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Population dynamics and development of weather-based prediction model for the incidence of whitefly, *Bemisia tabaci* Gennadius and its predator, *Nesidiocoris tenuis* (Reuter) in tomato

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ABSTRACT: Population of whiteflies and its natural enemy *Nesidiocoris tenuis* were recorded for the period of three years and averages were computed and subjected to simple correlation by considering weather parameters as the dependent variable. During observed years, population of whiteflies peakranged within 33rd to 37th SMW, the mean occurrence of the *N. tenuis* started with the build-up of its prey population and peaked at 40th SMW, declined thereafter and the populationof whiteflies had significantly positively correlated with maximum temperature, minimum temperature, evening relative humidity, and wind speed, respectively. Rainfall had a positive correlation but was not significant. In the present study, the population of *N. tenuis* was dependent only on the prey density but not on the weather parameters. The established model validated satisfactorily(R^2=0.75; RMSE = 2.05).

Keywords: Whitefly, *Nesidiocoris tenuis,* tomato, weather, forecast, population.

Tomato, *Solanum lycopersicum* L. (Solanaceae) is a highly valued, all-season vegetable commodity cultivated extensively worldwide for its edible fruits which are rich in antioxidants, dietary fibers, minerals, and vitamins. Globally, 177 MT of tomatoes are being produced every year, in India, tomato stands second after China with production of 21.9 MT (Agricultural statistics at glance, 2020). Tomato cultivation demands significant investment in crop protection against biotic stress, as their management needs costly pesticides, apart from that resistance, resurgence, and outbreak due to change in climate takes a big toll on farmers. Among pests whiteflies, *Bemisia tabaci* Gennadius are major followed by thrips *Thrips tabaci* Lindeman, fruit borer, *Helicoverpa armigera* (Hubner) and tomato pinworm, *Tuta absoluta* (Meyrick). Whiteflies suck sap from the phloem, which results in chlorosis of leaf, spotting, curling, irregular fruit ripening, and honeydew favoured sooty mould growth affect photosynthesis. It affects plants through the transfer of Begomovirus, Crinivirus, Closterovirus, and Ipomovirus (Tiwari *et al.,* 2013) and causes 100 % damage when control is not undertaken at right time (Schoonhoven *et al.,* 2005). To take the right management action against whiteflies at right time to evade the plants from damage, understanding on changing status of the population with weather factors and their interaction with its predator *N. tenuis* is of prime importance.

Change in weather or more precisely change in climate would directly influence the occurrence and dynamics of pests and their natural enemies, favourable weather favours the pest, and unfavourable would deter. Among the weather factors, the influence of temperature, rainfall, relative humidity on pests had reported in cotton against sap feeders (Vennila *et al.,* 2018), tomato fruit borer, *H. armigera* (Khokhar *et al.,* 2019), and beet armyworm, *Spodoptera exigua* Hubner (Kamakshi *et al.,* 2018) e. t. c. Establishing the relationships of pest dynamics and prevailing natural enemy incidence with weather factors through models would guide when to undertake pest management which is lacking in the case of whiteflies infesting in tomatoes. Keeping this backdrop in view, the influence of weather variables was worked out concerning pest and prey population in the present study.

MATERIALS AND METHODS

Field experiments were conducted for three years at ICAR-Indian Agricultural Research Institute, New Delhi. Tomato variety Pusa Ruby was planted in an acre of land in July based on the recommended horticultural practices and harvested in May. For whiteflies, data were collected for the development and validation of the forecast model by direct counting and the yellow sticky trap was used for counting *N.tenuis*. In the case of the direct count method, numbers of whiteflies were counted from the lower, mid,

Table 1. Correlation of population of *B. tabaci* and *N. tenuis* with weather factors

Weather Factor	*B. tabaci*			*N. tenuis*		
	2017	2018	2019	2017	2018	2019
Tmax °C	**0.667****	0.444	**0.731****	0.343	0.185	0.072
Tmin °C	**0.808****	**0.653****	**0.833****	-0.066	-0.003	-0.035
RH1(%)	0.441	-0.134	0.195	0.319	0.145	0.142
RH2 (%)	**0.760****	**0.635**	**0.667****	-0.272	-0.176	-0.285
RF (mm)	0.450	0.409	0.316	0.000	-0.227	-0.332
SS (hr)	0.103	-0.256	0.043	0.454	0.541*	0.538*
WS (kmph)	**0.564****	0.385	0.188	-0.326	-0.204	-0.472

