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Formulation of Abiotic Triggers for Prediction of Thrips and Whitefly Pest in Bt Cotton under Rainfed Condition of Maharashtra

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Abstract: Thrips and whitefly is the destructive insect of Bt. cotton worldwide. We analysed infestation dynamics of these pests in Bt. cotton during crop growing season of 2002–2018 (17 years), and predicted the factors influencing its abundance. Rainfall, maximum-minimum temperature, maximum-minimum relative humidity, bright sunshine hours and wind influencing the thrips and whitefly population build-up were predicted using MRM technique with reasonable accuracy (R square= 0.83 to 98). The results also showed that light rainfall (<13 mm/h) and medium rainy days (2-3 rainy days /week) combined with light air (WV<4-6 km/hr) and moderate to partially cloudy condition (BSS of 5-8 hrs./day) prevailing coupled with T_{max} (30.0-33.0 °C) for both pest, and T_{min} (21.0-22.0 °C), RH-I >80% and RH-II >50% for thrips and T_{min} (15.0-22.0 °C), RH-I >75% and RH-II >40% for whitefly are favourable to build up optimal population (or above ETL) during the period 34-39 SMW and 38-44 SMW respectively, in which time required management to control both pest.

Keywords: Abiotic factors, Thrips, Whitefly, *Bt* cotton, MRM

India ranks first in cotton production with 38.41 and 26 % of the total world production and area, respectively (Anonymous 2017). Bt cotton was introduced during 2002 in India and currently it occupies over 93 percent of the area under cotton cultivation (Kumar et al 2018) and in general 98-99 percent in Maharashtra. Among various insect species infesting the Bt cotton crop at different growth stages, a complex of sucking pests viz., aphid, jassid, thrips and whitefly cause considerable damage and it causes 22.85% reduction in seed cotton yield under rainfed conditions (Mohapatra 2008). The insects damage cotton to the tune of 39.50 % and about 40-50 % of crop is damage due to sucking insect pests (Ali et al 2020). Though, previous field studies have investigated the higher population of whiteflies (*Bemisia tabaci*) and thrips (*Thrips tabaci*) in Bt-cotton as compared to conventional cotton crop (Naveen et al 2017). However, it is seen that any pest can only progress if the conditions provided by the host plants as well as weather are favourable, and weather is one of the major factors responsible for infestation of pests in the crop. Many earlier workers have identified the favourable ranges of weather parameters for thrips and whitefly. Findings of different researchers in the past are mostly similar with each other (Kaur et al 2009, Akaram et al 2013, Panwar et al 2015, and Badgujar et al 2018). Nevertheless, some findings are contradictory regarding relationship of weather and pest which was under taken in the study (Tomar 2010, Jaybhaye and Shinde 2020). Hence, timely forewarning of insect-pest population would certainly be useful for management of pest control, or making strategic decision. Therefore, there is a need to develop forewarning systems, which can provide advance information for outbreak of the pest. The linear regression equation based on abiotic factors for prediction of sucking pest incidence on cotton is playing important role in pest management (Kumar et al 2018, Jaybhaye and Shinde 2020). Therefore, to standardise range of abiotic factors for optimal or above ETL pest population of *Bt* cotton, under rainfed condition is an urgent need. And the present study is useful to get an idea for environment friendly and economical integrated pest management in advance by using district wise medium range weather forecast issued by IMD (Jaybhaye et al 2018, Jaybhaye and Shinde 2020). With this background present study was conducted to identifying weather triggers and forewarning of the incidence of sucking pests (thrips and whitefly) at different standard meteorological week (SMW) during Bt cotton crop growth period under rainfed climatic condition.

MATERIAL AND METHODS

Field experimentation: Field experiments were carried out for the period of 17 years (2002 to 2018) at Department of Agricultural Meteorology and Department of Agricultural

Entomology, VNMKV, Parbhani, Maharasthra, India. Experiments were conducted without plant protection with a plot size of 9.6 m X 9.0. After receipt of monsoon rainfall, more than 100 mm in one meteorological week (MW), Bt cotton crop were sown at spacing 120 x 45 cm under rainfed farming, in the *kharif* seasons (25 SMW to 52 SMW). The *Bt.* cotton crop Hy. MECH-184 (2002 to 2005), Hy. Rasi-2 (2006 to 2015) and Hy. RCH-659 BG II (2016 to 2018) was taken during experimentation.

