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Population dynamics of whitefly (*Bemisia tabaci*, Gennadius) on tomato (*Solanum esculentum*, Mill.) crop under protected conditions in Kashmir

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Abstract
An experiment was conducted to study the seasonal population buildup of whitefly (*Bemisia tabaci*, Gennadius) on tomato (*Solanum esculentum* Mill.), during 2017 and 2018, under protected conditions and its correlation with temperature (maximum and minimum), relative humidity (maximum and minimum) inside polyhouse was observed. It was revealed that the infestation first started with the appearance of adults in the 2nd fortnight of June and reached maximum during 1st to 2nd fortnight of August (nymphs) and 1st fortnight of September (adults) during the two year study. A positive significant correlation between whitefly population (nymph and adult) and weather parameters *viz.* temperature (maximum and minimum) was observed. The relative humidity (maximum) exhibited positive nonsignificant whereas relative humidity (minimum) showed a negative nonsignificant correlation with population.

Keywords: Population dynamics, protected, tomato, whitefly

Introduction
Tomato (*Solanum esculentum* Mill.) belongs to family solanaceae and is an important vegetable crop that is grown on a commercial scale in India and has worldwide consumption. It has high nutririve value and is the major source of vitamins and minerals. It ranks second in importance after potato in India and is cultivated in nearly all parts of the country occupying an area of 8.09 lakh hectares approximately with total production of 197 lakh tonnes and productivity of 24 tonnes per ha [1]. In Kashmir, it is cultivated on the total area of 22517.96 Ha with the annual production of 1539.58 MT [2]. Whitefly (*Bemisia tabaci* Gennadius, Hemiptera: Aleuyrodidae.) is one of the destructive pests of tomato crop causing serious damage through sucking of plant sap, excretion of honeydew and transmission of leaf curl virus which affect the yield causing huge losses [3]. Both nymphs and adults suck the sap and weaken the plant. The excretion of honeydew promotes the growth of sooty mould that affects the process of photosynthesis and thereby reduces the quantity and quality of the yield [4]. *B. tabaci* is polyphagous and most widely distributed in tropical and subtropical regions however due to changing climatic conditions it has now become an emerging pest of tomato in temperate climates particularly under protected conditions. Since whitefly is an invasive pest and is still emerging in Kashmir region, it is therefore necessary to control to pest at earliest to prevent it spread owing to its polyphagous nature and capacity to develop resistance. Therefore, in order to prevent the crop loss and curb the whitefly infestation, the use of effective measures at appropriate time is essential. Keeping this in view, the study on the population dynamics of whitefly was carried out to determine its relation with weather parameters and to identify the weak links in population buildup.

2. Materials and Methods
An experiment was conducted to study the population dynamics of whitefly (*B .tabaci*) on tomato crop and its relation to weather parameters at vegetable farm, Department of Horticulture at Habak, under polyhouse conditions. The experiments were conducted during the tomato growing season, summer 2017 and 2018.

2.1. Layout of experiment
The population buildup of whitefly on tomato was studied under polyhouse conditions. The seedlings were transplanted keeping the row to row distance of 60 cm and plant to plant distance of 40 cm. The polyhouse was divided into four plots of size was 6x3m.The crop was raised in pesticide free conditions and agronomic practices were followed from time to time.

2.2. Population estimation
Five tomato plants were selected randomly from each plot and number of *B. tabaci* nymphs and adults were counted on three uniform sized leaves from each top, middle and bottom portion of plant. Observations were made at fortnightly intervals from the period 30 days after transplanting till final harvest. The weather parameters *viz.* temperature (maximum and minimum), relative humidity (maximum and minimum) inside polyhouse were recorded to study impact of these parameters on insect population.

2.3 Statistical analysis
The data obtained on whitefly population (nymphs and adults) and various weather parameters *viz.*, maximum and minimum temperature, morning and evening relative humidity was subjected to statistical analysis to determine the coefficient of correlation and regression as given by Senedcor and Cochran 1967 [5].

