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ENTOMOLOGY

Identification of prediction model on population build up of *Singhiella pallida* Singh on *Piper betle* L. for timely intervention

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Abstract

Whitefly *Singhiella pallida* Singh is an important pest of betelvine, *Piper betle* L. infesting the crop throughout the year. The temperature played a crucial role in the population build up of the pest. The moderate temperature falling between 16°C to 20°C was found very much conducive for pest population development. However, relative humidity had a little role in population build up of the pest as compared to temperature. In contrary, rainfall was found detrimental to it. Prajneshu growth model was found to be most suitable non-linear growth model for prediction of the pest population build up. The 48th standard week was identified as the optimum time for intervention through insecticidal application as a prophylactic measures to check the peak pest population; supposed to be attained at the 52nd standard week as evidenced from pattern of population growth.

Highlights

- Temperature regime between 16°C to 20°C was found most important for population buildup of betelvine whitefly *Singhiella pallida*.
- Prajneshu growth model (1998) can be used for predicting the betelvine whitefly population buildup and calculating the time for effective control of the pest.
- The 48th Standard week was identified as optimum time for insecticidal application to check the pest population buildup.

Keywords : Betelvine whitefly, temperature, non-linear growth model

Betelvine (*Piper betle* L.) is a perennial, evergreen, dioecious creeper commonly known as 'Pan', grown in shady conditions with high humidity. It belongs to the order Piperales and family Piperaceae and is probably the native of Malaysia. It is one of the most important cash crops of rural India. It covers in about 55,000 ha areas, mainly used by 15-20 million people of our country for chewing purpose. It is a valuable foreign exchange earner in Indian trade; worth of which is ₹ 9000 million every year (Kaleeswari and Sridhar, 2013). In the Asiatic region, betelvine ranks second to coffee and tea in terms of daily consumption (Kumar *et al.,* 2010).

In addition to the tremendous market value of the crop, betel leaf is fairly rich in nutrients and minerals (Guha, 2006). It's essential oil possesses great medicinal property and is used in industrial purpose. Other than the great antioxidant property of betel leaf (Murata *et al.,* 2009), it has strong antimicrobial properties and found very effective against the harmful bacteria causing diseases in human (Datta *et al.*, 2011).

In India, the cultivation of this crop is also seriously threatened by several insect pests (Raut and Bhattacharya, 1999), but only a few homopteran insect-pests cause severe damage to the crop, among which whitefly, *Singhiella pallida* Singh is the most important pest of betelvine (Das and Mallik, 2010), which sucks cell sap from leaves but upper leaves of the plant canopy are highly preferred by the pest followed by the middle and lower leaves. It is the predominant pest found throughout the year, population being higher during November to March (Dahal *et al.*, 2009). The economic threshold level varies from 3-4 pests/leaf based on different climatological week (Pal *et al.,* 2013). It reduces leaf yield upto 13.39%, when mean population of flies is 43.4 per vine with an overall monetary loss is 29.63% (Das and Mallik, 2009).

Therefore, betelvine is not only an important cash crop of rural India but also has the tremendous importance in medical industries. However, its production is badly hampered by the homopteran whitefly *S. pallida* Singh. So, the research programme has been drawn to study the occurrence of the pest and elucidate the crop-pest-weather relationship. Moreover, emphasis was also given for prediction on population buildup of the pest. So, the optimum time for insecticidal application could be determined for effective control of the pests in the peak period of infestation.

Materials and Methods

The experiments were conducted in artificial closed conservatory ('Boroj') at the Instructional farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar, West Bengal during 2009 to 2012. The experimental domain comes under terai agro-climatic zone of West Bengal; situated between 25°57`N and 27°N latitude and 88°25`E longitude.

The visual observation on occurrence of white fly was carried out in a closed conservatory on betelvine cv Kali Bangla. The plantation was maintained in a plot size of 10 m x 5 m, having paired row of 5 m length each with a spacing of 10 cm x 10 cm x 50 cm. Three such plots were maintained in the *boroj.* Standard agronomic practices were followed for better growth and development of plants. All sorts of precautions were adopted for disease control.