Pest data collection: Each experiment plot was divided in to four quarters of 4.8 m X 4.5 m to record observations. Population of thrips and whitefly were recorded before 1000 hrs at weekly intervals from three leaves (each from top, middle and bottom of crop canopy) on five randomly selected plants from each of the quadrant as per standard procedure (Jaybhaye and Shinde 2020, Pathania et al 2020). Biotic factors (i.e. thrips and whitefly population values) for the study period (2002-2018) were recorded weekly from 28 SMW to 52 SMW. Recorded weekly average pest values were converted into meteorological week wise long-term average (Fig. 1).

Weather data collection: Seasonal abiotic factors (RF: rainfall, RD: rainy days, T_{max}: maximum temperature, T_{min}: minimum temperature, RH-I: morning relative humidity and RH-II: afternoon relative humidity, BSS: bright sunshine hours and WV: wind velocity for the experimentation period were recorded daily from the agrometeorological observatory located at Dept. of Agril. Meteorology VNMKV, Parbhani and as per standard meteorological week (SMW), it was converted into average (Fig. 1).

Statistical analysis: The population occurrences of thrips and whitefly have quantified the relationship with climatic variables, including RF, RD, T_{max}, T_{min}, RH-I and RH-II, BSS, and WV, using Pearson's correlation analysis with regards to crop season from 33 SMW to 52 SMW. Significant correlation coefficient (R) values were taken as criteria to select suitable factor(s) for developing multiple linear regression (MLR) models with observed pest population. The correlation between weather factors and pest population dynamics were under taken. Correlations worked out between observed pest populations and weather factors for a SMW (Table 1).

Development of multiple regression models (MRM): Simple regression analysis generated in between weekly mean thrips/whitefly population and weather parameters independently. Multiple linear regression (MLR) also known simply as multiple regression (MR) and MLR equation also known multiple regression model (MRM), is a descriptive statistics analysis technique that used to for prediction of pest population were developed. The objective of MRM is the transfer of information among several abiotic factors observed simultaneously and the estimation of the dependent variable from these independent variables. MRM with a stepwise selection method was developed, considering weather variables to achieve a maximum coefficient of determination (R^2) for estimating the pest population. MR is a statistical method in regression for analysis of relationships between a single dependent variable and two or more independent variables (Jaybhaye and Shinde 2020) in the form (Equation (1))

$$Y = b_0 + b_1x_1 + b_2x_2 + \ldots\ldots. + b_nx_n \quad (1)$$

Where, Y is the dependent variable (predicated or expected value of pest population), b_0 is the y-intercept (value of y when all other parameters are set to 0) and b_1, b_2,…, b_n are the regression coefficients and x_1, x_2,…, x_n are the independent variables (abiotic factors). The MRM's were generated by IBM SPSS Statistic 22.0 (Anonymous 2013). The MRM's were developed based on the descriptive

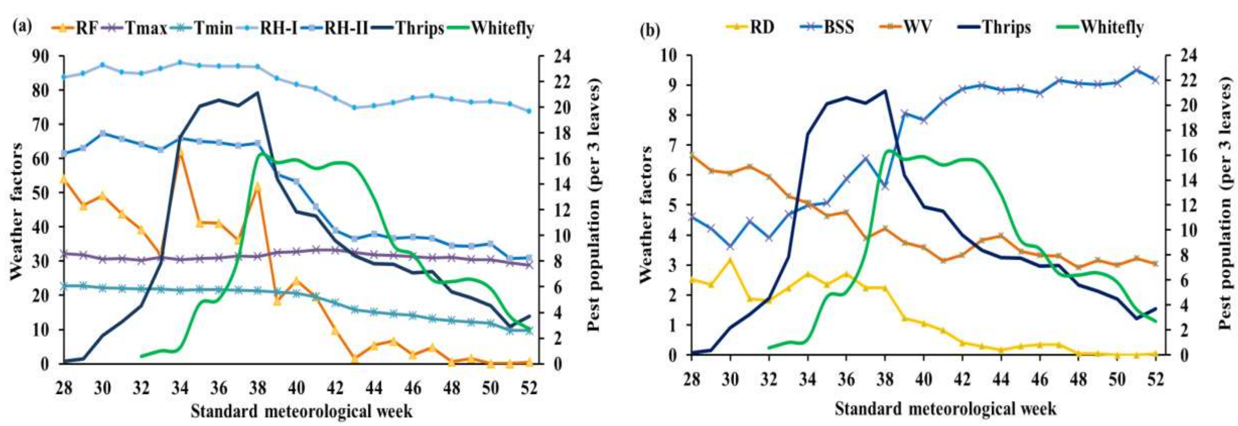

Fig. 1. Population dynamics of thrips and whitefly in relation to weather factors (a) rainfall, maximum and minimum temperature, morning and afternoon relative humidity (b)rainy days, bright sunshine hours, wind velocity etc. having significant relationship

