy habitats, respectively. The population of whitefly adults remain low with the population count of 1.26, 1.06 and 1.03 adults per leaf during 30th, 31st and 32nd SMW, respectively in non-weedy habitat and population in weedy habitat from 30th to 32nd week was also low, but remain higher than the non-weedy habitat (Fig.1 and 2). The population starts increasing after 32nd SMW and the adult whiteflies remained most active during 33rd SMW to 37th SMW and during this period the population count were more than 4.90 adults per leaf and more than 5.14 adults per leaf in non-weedy and weedy habitats, respectively. Population of whitefly adults per leaf in weedy habitat remain higher than non-weedy habitat throughout the growing period except in 37th SMW as shown in fig 1. The second peak of whitefly observed in 35th SMW with a population density of 8.96 and 10.89 adults per leaf in non-weedy and weedy habitats, respectively. As per Figure 2, after 37th SMW population of whitefly reduced due to rainfall in three consecutive weeks (37th to 39th SMW) and again increased in 40th week with population count of 5.97 and 6.23 adults per leaf in non-weedy and weedy habitats, respectively.

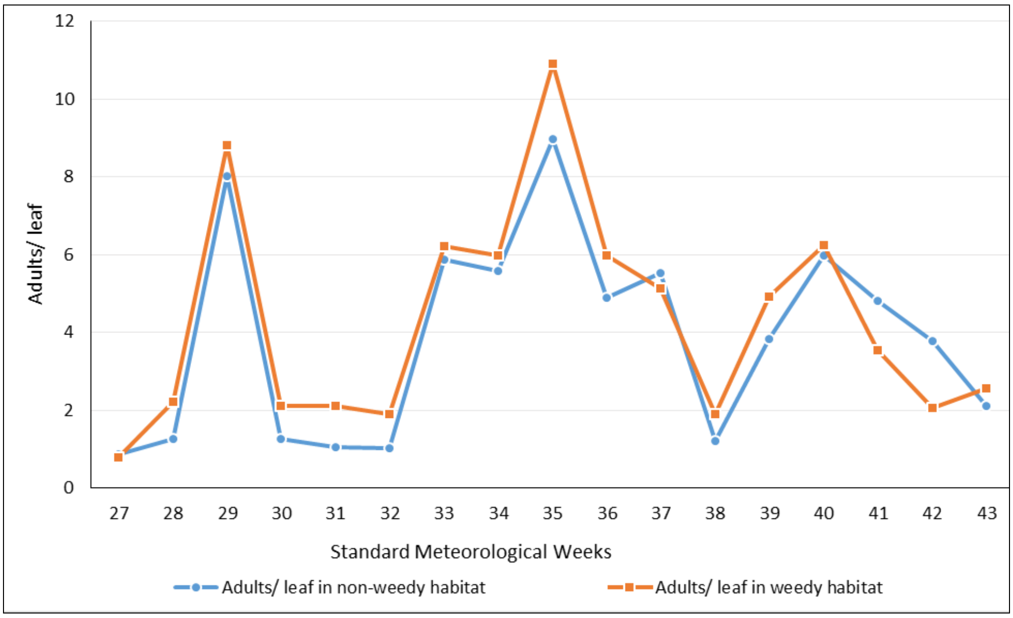

Fig 1: Whitefly, *Bemisia tabaci* adults population in weedy and non-weedy (weedfree) habitats during the crop season

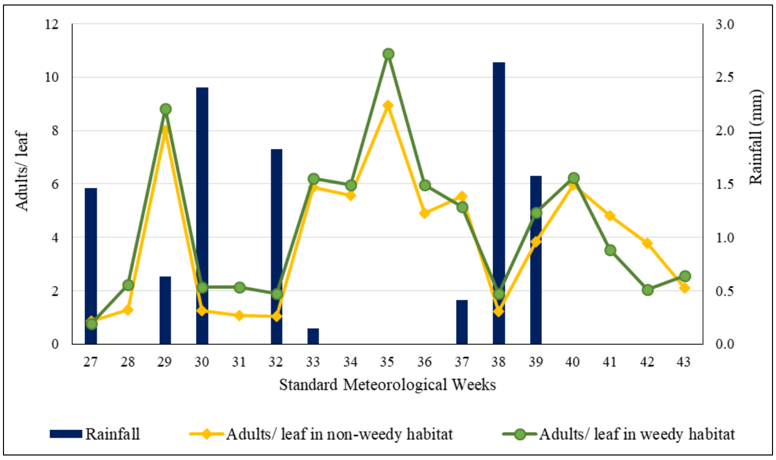

Fig 2: Relationship of whitefly, *Bemisia tabaci* adults population in weedy and non-weedy (weed free) habitat with rainfall