Tmax (°C)-Temeprature maximum; Tmin °C – Temperature minimum; RH1(%)- Morning relative humidity; RH2 (%) – Evening relative humidity; RF (mm) – Rain fall; SS (hr)-Sunshine; WS (kmph)- Wind speed; ** Correlation significant at 1% and * Correlation significant at 5%.

and upper leaf on randomly selected five plants early in the morning, whereas in the case trap catches, 5 yellow sticky traps were installed and data was collected by counting trapped *N. tenuis*. Counts were made twice a week and expressed as the mean number of flies per each SMW (Standard Meteorological Weeks) and the variation in the data was normalized by subjecting into square root transformation.

The two years population data was used for the development of the model by multiple regression and validated with third year data. Weather variables like maximum temperature (Tmax), minimum temperature (Tmin), rainfall (RF) morning relative humidity (MRH), evening relative humidity (ERH), sunshine hours (SSH), and wind speed (WS) were collected from the Division of Agricultural Physics, ICAR-Indian Agricultural Research Institute, New Delhi and correlated using simple correlation co-efficient with the whiteflies population for current week. A multiple linear regression model was developed for positively correlated weather factors then step-wise regression was done to know the magnitude of influence of different weather factors on the build-up of whiteflies population.As weather parameters were not significant for *N. tenuis* it was not considered for development and validation.

RESULTS AND DISCUSSION

Seasonal dynamics of whiteflies and its predator *N. tenuis*

The initial occurrence of whiteflies was observed right after transplanting during 27th SMW during all the observed years, due to the presence of alternate hostsand weed hosts around the experimental area. Peak occurrence was noticed at 35th SMW @ 8 whiteflies per plant during 2017,bi-peaks on 33rd and 36th SMW with 16 and 18 whiteflies per plant, during 2018, and during 2019, the peak was noticed at 37th SMW @12 whiteflies per plantand gradually declined thereafter (Fig. 1). Observations of the present study results are similar to that of observations of the Marabi *et al.,* (2017a), who reported the occurrence of whiteflies from 28th SMW and peak was recorded at 30th SMW in Blackgram. Mean occurrence of the *N. tenuis* started with the build-up of whiteflies population, its appearance was recorded at 30th SMW and gradually increased with increase in population density of prey and peaked at 40th SMW and declined with respect to decline in the prey density (Fig 2). Increasing the population peaks of predators after an increase in the prey proves that the availability of the prey is the prime driving factor for the occurrence of predators.

Correlation of whiteflies and its natural enemy *N. tenuis* with different weather factors

Correlation studies between whitefly and *N. tenuis* with the prevailing weather factors revealed that the population of whiteflies had a significantly positive correlation with maximum temperature (r=0.666, r=0.731 during 2017 and 2018), minimum temperature (r=0.808; r=0.653, r=0.833 during 2017, 2018, 2019), evening relative humidity (r=0.760, r=0.635, r=0.667 during 2017, 2018 2019) and wind speed (r=0.564 during 2017), respectively. In the case of *N. tenuis* maximum temperature, morning relative humidity and

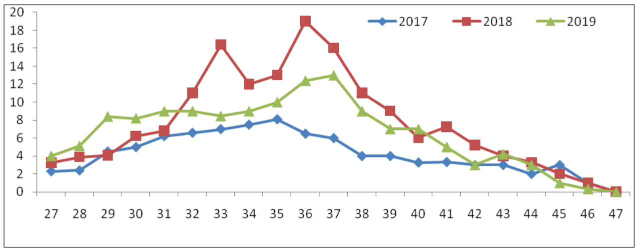

Fig. 1. Population dynamics of whiteflies *B. tabaci* with respect to standard meteorological week in Tomato

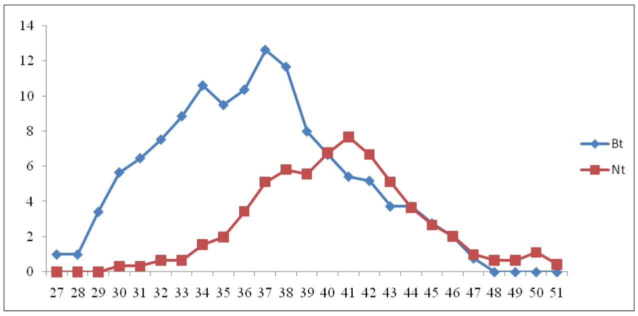

Fig. 2. Population dynamics of whiteflies *B. tabaci* in response to its predator *N. Tenuis*