statistics analysis of dependant variables (Thrips/whitefly population values) and independent variables (weather factors) of the same SMW were considered. To develop MRM's for forewarnings MRM of thrips, eight, six and three selective independent variables (i.e. abiotic factors) and for whitefly, eight, five, four and two selective independent variables (i.e. abiotic factors) were taken, respectively. And out of available 25-week data (28-52 SMW), 20 weeks data (33-52 SMW) for thrips and 15 weeks data (38-52 SMW) for whitefly is taken, during this period of thrips/whitefly population values were recorded more or at Economic Threshold Level (ETL). The ETL level of thrips and WF (30 adult/ 3 leaves) was reported by Bhede and Bhosle (2012) which is useful to decide spraying schedule. In this study Model 1, Model 2, Model 3 and Model 4 are represented by MRM-1, MRM-2, MRM-3 and MRM-4 respectively to different models (Table 2). The performance evaluations of models during development and validation period (SMW) were carried out with comparison of predicted and observed values of pest population. The performance criteria adopted here is the highest correlation coefficient (R^2) and the lowest values of standard error (SE) and lower error % in observed-estimated values by MRM. The error % in pest population based on multiple regressions models were worked out as per Jaybhaye and Shinde (2020).

RESULTS AND DISCUSSION

The weekly mean data on population dynamics of thrips and whitefly infesting *Bt* cotton showed highly significant differences among the years (2002 to 2018) and week to week may be due to the variation in year to year climatic and week to week weather condition i.e. abiotic factors (*viz.,* RF, RD, T_{max}, T_{min}, RH-I, RH-II, BSS and WV etc.). The changes in the abiotic factor (independent factor) forced to changes in the thrips and whitefly incidence i.e. biotic stress (dependent factor) during the crop growing period. The insects in nature are not under the influence of one single factor but are subjected to abiotic factor and availability of food (i.e. change in the crop growth stage and crop condition) which plays a role in the distribution and abundance of pest (Jaybhaye and Shinde 2020). The microclimatic conditions largely influence the pest number and activity either directly or indirectly (Kaur et al 2009, Pathania et al 2020). Consequently, it is evident that all the abiotic factors either significant or highly significant correlation with the thrips/whitefly population or these correlations can be used to predict the population or its trends. Nevertheless, forewarning needs to be made in advance at least one week, which has considerable worth for thrips and whitefly infestation management and this statement is assenting with Jaybhaye and Shinde (2020) developed regression models to predict aphids and jassid population based on abiotic factors.

Thrips (*Thrips tabaci* Lindeman)

Population dynamics: The present results revealed that thrips builds up its population for 28th SMW after sowing and it was ranged in between 4 to 21 thrips/three leaves. Thereafter, it increased gradually and reaches at the peak during 38th SMW and after that decreased sharply (Fig. 1).

Table 1. Correlation matrix of weekly average thrips and whitefly population with weather factors under Bt cotton at Parbhani (2002-2018)

Pest	RF (mm)	RD (days)	Tmax (°C)	Tmin (°C)	RH-I (%)	RH-II (%)	BSS (hrs)	WV kmhr^{-1}
Thrips	0.89**	0.89**	0.23	0.87**	0.88**	0.90**	-0.78*	0.64*
Whitefly	0.66*	0.69*	0.90**	0.94**	0.60	0.75*	-0.61	0.70*

* Significant at 5% level** Significant at 1% level

Table 2. Correlation coefficient and regression equations of thrips and whitefly with respect to weather parameters

Weather parameters	Regression equation	Correlation coefficient
(a) Thrips		
Rainfall (mm)	$Y= -0.0085RF^2 + 0.8154RF$	0.56
Rainy days (Numbers)	$Y= -4.3425RD^2 + 18.07 RD$	0.61
Minimum temperature (°C)	$Y= 0.0384Tmin^2 -0.0536Tmin$	0.76
Morning relative humidity (%)	$Y= 0.0114RH\text{-}I^2 -0.788RH\text{-}I$	0.77
Afternoon relative humidity (%)	$Y= 0.0036RH\text{-}II^2 +0.0511RH\text{-}II$	0.81
Bright sunshine hours (hrs)	$Y= -0.7261BSS^2 + 7.3022BSS$	0.75
(b) Whitefly		
Rainfall (mm)	$Y= -0.0141RF^2 + 0.8592RF$	0.72
Maximum temperature (°C)	$Y= -0.1141Tmax^2 – 3.3005Tmax$	0.70