Population dynamics of *B. tabaci* nymphs in non-weedy and weedy habitat

As depicted in Fig. 3 and table 1, the population of whitefly nymphs was higher on weedy habitat as compared to non-weedy habitat during 27th to 43th SMW (1st week of July to October) except in 27th (1st week of July) and 37th SMW (2nd Week of September). The population of whitefly nymphs during 27th SMW recorded very low *i.e.,* 1.28 and 1.72 nymphs per leaf in non-weedy and weedy habitat, respectively. The population increased from 27th SMW and reached to a population count of 9.89 in non-weedy and 11.76 nymphs per leaf in 29th SMW (3rd week of July) count observed in weedy habitat. The nymphal population showed higher presence in 29th SMW *i.e.,* 9.89 and 11.76 nymphs per leaf in non-weedy and weedy habitats, respectively and then from 33rd to 37th SMW (3rd week of August to 2nd week of September) where the nymphal count remain more than six nymphs per leaf in both the habitats (Table 1 and fig. 3).

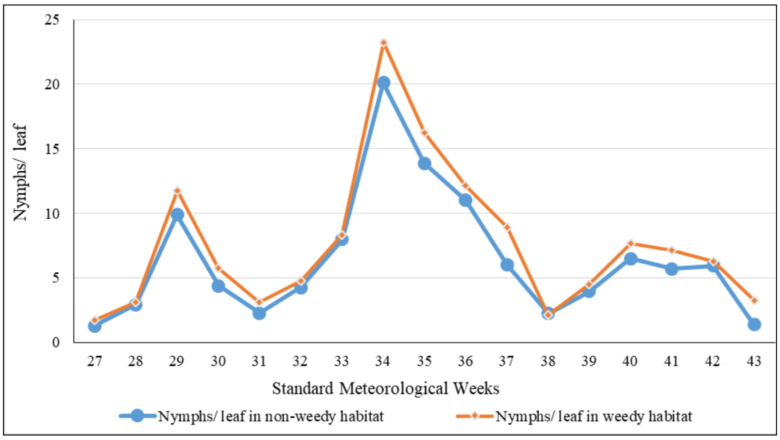

Fig 3: Nymphal population of whitefly, *Bemisia tabaci* in weedy and non-weedy (weedfree) habitats during the crop season

Table 1: Population of whitefly, *Bemisia tabaci* adults and nymphs in non-weedy and weedy habitats

SMW*	Population				Weather Parameters							
	Adult Whitefly Population per leaf		Nymphal Population per leaf		Relative Humidity (%)			Temperature (°C)			Average Rainfall (mm)	Wind Speed (km/hr)
	Non weedy	Weedy	Non weedy	Weedy	Morning	Evening	Average	Max	Min	Average		
27	0.86	0.78	1.28	1.72	79.57	58.86	69.21	35.79	24.37	30.08	1.46	3.04
28	1.27	2.22	2.92	3.14	73.43	53.71	63.57	38.14	27.01	32.58	0.00	3.99
29	8.01	8.82	9.89	11.76	78.00	66.57	72.29	35.41	26.50	30.96	0.63	1.82
30	1.26	2.12	4.39	5.75	83.71	64.71	74.21	35.08	26.36	30.72	2.40	2.49
31	1.06	2.12	2.26	3.11	65.00	52.14	58.57	36.24	27.43	31.83	0.00	3.92
32	1.03	1.89	4.26	4.78	79.00	66.57	72.79	34.19	25.82	30.01	1.83	3.05
33	5.86	6.22	7.96	8.29	83.29	59.43	71.36	35.49	26.07	30.78	0.14	1.01
34	5.58	5.97	20.12	23.21	79.86	59.43	69.64	35.74	27.43	31.59	0.00	2.71
35	8.96	10.89	13.89	16.21	72.71	56.00	64.36	35.76	26.97	31.36	0.00	1.14
36	4.90	5.97	11.01	12.13	76.14	58.57	67.36	35.10	26.64	30.87	0.00	1.70
37	5.53	5.14	6.03	8.94	77.57	54.71	66.14	35.06	25.36	30.21	0.41	1.57
38	1.21	1.89	2.23	2.12	74.00	56.00	65.00	34.14	24.09	29.11	2.64	2.52
39	3.83	4.92	3.94	4.53	91.14	61.00	76.07	31.47	22.37	26.92	1.57	0.53
40	5.97	6.23	6.49	7.63	87.57	44.29	65.93	34.44	22.00	28.22	0.00	0.38
41	4.81	3.53	5.69	7.11	74.14	47.71	60.93	32.37	19.21	25.79	0.00	0.48
42	3.78	2.06	5.93	6.29	70.29	28.43	49.36	33.40	18.54	25.97	0.00	0.17
43	2.11	2.56	1.39	3.26	62.14	33.00	47.57	32.54	16.79	24.66	0.00	0.08
Mean	3.88	4.31	6.78	8.13	76.92	54.12	65.55	34.73	24.29	29.51	0.65	1.80