3. Results and Discussion
The data regarding whitefly population (nymphs and adults) count versus weather parameters during summer 2017 and 2018 were recorded to determine the population dynamics and its relation to weather parameters *viz.* maximum temperature, minimum temperature, relative humidity (maximum) and relative humidity (minimum) has been summarised.

3.1. Population fluctuation of whitefly during 2017 and 2018
The pest first appeared in the second fortnight of June with the average population of 0.15 whiteflies/ leaf and 0.30 whiteflies/leaf during 2017 and 2018, respectively. The adult whitefly population reached its peak in the first fortnight of September during 2017 with population 2.35/leaf when maximum and minimum temperature were 33.0 ^{0}C and 18.58 ^{0}C whereas maximum and minimum relative humidity were 72.46% and 35.66%, respectively (Table 1).Similarly, during 2018, the peak population of 2.70/leaf was recorded in first fortnight of September when maximum, minimum temperature and relative humidity were 35.43 ^{0}C, 19.32 ^{0}C, 65.46% and 37.60%, respectively. The nymphs first appeared during first fortnight of July with population of 0.75 and 0.90 nymphs/leaf during 2017 and 2018 respectively. The population then increased till it attained peak of 3.75/leaf in second fortnight of August during 2017 when maximum, minimum temperature and relative humidity were 34.10 ^{0}C, 19.07 ^{0}C,70.80% and 40.26%, respectively (Table2). During 2018, the nymphal population reached its peak of 2.70/leaf in first fortnight of August when maximum temperature, minimum temperature and relative humidity were 35.23 ^{0}C, 22.09 ^{0}C, 67.80% and 46.53%, respectively. The whitefly population showed a decline after attaining peak during both years of study. This is due to decrease in temperature and increasing age of plant as whitefly feeds on the succulent part of the plant and dry matter accumulation increases with older age of the plant and thereby population as well as infestation of whitefly is reduced [6-7].

3.2. Correlation and regression studies between whitefly population and weather factors
The correlation coefficient was significantly positive between the whitefly population and maximum temperature with r= 0.691* and 0.570* and r= 0.633*and 0.551* for nymphal and adult population during 2017 and 2018, respectively (Table 3).The minimum temperature showed positive correlation with r=0.222 and r= 0.549* for nymphal; and r= 0.255 and r=0.693* for adult population during the 1st and 2nd year, respectively but the correlation was statistically non-significant during 1st year. The relative humidity (maximum) showed positive nonsignificant correlation (r=0.308 and 0.514) with nymphal and adult population (r=0.304 and 0.534) during 2017 and 2018, respectively. The relative humidity (evening) exhibited negative nonsignificant correlation, r= -0.188 and-0.09 with nymphal and r= -0.047 and -0.097 with adult population during the respective years, 2017 and 2018. Regression studies of whitefly population with weather parameters viz., maximum temperature, minimum temperature, relative humidity (maximum) and relative humidity (minimum) was worked out (Table 4) with R^2 values 0.58 and 0.55 for nymphal and 0.64 and 0.83 for adult population, respectively for year 2017 and 2018. The R^2 values indicated that weather parameters contributed actively to the population fluctuation of Whitefly on tomato. The present study is in agreement with Sharma *et al.*, [8] who reported significant positive correlation of whitefly population with maximum and minimum temperature and negative correlation with relative humidity (minimum) on tomato. The results were also in accordance with Singh and Pandey [9] where whitefly population showed significant positive correlation with maximum and minimum temperature while relative humidity was negatively correlated with whitefly on cowpea. Shrivastva and Prajapati [10] also reported significant positive correlation of whitefly population with maximum temperature while mean relative humidity (r= -0.83) exhibited negative correlation with whitefly population in blackgram (*Vigna mungo*).Researchers also reported the significant positive association of adult whiteflies with temperature [11]. This study is in conformity with Meena and Bairwa [12] who revealed that a positive and significant association between the whitefly population and maximum and minimum temperature on tomato.

Table 1: Population fluctuation of whitefly nymphs and adults on tomato in relation to weather parameters under protected conditions during the year 2017.