Zanwar et al (2014) reported thrips population was observed during early growth stage and continued till the end of crop growth in Bt cotton. This study has shown that the favourable weather conditions for development and progression of thrips population was light rainfall (<13 mm/h) and medium rainy days (2-3 rainy days /week) combined with light air (WV<4-5 km/h), and moderate to partially cloudy condition (BSS of 5-8 h/day) prevailing coupled with T_{max} (30.0-33.0 ^{0}C) (T_{min} (21.0-22.0 ^{0}C), RH-I >80% and RH-II >50%, respectively to build up optimal population (above ETL) of thrips during the 34-39 SMW period (Fig. 1). Kudale (2000) observed maximum population of thrips in 39th MW when temperature and RH were 31.0 ^{0}C and 83 %, respectively and these results were assenting with Ali et al (2020). However, inverse condition was determined; moderate to heavy rainfall (>13 mm/hr) and more number of rainy days (>2), moderate to heavy winds (> 5-6 km/hr.), clear weather (>8 hrs/day of BSS) were not favourable weather condition. These results are in agreement with Shivanna et al (2011) who stated that more precipitation was negative effect on the thrips and whitefly pest of cotton.

In general, year to year variation in first incidence of thrips was observed by 4-5 weeks (w.e.f. 28th to 32nd SMW) and it might be because of variation in date of monsoon initiation, which are influenced on sowing dates of Bt. cotton, and more or less similar trend was observed in peak incidence and completely cessation period. The large variation observed in numbers of count (11.9 to 75.6 thrips /three leaves) at peak incidence of thrips. These fluctuations in population build up were prominently due to variation in weather factors. It could be due to a reason stated earlier (Kaur et al 2009, Jaybhaye and Shinde 2020, Pathania et al 2020).

Correlation: The correlation between weather parameter and thrips population, and their significance is presented in Table 1. The analysis showed that cumulative RF, RD, Tmin, RH-I and RH-II was significantly and highly positive correlated and WV was significantly and positively correlated, while BSS was significantly and negatively correlated with thrips population. Positive and significant correlation between temperatures with population of thrips is also seen in other studies (Arif et al 2006, Akram et al 2013). Unlike these observations, thrips population was reported to be positively and significantly correlated with Tmax and significantly negative with BSS (Babu and Meghwa 2014). Similar positively significant correlation between RD, Tmin and RH-I was observed by Panwar et al (2015).

Regression models: Simple regresson models based on individual abiotic factor, which can be predicted population fluctuation of thrips and coefficent of determination is given in Table 2a and Figure 2 Simple regression study indicated that thrips population increases with increasing amount of rainfall (up to 50 mm/week) and rainy days (up to 2.5 i.e. 3 rainy days/week) and thereafter decreasing thrips population (Fig. 2a, b). Shivanna et al (2011 reported that more precipitation was negative effect population. The very good significant positive relationship of thrips population was established with T_{min}, Rh-I, RH-II and WV, and it was increased, increases thrips population (Fig. 2d-f and 2h). The negative significant relationship was observe with RF, RD and BSS (Fig. 2a, 2b and 2g), which indicate that as increase in these factors beyond certain range decreased population. Similar results were reported by Arif et al (2006), Akaram et al (2013), Pawar et al (2015).

The regression equation for the prediction of infestation of thrips in Bt. cotton computed by multiple linear regression analysis using data on thrips population dynamics and weather parameters. The computed regression equations were given in Table 3 (a), the coefficient of determination (R^2) was tested for significance at both 5% and 1% level of probability. The R^2 value indicated that how much % variation in thrips population is explained by the weather parameters involved in equation, but as seen by the regression equation,