*Standard Meteorological Week

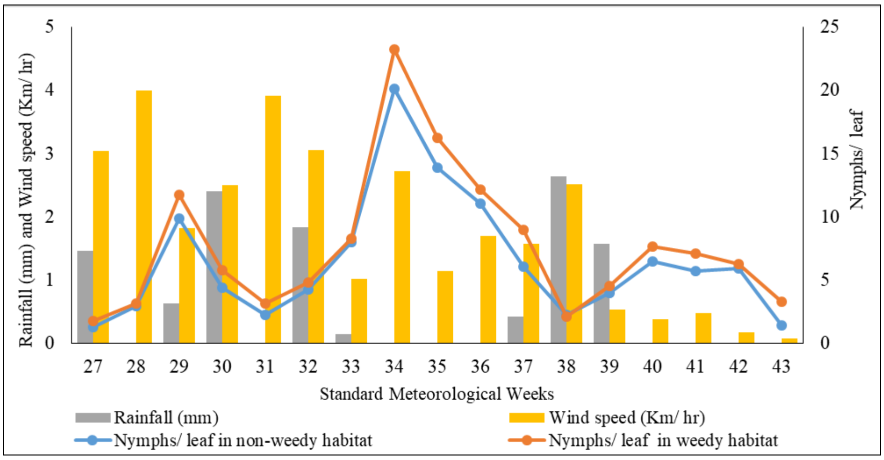

Fig 4: Relationship of nymphal population of whitefly, *B. tabaci* in weedy and non-weedy habitats with rainfall and wind speed

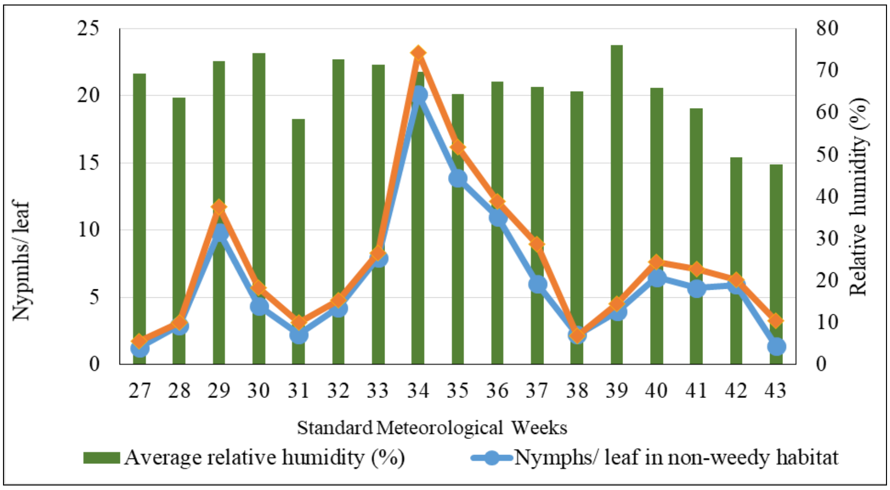

Fig 5: Relationship of nymphal population of whitefly, *B. tabaci* in weedy and non-weedy habitats relative humidity