Fortnight	Temperature ^{0}C		Relative Humidity (%)		no. of nymphs/leaf*	no. of adults/leaf*
	Max.	Min.	Max.	Min.		
2-May	31.43	16.12	67.6	40.53	0	0
1-Jun	31.70	16.61	63.4	36	0	0
2-Jun	31.80	19.59	71.73	49.46	0	0.15
1-Jul	34.76	21.62	68.33	38.8	0.75	0.25
2-Jul	35.20	23.1	69.6	40.86	1.1	0.70
1-Aug	36.66	23.34	67.4	40.00	2.05	1.55
2-Aug	34.10	19.07	70.8	40.26	3.75	0.85
1-Sep	33.00	18.58	72.46	35.66	2.65	2.35
2-Sep	33.96	14.86	71.93	25.33	2.00	1.10
1-Oct	33.43	11.29	71	21.86	1.7	0.75

*Mean population on 20 plants based on three leaves fromtop, middle and bottom of plant.
Max.: maximum temperature; Min.: Minimum temperature.

Table 2: Population fluctuation of whitefly nymphs and adults on tomato in relation to weather parameters under protected conditions during the year 2018.

Fortnight	Temperature ^{0}C		Relative humidity (%)		no. of nymphs/leaf*	no. of adults/leaf*
	Max.	Min.	Max.	Min.		
2-May	31.23	13.82	52.46	32.06	0	0
1-Jun	36.83	18.45	53.6	36.63	0	0
2-Jun	27	18.17	61.86	53.26	0	0.3
1-Jul	32.63	21.15	72	50.6	0.9	0.45
2-Jul	34.1	23.42	75.2	49.06	1.65	0.90
1-Aug	35.23	22.09	67.8	46.53	5.1	1.60
2-Aug	35.9	21.4	72.53	35.73	4.85	2.00
1-Sep	35.43	19.32	65.46	37.6	3.2	2.70
2-Sep	32.13	15.49	71.53	36.53	2.55	1.45
1-Oct	28.13	11.04	70.8	43.06	2.1	1.15

*Mean population on 20 plants based on three leaves from top, middle and bottom of plant.
Max.=maximum; Min.= minimum.

Table 3: Correlation coefficient of whitefly population on tomato with weather parameters during the 2017 and 2018**.**

Weather parameters	Correlation Coefficients			
	2017		2018	
	Nymphs/ leaf	Adults/leaf	Nymphs/ leaf	Adults/leaf
Max. temp.^{0}C	0.691*	0.633*	0.570*	0.551*
Min. temp.^{0}C	0.222	0.255	0.549*	0.693*
Relative humidity max.(%)	0.308	0.304	0.514	0.544
Relative humidity min.(%)	-0.188	-0.047	-0.092	-0.097

*Significant at 0.05% level of significance.

Table 4: Regression equation of whitefly population with weather parameters during year 2017 and 2018.

	2017		2018	
Pest population	**Regression equation**	**R^2**	**Regression Equation**	**R^2**
Nymphs	Y1 = -36.70+ 0.991X1+0.274X2+0.10X3 -0.08X4	0.58	Y1 = -4.65+ 0.18X1+ 0.264 X2+ 0.113X3 - 0.130X4	0.64
Adults	Y2 =-19.72+0.551X1+0.213X2+0.041X3-0.081X4	0.55	Y1 = -5.36+ 0.009X1+ 0.20 X2+ 0.096X3 - 0.073X 4	0.83

Y1= Whitefly nymph per leaf; y_2= Whitefly adults per leaf; X1= Maximum temperature (oC); X2= Minimum temperature (oC); X3= Maximum relative humidity (%); X4= Minimum relative humidity (%)

4. Conclusions

The present experiment provides basic information of population fluctuation of whitefly on tomato in relation to weather parameters viz. temperature (maximum and minimum) and relative humidity (maximum and minimum) under the microclimatic protected conditions. The population fluctuations of whitefly on tomato were actively influenced by weather parameters. This experiment provides baseline data for the monitoring of whitefly pest and its sustainable integrated pest management.

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