Table 3. Multiple regression models for forewarning of thrips and whitefly

Model No.	Equation	R Square	Std. Error
(a) Thrips			
MRM-1	Y= -19.97+0.08 (RF)+9.34(RD)+3.22(T_{max})-1.94(T_{min})-1.12(RH-I)+0.88(RH-II)+1.58(BSS)-2.99(WV)	0.93	2.16
MRM-2	Y= -9.0 +0.14 (RF)+5.08(RD)-0.01(T_{min})-0.48(RH-I)+0.46(RH-II)+3.84(BSS)	0.91	2.24
MRM-3	Y= -0.962 +0.132 (RF)+0.963(RD)+0.496(T_{min})	0.83	2.73
(b) Whitefly			
MRM-1	Y= -7.31+0.02 (RF)-0.27(RD)+1.12(T_{max})+1.01(T_{min})-0.42(RH-I)-0.05(RH-II)-0.71(BSS)+2.33(WV)	0.98	0.99
MRM-2	Y= -14.97+0.05 (RF)+0.40(RD)+0.42(T_{max})+1.58($_{Tmin}$)-0.31(RH-II)	0.94	1.50
MRM-3	Y= -16.61 +1.58 (RD)+0.49(T_{max})+1.53(T_{min})-0.31(RH-II)	0.94	1.43
MRM-4	Y= -5.82+1.80 (T_{min})-0.28(RH-II)	0.94	1.32

RF in all three model, RH-I in first two model and WV in first model had a negative influence on thrips population, while other all the weather parameters had a positive influence in respective models.

On the basis of descriptive statistics analysis, generated MRM's and evaluated of all three MRM (Table 3a) were accepted and validated for forewarning of thrips population in *Bt* cotton. The comparison in between predicted and observed thrips population values shows very good agreement for the seasonal comparison and slope of the regression line (regression coefficient- R^2) for predicated vs observed thrips population values was significantly <1 (Figure 3-1 to 3). Separate regression for the three different models indicates accuracy of models and linear regressions are (1) y=0.986x, R^2=0.97; (2) y=1.0x, R^2=0.95 and (3) y=0.947x, R^2=0.93 whereas, x= observed thrips population values. The R^2 value indicated that 93 to 97 % accuracy of forewarned model with observed thrips population.

The observed mean error percentage of MRM 1, MRM 2 and MRM 3 was quite low (1.0, 3.0 and 1.4 % respectively). The seasonal prediction error of the model below 10-15% is acceptable error, considering the criteria for ETL of thrips (Jaybhaye and Shinde 2020). The present investigation of SMW wise seasonal prediction error was shown by MRM 1 to MRM 3 is 11-14 % except 34, 35, 37, 51 and 52 SMW. The error % observed more in the estimated values of models may be due to error in the data which could be caused due to error induced by human beings or by instruments during collection of data/processing of data, and similar observations were reported by Pathania et al (2020). Thus, all models (MRM 1 to 3) (Table 3a) can be used in the field of Bt. cotton to forewarning of thrips infestation under given environmental conditions for one week in advance.

Whitefly (*Bemisia tabaci* Genn)

Population dynamics: The whitefly builds up its population for 31st SMW after sowing and it was ranged in between 3 to

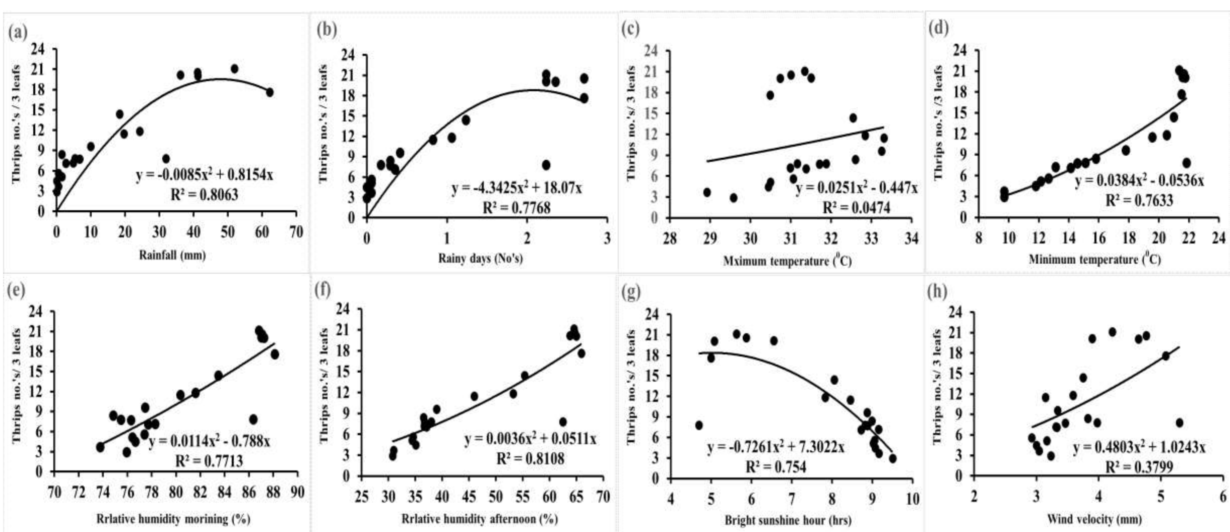

Fig. 2. Relation between thrips population and weather factors (a-rainfall; b- rainy days; c-maximum temperature; d-minimum temperature; e-morning relative humidity; f-afternoon relative humidity; g-bright sunshine hours and f-wind velocity)