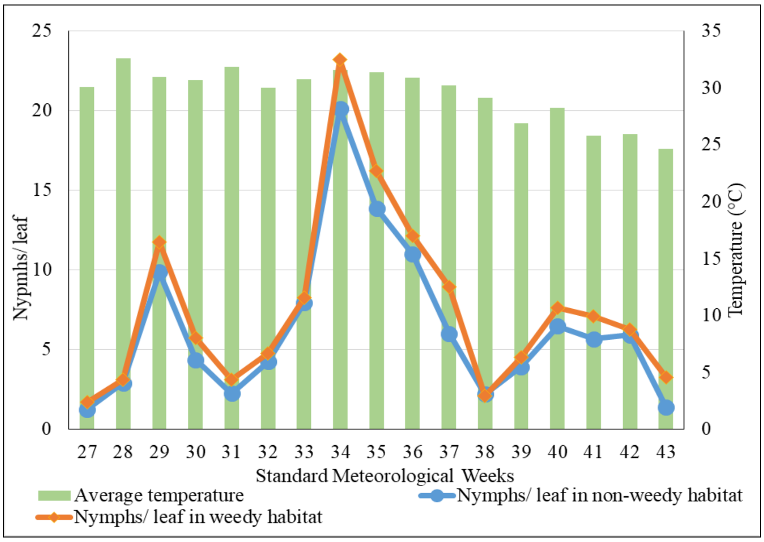

Fig 6: Relationship of nymphal population of whitefly, *B. tabaci* in weedy and non-weedy habitats temperature

Peak of whitefly nymphs *i.e.*, 20.12 and 23.21 nymphs per leaf in non-weedy and weedy habitats, respectively was observed in 34th SMW (2nd Week of August) at the time when average temperature during the day was 31.59°C, average relative humidity was 69.64 per cent, wind speed 2.71 km/hr and no rainfall (Fig. 4, 5 and 6). The population count started to decline from 35th SMW (3rd week of August) and reached to count of 2.23 and 2.12 nymphs per leaf in non-weedy and weedy habitats, respectively in 38th SMW (3rd week of September) as shown in table 1. The whitefly nymphs again reached up to the count of 6.49 and 7.63 nymphs per leaf in non-weedy and weedy habitat, respectively and then continuously declined up to the maturity of cotton crop.

In present study whitefly incidence started in first week of July (27th SMW), but population transcribed below ET during first fortnight of July that started increasing afterwards. Whitefly population attained peak level in July to August in an experiment in year 2015 [18] as evident in present findings.

The whitefly population in weedy and non-weedy habitats fluctuated with same trend. Mean adult population peaked twice during the study *i.e.,* in the month of July during 29th SMW (8.01 and 8.82 adults per leaf in non-weedy and weedy habitats, respectively) and in the month of August during 35th SMW (8.96 and 10.89 adults per leaf in non-weedy and weedy habitats, respectively). Similar findings of two closer peaks of adult population were observed *i.e.,* during 30th and 35th SMW in year 2013 [10] with number as high as 29.5 and 27.4 adults/leaf, respectively on RCH 134 variety of cotton. The population of whitefly nymphs peaked in month of August during 34th SMW (20.12 and 23.21 nymphs per leaf in non-weedy and weedy habitats, respectively), but it remained higher than that of adults population throughout the crop season. Population of nymphs reported as low [14] during initial period of crop growth, but remain higher than the adult population and peaks of whitefly adults equally recorded during 33th and 39th SMW (*i.e.,* month of August and September) with nymphal population as high as 45.26 and 62.93 nymphs per leaf so as depicted in the present results. However, contradictory results have been reported by Chavan *et al.* (2016) [6] as they informed the peak population of whitefly was observed during month of November at Parbhani (Maharashtra). It may be due to different agro-climatic conditions experienced by insect-pests in cotton crop.

Whitefly (adults and nymphs) population in weedy habitat was found higher than non-weedy plot during most of the period of observation, which show that presence of weeds helped in population build-up of whitefly and supposed to enhance the activities of whitefly by acting as host or breeding site in a number of ways. These findings are documented as complete eradication of weeds in okra field [12] reduced the activities of whitefly.