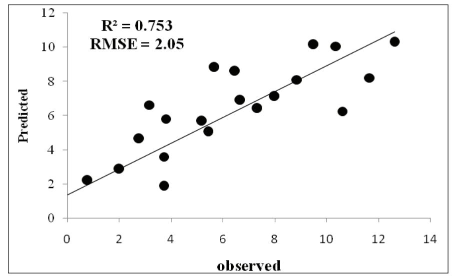

Fig. 3. Validation of Whiteflies B. tabaci weather based model

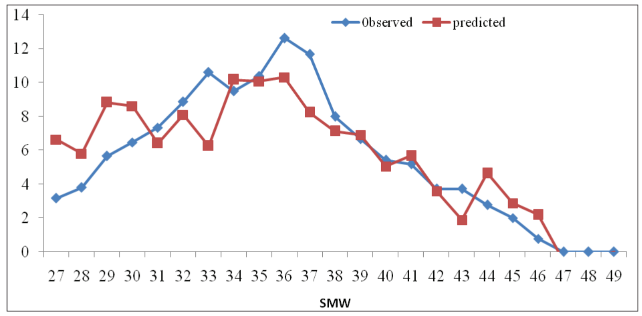

Fig. 4. Observed and Expected population of Whiteflies B. tabaci with respect to standard meteorological week

sunshine hours had positively correlated and minimum temperature, evening relative humidity, and wind speed were negatively correlated but not significant, this shows the population dynamics of *N. tenuis* was majorly influenced by the density of prey compared to weather factors (Table 1). Marabi *et al*., (2017b) reported the significant positive correlation of whitefly population with maximum temperature, minimum temperature, evaporation, and morning vapour pressure and non-significant correlation of morning and evening relative humidity in soybean. In blackgram, Miraba *et al.,* (2017a) reported a significant positive correlation of whiteflies with maximum temperature and whereas wind speed and rainfall had negatively correlated. All reports had shown a significant positive correlation with maximum temperature but Patidar (2015) had contrasting evidence of negative correlation of maximum temperature in blackgram.

Development and validation of the weather-based model

Step-wise regression equationswere developed for the four weather factors which are significantly correlated *viz.,* temperature maximum, temperature minimum, evening relative humidity, and wind speed turned out as Y=8.37-0.055 (Temperature maximum) +1 (Temperature minimum) +0.02 (Evening relative humidity) -1.79 (Wind speed) (R^2=0.75; RMSE=2.05). The equation revealed that for every unit increase in maximum temperature and wind speed the population of whiteflies decreases by 0.055 and 1.79 units. Whereas for every unit increase in minimum temperature and evening relative humidity the population of whiteflies increases by 1.0 and 0.02 units, respectively. Effect of weather parameters on the population of whiteflies indicates that 75 % of the change in their population was influenced by maximum temperature, minimum temperature, evening relative humidity, and wind speed and the remaining 25 % is due to some other unidentified factors. Whiteflies activity was greatly influenced by the surrounding temperature so low temperature inhibited the population and higher stimulated it. Rainfall had an insignificant impact this may be due to heavy showers physically affecting the adult flies but not the sessile immatures, having short life cycle population was surged by the existing immature population and by getting the favourable humidity amid rainfall. The findings of the current work are corroborated with the results of previous work by Marabi *et al*. (2017a) and Srinivasa (2014) reported that abiotic factors like temperature and humidity explain the 65% variation in the population dynamics of the whiteflies. The established model was validated by keeping the 2017 and 2018 predicted whitefly count with the 2019 whitefly count. The developed model was validated satisfactorily with RMSE = 2.05 (Fig.3). The observed and expected population of whiteflies were followed a similar trend (Fig. 4).

Considering the direct or indirect influence of abiotic factors on population abundance and crop damage, developing a real-time monitoring system supported by information and communication technological (ICT) tools and its forecasting to farmers with the help of electronic message, social media, web hosting, and broadcasting media would provide information at right time to take up the management of whiteflies to reduce damage.

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