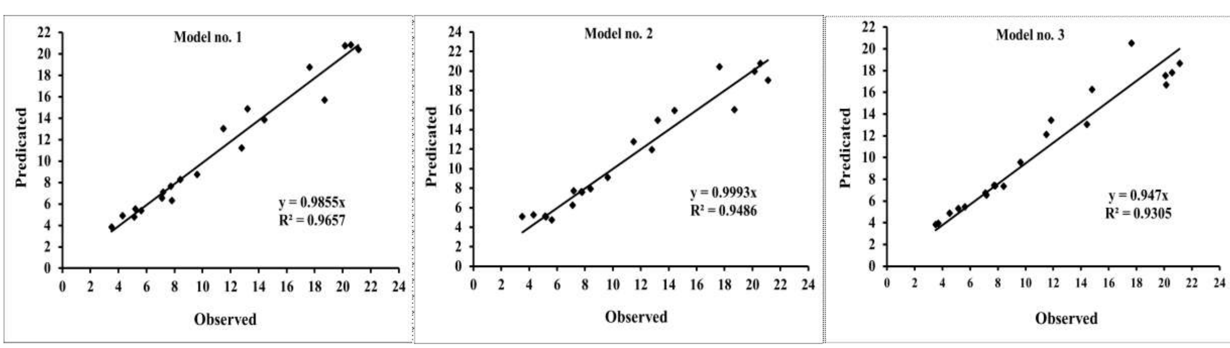

Fig. 3. Relation between observed and predicated thrips population

16 whitefly/three leaves. Thereafter, it increased gradually and reaches at the peak during 38[th] SMW and after that more or less constant up to 43[rd] SMW and decreased sharply thereafter (Fig. 1). The light rainfall (<13 mm/hr) and medium rainy days (2-3 rainy days /week) combined with light air (<5-6 km/hr) and moderate to partially cloudy condition (BSS of 5-8 hrs/day) prevailing, coupled with T_{max} (30.0-33.0 ^{0}C) (T_{min} (15.0-22.0 °C), RH-I >75% and RH-II >40% were congenial to build up optimal population (or above ETL) of whitefly (which have need to control through management) and which was observed during the 38-44 SMW period. Though, opposite condition was determined, weekly mean moderate to heavy RF (>13 mm/hr.) and a greater number of rainy days (>2/week) to moderate heavy winds (>5-6 km/hr), clear weather (>8 hrs./day of BSS) weather condition are not favourable for development and growth in population of whitefly under rainfed Bt. cotton.

The present findings on the activity, peak incidence and impact of abiotic factor on the whitefly are in agreement with the findings of Badgujar *et al.* (2018) who reported the population fluctuation of whitefly during *kharif* 2008-2010 on BG-I Bt cotton ranged from 0.2 to 61.0 whiteflies/3leaves, incidence started at 35[th] SMW and peak activity was observed during 41[st] to 45[th] SMW and thereafter decreased suddenly. Similar to present findings Ali *et al*. (2020) reported that they were reported that the population density of white fly was gradually increases by increase in temperature up to 35°C but decreasing the population size above 35°C. The population size was increased with the increase of humidity level but above 60% of humidity level it was highest. The fluctuation of population size was observed with the increase of wind speed which has no significant effect on population density of this pest. These findings are also supported with those of Sharma et al (2004), Mohapatra (2008), Pawar et al (2015), Parsai and Shastry (2009). Similarly, Selvaraj and Ramesh (2012) reported that maximum population (7.99/3 leaves) was build up at temperature ranged from 26.0 °C to 35.0 °C, relative humidity ranges from 84 and 67 per cent, wind velocity 6.30 km/hr, total shine hours (9.4 hrs), evaporation (52.20 mm), dewfall (0.708 mm) coupled with no rains weather condition. Similar results were reported by Shivanna et al (2011) where more precipitation was negative effect on whitefly. In general, year to year variation in first incidence of whitefly was observed by 2-5 weeks (w.e.f. 31[st] to 35[th] SMW) and more or less similar trend was observed in peak incidence and completely cessation period as mentioned above in mean population dynamics; it is because of earlier stated reason under thrips. Large variation observed in numbers of count (1 to 38 whitefly /three leaves) at peak incidence of thrips. These fluctuations in population build up were prominently due to variation in weather factors (Jaybhaye and Shinde 2020, Pathania et al 2020).