Five vines were taken randomly from each row of the plot and adult whitefly population were recorded from top three apical leaves of each of the randomly chosen vine by visual observations. The observations

Table 1. Relation between weather parameters and whitefly infestation on betelvine

Pearson Correlation Coefficients, N = 52 Prob > |r| under H0: Rho=0					
Parameters	**Y**	**X_1**	**X_2**	**X_3**	**X_4**
Y (Insect Population)		-0.73760 (<.0001)	-0.20266 (0.1496)	-0.43278 (0.0014)	-0.04734 (0.7389)
X_1 (Average Temperature)	-0.73760 (<.0001)*		0.52822 (<.0001)	0.48045 (0.0003)	-0.07871 (0.5791)
X_2 (Average Relative Humidity)	-0.20266 (0.1496)	0.52822 (<.0001)		0.45672 (0.0007)	-0.56654 (<.0001)
X_3 (Rainfall)	-0.43278 (0.0014)	0.48045 (0.0003)	0.45672 (0.0007)		-0.38043 (0.0054)
X_4 (Sunshine Hours)	-0.04734 (0.7389)	-0.07871 (0.5791)	-0.56654 (<.0001)	-0.38043 (0.0054)	

*Values in parentheses indicates the exact probability level of significance were taken in every standard week throughout the period of investigation from February, 2009 to January, 2012. The insect population data, thus obtained in every standard week were pooled for studying the trends of infestation of the pest.

Weekly data of abiotic factors such as maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity, total rainfall and daily sunshine hours were recorded properly from the Agro-Meteorological Centre of the University. Correlation and regression studies were carried out between white fly population and weather parameters to elucidate their relationship. The contribution of each factors were also calculated. linear growth model for prediction of white fly population buidup.

Eight (8) non-linear growth models (Eleroglu *et al.*, 2014; Karadavut *et al.*, 2010; Khamis *et al.*, 2005; Parjenshu and Das, 2000; Prajneshu, 1998 and Seber and Wild, 1989) were used. They were compared to find out the best fit non-linear growth model for prediction of white fly population buildup.

For the purpose of finding out the best model, two measurements were used and these are namely, root means square error (RMSE) and coefficient of determination (R^2). Further the main assumptions of randomness and normality of residuals were examined by using well known run test and Shapiro-Wilk test (D'Agostino and Stephens, 1986).

The optimum time for insecticidal application was calculated by the mathematical expression derived from Prajneshu model (1998). It was :

Model Expression: $X(t) = (a \exp(bt))/(1+c \exp(bt))^2 + e$

$$t^* = (-1/b)(\ln[(3(1+ab)+(9a^2b^2+30ab+1)^{1/2})/2c(-2+3ab)])$$

where X(t), the white fly population at time t; a, b, c, d the parameters, e, the error term and t*, the optimum time for spraying insecticide.

Data computation and statistical analysis was done in SAS-9.2.

Results and Discussion

The relationship between the weather parameters and whitefly population buil up is presented in figure 1, 2 and 3. Betelvine was infested by the pest *S. pallida* throughout the year. However, the crop is heavily infested by the pest in the winter months. The pooled observations based on standard weeks showed highest whitefly population in the month of December. A steady increase of white fly population was observed on and from 42nd standard week and reached its peak at 52nd standard week. However, the high population of pest was found between

Table 2. Estimated model equations, diagonistic checks and different precision criteria for eight growth model

Sl. No.	Name of Non-Linear Mechanistic Growth Model	Model Expression	Goodness of Fit		Run-test	Shapiro-Wilk test(W)
			RMSE	R^2	|Z|	
1.	Gompertz model	X(t)=c exp(-b exp(-at))+e	4.135	0.199	4.270	0.860
2.	Logistic model	X(t)=c/(1+b exp(-at))+e	4.094	0.215	2.578	0.868
3.	Prajneshu model	$X(t)=(a \exp(bt))/(1+c \exp(bt))^2 + e$	2.397	0.731	1.875	0.899
4.	Weibull model	$X(t)=a-b \exp(-ct^d) + e$	4.201	0.190	4.700	0.634
5.	Morgan-Marcar-Flodin model	$X(t)=(bc+at^d)/(c+t^d) + e$	3.568	0.416	2.564	0.980
6.	Richards model	$X(t)=c/(1+b \exp(-at))^{1/d}+e$	4.359	0.128	3.457	0.6888
7.	Monomolecular model	X(t)=c-(c-b) exp(-at) +e	2.719	0.654	1.756	0.973
8.	Mixed-influence model	X(t)=(c(a+bd)-a(c-d)exp(-(a+bc) t))/((a+bd) +b(c-d) exp(-(a+bc) t)) +e	4.203	0.189	3.218	0.638

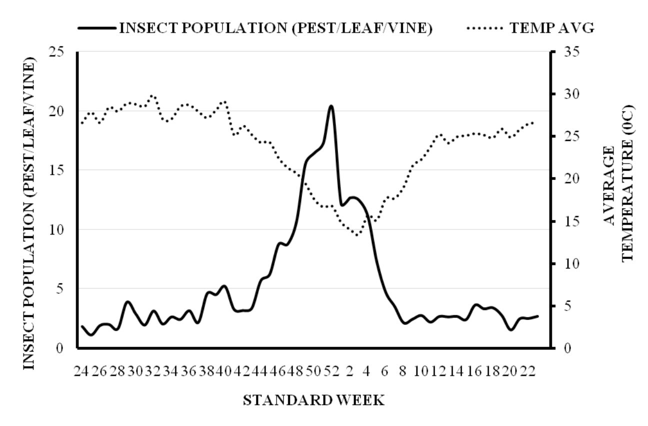

Figure 1. Influence of average daily temperature on population fluctuation of betelvine white fly during 2009-2011