Plate 1: Whitefly, *Bemisia tabaci* emerging from fourth nymphal stage

Plate 2: Whitefly, *Bemisia tabaci* adult and egg on cotton leaf

Correlation of whitefly, *B. tabaci* population in non-weedy and weedy habitats in relation to weather parameters

The correlation between weather parameters and *Bemisia tabaci* (nymphs and adults) in the table 2 revealed that whitefly adult population exhibited a non-significant positive correlation with morning (r=0.214 in non-weedy and r=0.233 in weedy habitat), evening (r=0.052 in non-weedy and r=0.233 in weedy habitat) and average relative humidity (r=0.134 in non-weedy and r=0.265 in weedy habitat) and also with minimum temperature (r=0.106 in non-weedy and r=0.301 in weedy habitat) and average temperature (r=0.073 in non-weedy and r=0.251 in weedy habitat) in both habitats. Maximum temperature shown an attribute of a non-significant negative correlation (r= -0.009) in non-weedy habitat, but a non-significant positive correlation (r= 0.108) with whitefly adults in weedy habitat. There were a significant negative correlation of rainfall (r= -0.502) and wind speed (r= -0.515) with whitefly adults population in non-weedy habitat. So, rainfall and wind speed caused the decrease in adult population in non-weedy habitat (Fig. 2). Though, the correlation of rainfall (r=-0.403) and wind speed (r=-0.354) demonstrated statistically non-significantly negative with whitefly adults population in weedy habitat, but population count of adults in weedy habitats also shows deceasing trend with increase in rainfall and wind speed as shown in figure 2.

In general, no clear cut relationship could be worked out between whitefly population and weather parameters. However, non-significant correlation of whitefly worked out with morning relative humidity (r=0.214 in non-weedy and r=0.233 in weedy habitat), evening relative humidity (r=0.052 in non-weedy and r=0.233 in weedy habitat, maximum temperature (r= -0.009 in non-weedy and r=0.108 in weedy habitat), minimum temperature (r=0.106 in non-weedy and r=0.301 in weedy habitat); results of present experiments are in-line with studies [1] based on cotton concluded that *B. tabaci* population exhibited a non-significant positive correlation with both maximum (r=0.463) and minimum temperature (r=0.293) in year 2013. Outcome of present study also supported by credentials [14] that whitefly adults population have positive correlation with morning relative humidity (r=0.455) and negative correlation (r= -0.404) with maximum temperature. Population of whitefly on cotton associated non-significantly positive (r=0.36) with average temperature [13]. Nymphal population in both habitats exhibited non- significant positive correlation with morning relative humidity (r=0.134 in non-weedy and r=0.265 in weedy habitat) and evening relative humidity (r=0.134 in non-weedy r=0.265 in weedy habitat), maximum temperature (r=0.134 in non-weedy and r=0.265 in weedy habitat) and minimum temperature (r=0.134 in non-weedy and r=0.265 in weedy habitat). Whitefly nymphs on cotton also demonstrated positive correlation [10] with morning relative humidity (r=0.286), evening relative humidity (r=0.473) and minimum temperature (r=0.245).

In present study, the correlation of whitefly adult population with rainfall was significantly negative (r=-502) in weedy habitat. Both abiotic factors namely heavy rainfall and high wind speed adversely affected the population of whitefly adults mainly during 30th SMW (3rd week of July) and 38th SMW (3rd week of September) resulted in reduction of the population as earlier also it is reported a significant negative correlation between whitefly population and rainfall [5], [9] [14}, [10]. Present analysis shows that adult population in weedy habitat (r=-0.403) and nymphal population in both habitats (r=-0.396 and r =-0.413 in non-weedy and weedy habitat, respectively) was non-significantly negatively correlated with rainfall as registered that a non-significant negative correlation (r= -0.03) of whitefly population [13] on cotton exists with rainfall, significant inverse proportional with rainfall documented in case of sucking insect-pests particularity leafhopper, whitefly, thrips and aphids [11]. In our present studies, it is found that adult population of whitefly in weedy habitat and nymphal population in both habitats hold a non-significant negative correlation with wind speed, but adult population in weedy habitat was significantly negative associated with wind speed. Nymphal population was non-significant negative correlated with wind speed [10] in three consecutive years; also with the wind velocity [7].