Correlation: Figure 1 clarifying the relationship in between weather parameters and whitefly population dynamics and the correlation study revealed that the whitefly population was significantly and highly positive correlated with T_{max} and T_{min}; significantly and positively correlated with RF, RD, RH-II and WV (Table 1).

Shivanna et al (2011) observed that whitefly population in range of 3.9 to 42.0 per 3 leaves and rainy days and relative

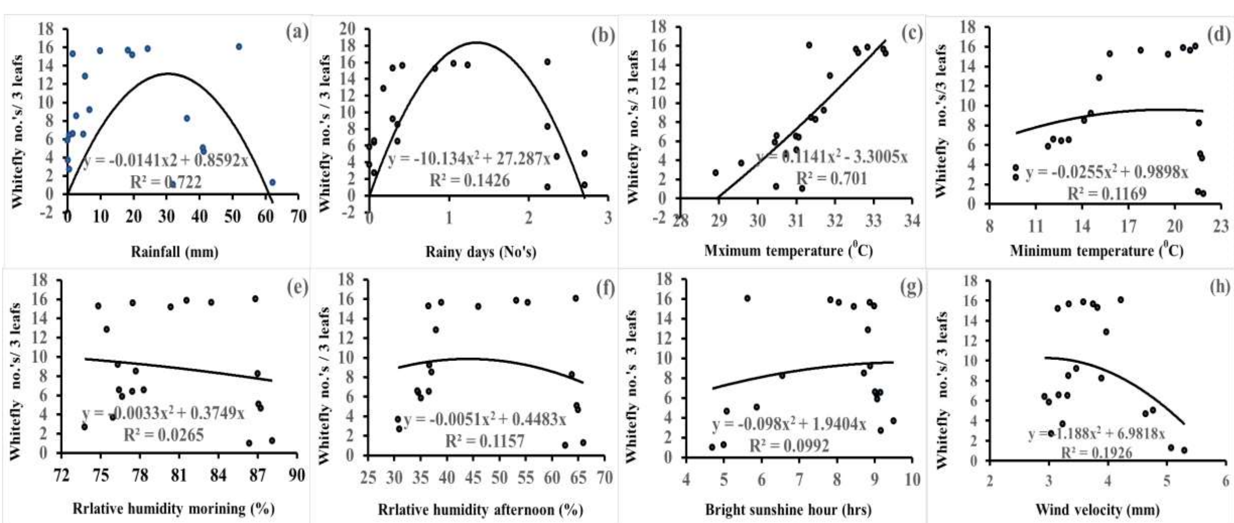

Fig. 4. Relation between whitefly population and weather factors (a-rainfall; b- rainy days; c-maximum temperature; d-minimum temperature; e-morning relative humidity; f-afternoon relative humidity; g-bright sunshine hours and f-wind velocity)