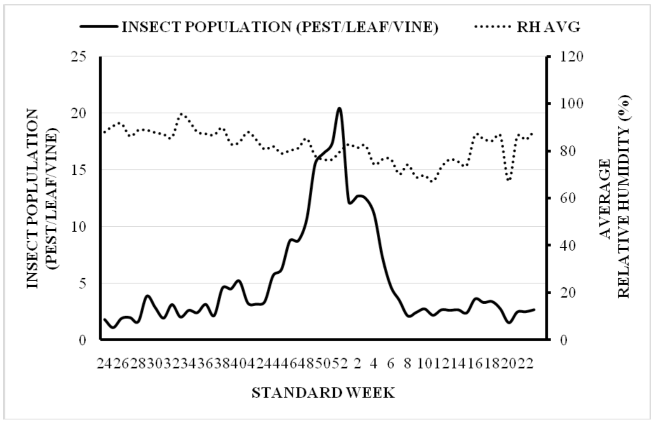

Figure 2. Influence of average relative humidity on population fluctuation of betelvine white fly during 2009-2011

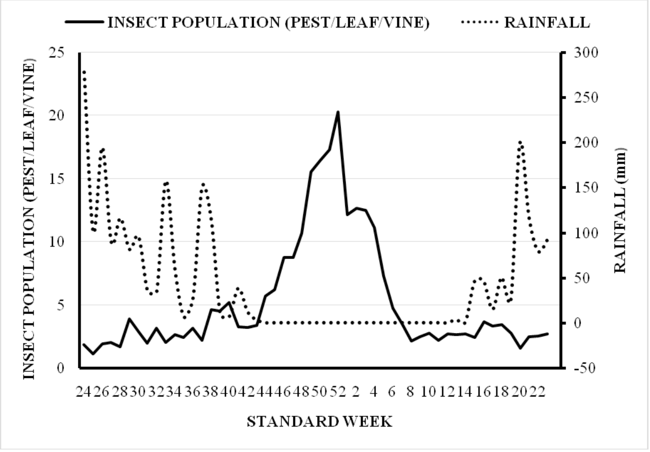

Figure 3. Influence of rainfall on population fluctuation of betelvine white fly during 2009-2011

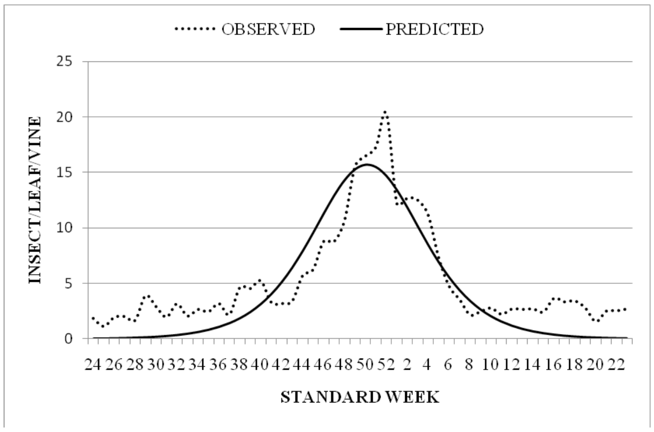

Figure 4. Observed versus predicted value of white fly population in Prajneshu Model

49th – 52nd standard weeks, when average daily temperature ranged from 16.65°C to 19.43°C.

A steady fall of average daily temperature was noticed from 42nd week and it continued upto 5th standard week. The highest white fly population (20.28 adults/leaf/vine) was observed in 52nd standard week, where the daily average temperature and relative humidity was noticed as 16.75° C and 79.97% respectively and was completely free from rainfall.

The daily average temperature fell down below 16°C on and from 1st standard week and continued upto 5th standard week. The insect population also started declining from 1st standard week. The daily average temperature then gradually raised to more than 20°C on and from 9th standard week. The insect population became low and such low population was observed upto 37th standard week.

So, it has been clearly noticed that whitefly population thrived well between temperature regimes of 16°C to 20°C. The pest population was declined below or above this temperature range.