Multiple regression analysis between whitefly, *B. tabaci* population and weather factors in non-weedy and weedy habitat

The multiple regression analysis between abundance of *B. tabaci* (nymphs and adults) in non-weedy and weedy habitats with weather parameters (Table 3) revealed that weather parameters together with, accounted for significant variation of 86.0 and 57.0 per cent in adult and nymphal populations, respectively in non-weedy as well as weedy habitats. The result of multiple regression analysis shows that the accountability of each factor varied, but the cumulative effect of weather parameters was equal for whitefly irrespective of habitats. The collective effect of all the weather parameters *i.e.*, temperature, relative humidity, wind speed and rainfall was significant and high on whitefly adults (R^2=0.86) and nymphal (R^2=0.57) population (Table 3). The significant collective effect of weather parameter shows that although the effect of each factor (except rainfall and wind speed) was non-significant but their collective effect may play an important role in population fluctuation of whitefly and can cause outbreaks.

Multiple regression analysis in present studies shown that the weather parameters collectively attributed to 86.0 (R^2=0.86) and 57.0 (R^2=0.57) per cent variability on whitefly adult and nymphal population, respectively on cotton. These significant collective effects of weather parameters shown that although the effect of each factor (except rainfall and wind speed) was non-significant, but their collective effect may play an important role in population fluctuation of whitefly and can cause outbreaks in the cotton agro ecosystem. Reflections of present observations are observed in study of Balabantaray *et al.* (2018) that collective effect of weather parameter was significantly high *i.e.,* 81.0 per cent (R^2=0.81) in adult and 69.0 per cent (R^2=0.69) in nymphal population [5]. However, influence of weather parameters on whitefly adult population on cotton was non-significant [20] with only 38.2 per cent variation in population. It may have happened due to the experimental parameters as conducted in Andhra Pradesh being in different agro-climatic zone and the variation in weather parameter that prevails in Haryana conditions.

Table 2: Correlation coefficients between population of whitefly, *B. tabaci* (adults and nymphs) and weather parameters

Weather Parameters	Correlation coefficients (r)			
	Adult Whitefly Population		Nymphal Population	
	Non-weedy Habitat	Weedy Habitat	Non-weedy Habitat	Weedy Habitat
RH% Morning	0.214	0.233	0.180	0.147
RH% Evening	0.052	0.233	0.228	0.209
RH% Average	0.134	0.265	0.237	0.209
Temperature Max (°C)	-0.009	0.108	0.213	0.195
Temperature Min (°C)	0.106	0.301	0.387	0.363
Temperature average (°C)	0.073	0.251	0.348	0.325
Rainfall	-0.502*	-0.403	-0.396	-0.413
Wind speed	-0.515*	-0.354	-0.103	-0.120

Table 3: Multiple regression analysis between whitefly, *B. tabaci* population and weather factors

Growth Stage	Habitat	Regression equation	R^2
Whitefly adult	Non-weedy	$Y=-17.22 - 0.05RH_m + 0.11RH_e + 0.40T_{max} + 0.43Tmin - 0.92RF - 2.52WS$	0.86
	Weedy	$Y= - 17.27 - 0.09RH_m + 0.12RH_e + 0.31T_{max} + 0.67Tmin - 0.75RF - 2.75WS$	0.86
Whitefly nymph	Non-weedy	$Y=8.19 + 0.01RH_m - 0.03RH_e - 1.04T_{max} + 1.66Tmin - 2.27RF - 1.97WS$	0.57
	Weedy	$Y=12.17 - 0.03RH_m - 0.00RH_e - 1.15T_{max} + 1.78Tmin - 2.68RF - 2.32WS$	0.57

* RHm= morning relative humidity, RHe= evening relative humidity,
T_{max}= maximum temperature,
T_{min}= minimum temperature,
RF= rainfall and WS= wind speed

Conclusion

It is concluded that both whitefly adult and nymphal population incontestable a non-significant positive correlation with relative humidity and temperature in non-weedy habitat and weedy habitats. Notwithstanding, adult population of whitefly in non-weedy habitat was significantly negatively correlated with rainfall (r = -0.502) and wind speed (r = -0.515), whereas adults population in weedy and nymphal population in both habitat showed non-significant negative correlation. Above all, regression analysis revealed that weather parameters collectively can contribute upto 86.0 per cent variability in adults and 57.0 per cent variability in nymphal population in both habitats.

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