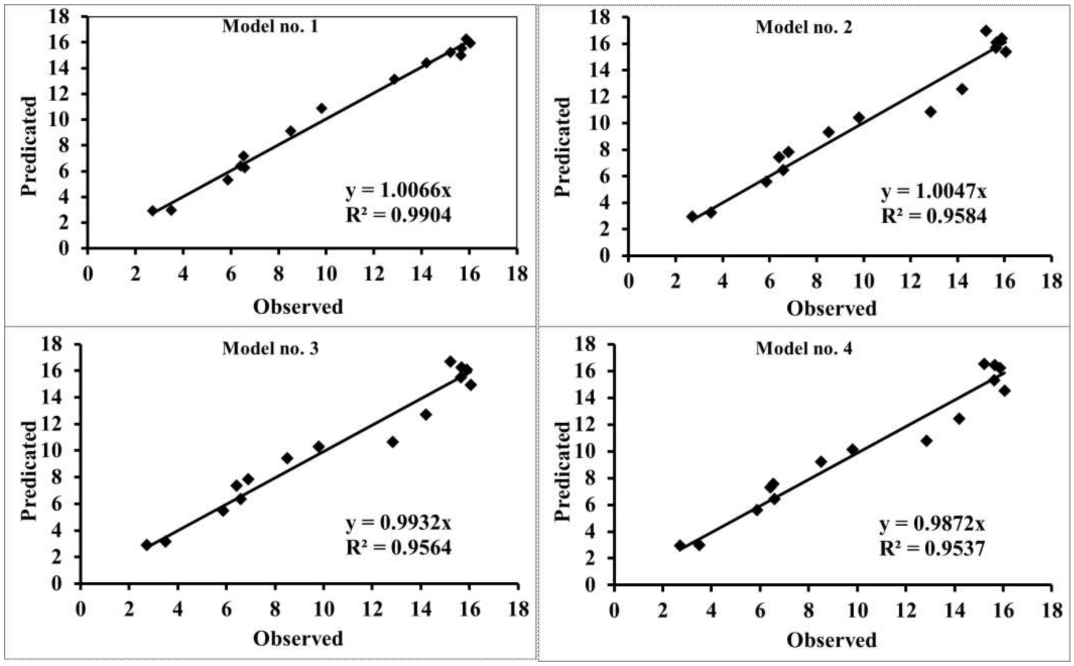

Fig. 5. Relation between observed and predicated whitefly population

humidity were the main significant contributing factors for maximum occurrence of whitefly in Bt cotton. Present results are in conformity with Ashfaq et al (2010) who reported that whitefly population to be positively correlated with the temperature and rainfall and the present findings is more or less agreeing with the results of Patel et al (2013), Akram et al (2013), Zanwar et al (2014), Babu and Meghwa (2014).

Regression models: The relationship between the recorded weekly mean abiotic factors independently and whitefly population (Fig. 4) and simple regression study indicated that population increases with increasing amount of rainfall (up to 40 mm/week) and rainy days (up to 2 rainy days/week) and thereafter decreasing population (Fig. 4a,b). The very good significant positive relationship of whitefly population was established with T_{max} and it was increased, increases population of whitefly (Figure 4c). The negative significant relationship with remaining abiotic factors (Fig. 4a-b and 4d-h), which indicate that as increase in above mentioned abiotic factors beyond certain range decreases population. These results are also assenting with Muchhadiya et al (2014) where that RF, T_{min}, RH-I and RH-II are significantly negatively associated with the whitefly incidence. Simple regression models based on individual abiotic factor, which can be predicated population fluctuation of whitefly, along with coefficient of determination is given in Table 2b. On the basis of descriptive statistics analysis, generated MRM's and evaluated of all four MRM (Table 3b) were accepted and validated for forewarning of whitefly population in *Bt* cotton. The comparison in between predicted and observed whitefly population values shows very good agreement for the seasonal comparison and slope of the regression line (regression coefficient) for predicated vs observed whitefly population values was significantly <1 (Fig. 5, 1-4). Separate regression for the four different models indicates accuracy of models and linear regressions are (1) y=1.007x, R^2=0.99; (2) y=1.005x, R^2=0.96 and (3) y=0.993x, R^2=0.96 and (4) y=0.987x, R^2=0.95; whereas, x= observed whitefly population values.

All models (MRM 1 to 4) (Table 3b) were accurate and acceptable to forewarning of whitefly infestation for one week in advance. This may be beneficial to management of in Bt cotton, because the observed mean error percentage in MRM 1, MRM 2, MRM 3 and MRM 4 was quite low (-0.4, -0.8 , -2.0 and -0.4 % respectively). In the present investigation of SMW wise seasonal prediction error was shown by MRM 1 to MRM 4 is 11-15 % except for 44 and 45 SMW. The error % observed more in the estimated values of models may be due to reason stated above (Pathania et al 2020). Therefore, statistical weather based thrips and whitefly pest models are required to continue verification and validation under filed condition for specific geographical location.

CONCLUSION

It can be concluded from the present study that thrips and whitefly are destructive pests up to some extent of the Bt. cotton crop and it will be more destructive in future with changing climate, and its population build-up and dynamics is greatly influenced by abiotic factors viz. rainfall, temperature, relative humidity and radiations which primarily affected the seasonal fluctuations and incidence thrips and whitefly in Bt. cotton under rainfed condition. August to October for thrips and September to November for whitefly are most crucial for population build up and further spread. Thus, planning and implementing management strategies against this pest under semi-arid climatic conditions during this time plays important role in sustainable rainfed Bt. cotton cultivation. Prediction or development of a Decision Support System for infestation and dynamics of a particular insect-pests involving the abiotic factors is of great significance in pest management. In general, the study warrants the adoption of pest monitoring for timely decision making in formulating pest management strategies. Need-based and timely Integrated Pest Management strategies are effective against thrips and whitefly under field conditions.

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