The rainfall started from 15th standard week and continued upto 43rd standard week. However, heavy rainfall received between 20th to 33rd standard weeks. The temperature regime varied from 24.88°C to 29.83°C. The white fly population became very negligible during that period. The lowest population (1.10 adults/leaf/vine) was observed in 25th standard week. This week received a total rainfall of 100.95 mm. Moreover, previous week received the highest rainfall of 278.05 mm during the period of investigation. Continuous heavy rain from the preceding week resulted into lowest white fly population in 25th standard week. The average daily temperature and relative humidity were recorded 27.85°C and 90.50% respectively.

It is revealed from the data that the weather parameters had immense influence on population build up white fly on betelvine. The highest population was observed during moderate temperature regime without any rainfall. In-contrary, the lowest population was observed during higher temperature regime with heavy rainfall

The correlation and regression studies were done between the abiotic factors of the climatic parameters (independent variables) and white fly population (dependent variables) and presented in Table 1. The independent variables maximum and minimum temperature as well as maximum and minimum relative humidity was excluded due to its co-linearity with the independent variables, average temperature and average relative humidity.

A significant negative correlation was found between whitefly infestation level (Y) with average temperature (X_1) and total rainfall (X_3), having correlation co-efficient (r) value -0.738 and -0.432, both significant at 1% level. The average daily temperature showed higher negative correlation with white fly population. The results clearly indicated that an increase of average temperature and rainfall reduced the whitefly infestation level on betelvine.

The multiple regression equation relating to whitefly population (dependent variable) with abiotic factors (independent variables) was found as : $Y = 8.467 - 0.821 X_1 + 0.208 X_2 - 0.014 X_3 - 0.032X_4$; where, X_1 = average temperature, X_2 = average relative humidity, X_3 = total rainfall and X_4 = daily sunshine hours.

The coefficient of determination (R^2) was found 0.617, indicates that 61.7% variability in whitefly population is explained by the regression model. It means that the abiotic factors altogether contributed 61.7% variation in whitefly infestation. The average temperature alone contributed 83.82% of total variation of insect population, while average relative humidity and rainfall contributed 11.85% and 4.33% respectively.

The step wise regression equation supported the outcome of multiple correlation studies. The regression equation was found as; $Y=8.043 - 0.824X_1 + 0.212X_2 - 0.013X_3$, where X_1 = daily average temperature, X_2 = average relative humidity, X_3 = total rainfall respectively. The value of co-efficient of determination (R^2) was found as 0.617, showing 61.7% variation in white fly population contributed by the abiotic factors of the environment. So, it signifies that the average temperature was the most important abiotic factor, which imparted major influence in variation of white fly population. However, rainfall and relative humidity had minor but significant role in the population build up of betelvine whitefly.

The results under present investigation are in agreement with the works illustrated by Dahal *et al.* (2009), where white fly population is observed to attain its peak in the month of December in terai region of West Bengal. The population build up of the pest is negatively correlated with temperature and rainfall, while positively with relative humidity.

Eight non-linear growth models were compared on the basis of the weekly average white fly population data for identifying the best fit model for prediction of the pest population build up and determining optimum spraying time. The results of the experiment are represented in Table 2.

Prajneshu model was found to be most attractive having highest R^2 (0.731) and lowest RMSE (2.379) followed by Monomolecular model (R^2=0.654, RMSE = 2.719) and Morgan-Mercer-Flodin model (R^2=0.416, RMSE= 3.568). Goodness of fit statistics for other model was found to be much poor.

For examination of the assumptions of residuals, run test statistic and Shapiro-Wilk test statistic were calculated and was presented in table-2. At the 5% significance level, a Z-score with an absolute value less than 1.96 indicates randomness. The calculated value of run test statistic ◎Z◎ is less than the tabulated value at 5% level for monomolecular and Prajneshu model but it is not true for Morgan-Mercer-Flodin model.

The calculated value for Shapiro-Wilk statistic lie in the acceptance region at 5% level particularly for three best fitted models namely, Prajneshu, Monomolecular and Morgan-Mercer-Flodin So, considering the above all criteria it may be concluded that Prajneshu model was the best model for prediction of population build up of whitefly on betelvine. The predicted value of white fly population was shown against the observed value in figure 4.

The opportunity for determining the optimum time for insecticidal spray from Prajneshu model was also explored and it was found that optimum time for insecticidal application was in the 48th standard week as a prophylactic measure to check the peak pest population, which was attained at the 52nd week.

It is clearly noticed that betelvine whitefly *S. pallida* infested the crop throughout the year and temperature is the most important factor for population buildup of the pest. The pest population starts increasing on and from 42nd standard week. So, the growth model described by Prajneshu (1998) can be explored for predicting the population buildup of the pest as well as exact time for intervention through insecticidal application to avoid the crop loss.

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