DOI : 10.5958/0974-0112.2017.00116.5

Indian J. Hort. 74(4), December 2017: 604-607

Short communication

Temporal modeling for forecasting of the incidence of litchi stink bug using ARIMAX analysis

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ABSTRACT

The litchi, *Litchi chinensis* Sonn. is an important sub-tropical evergreen fruit crop. Among various insect pests of litchi, stink bug, *Tessaratoma papillosa* (Drury) is a major one causing extensive damage in Mizoram. The forecasting model to predict stink bug incidence in litchi was developed by ARIMAX model of weekly cases and weather factors. In exploring different prediction models by fitting covariates to the time series data, model × (mean maximum and minimum temperature, morning and evening relative humidity and rainfall) was found best model for predicting the stink bug incidence; all covariates were found significant predictors except evening RH, which did not have any significant covariates as predictor of stink bug incidence.

Key words: Prediction models, weather factors, stink bug.

The litchi is an important sub-tropical evergreen fruit crop contributing significantly to the growers' economy in India. It is highly specific to climatic requirements and probably due to this reason its cultivation is restricted to few countries in the world. Among fruit crops, litchi ranks seventh in area (90,000 ha.) and ninth in production (5,59,000 MT) but is sixth in terms of value in India. Since, it has adapted to variable climatic conditions, the production and productivity are limited by insect pests and yield loss can approach 70% (Boopathi *et al*., 2). Among various insect pests of litchi, stink bug, *Tessaratoma papillosa* (Drury) (Hemiptera: Tessaratomidae) is one of the most widespread and destructive pest species that up to 25-30% of fruit damaged on litchi in India (Butani, 5). Nymphs and adults suck the sap of the growing buds, leaf petioles, tender branches, flowering and fruiting shoots, causing inflorescence fall or shedding, stem necrosis, fruit discoloration and premature drop. Attacked fruits typically have a tan lesion on the seed testa. Liu and Lai (8) stated that up to 30% of fruit damaged by litchi stink bug in commercial orchards are damaged despite chemical applications. *Tessaratoma papillosa* infestation normally reduces the fruit yield by 20-30%, and may reduce it by 80-90% if the infestation is heavy. Liu (7) gave detailed information on the reduction in litchi and longan yield in Dongguan county, Guangdong Province in South China. Recently, an outbreak of litchi stink bug was observed in the Chotanagpur plateau of Jharkhand, India, during February-April (Choudhary *et al*., 6).

Influence of weather parameters on stink bug incidence is lacking, which is essential for developing management strategies. Current studies showed that though the infestation was recorded throughout the year, it was found low in rainy season, moderate during post rainy season and high in summer. Therefore, these studies clearly show that besides the availability of new shoots and flowers, weather parameters also play an important role in the stink bug incidence in litchi orchards. The population buildup of any insect is very intimately related with the weather parameters (Boopathi *et al*., 1). Forecasting enables to prevent outbreaks and epidemics of stink bug incidence. Hence, this study also aimed at proposing a prediction model to use management practices well in advance.

The investigation was conducted for two years on eight-year-old litchi orchard (cv. Shahi) at ICAR Research Complex for NEH Region, Mizoram Centre, Kolasib, Mizoram. Ten trees were randomly selected and were kept free from insecticidal sprays during the period of investigation. Sampling was done at weekly interval accounting all stages of stink bug except eggs. In each tree, four terminal shoots were selected at random from the entire plant canopy. Thus, 40 shoots growing in all directions were sampled per week. The weather record from March 2009 to March 2010 was obtained from the Meteorological Unit, ICAR Mizoram Centre, Kolasib, Mizoram. Daily reported weather parameters include mean minimum and maximum temperature, morning and evening relative humidity (RH) and rainfall; these variables were collected and recorded at the weather station.

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ARIMAX model is an extension of autoregressive integrated moving average (ARIMA) modeling in attempt to predict the stink bug incidence using the weather factors and the stink bug population in corresponding weeks (Bowerman and O'Connell, 3; Box *et al.*, 4). The predictors in the model included the stink bug population in the corresponding week, mean maximum and minimum temperature, morning and evening RH and rainfall lagged at one week. The modeling of ARIMAX model was performed using SAS Software Version 9.3 (SAS, 9).

The population of stink bug varied from 2.29 to 8.34 (Fig. 1). The highest population of stink bug was during May (8.34), March (7.99) and June (7.73). A rapid decline in the stink bug population observed during October 2009 and December 2009 with small fluctuation in the stink bug incidence. An increase in minimum and maximum temperature, decrease in morning and evening RH were occurred during summer months, April (7.99), May (8.34), June 2009 (7.73) and July (5.87), favours the population build-up of stink bug.

The moving average intervals as 2, 4, 6 and 8. The moving average for 2 was the average of the previous one data point and the current data point. Similarly, the moving averages for 4, 6 and 8 were the average of the previous 3, 5 and 7 data points, respectively and the current data points. As a result, peaks and valleys were smoothed out. An increasing and decreasing trend was observed during the period of observation of the stink bug incidence (Fig. 2). The larger the interval (interval, 8), the more the peaks and valleys were smoothed out. The smaller the interval (interval, 2), the closer the moving averages were to the actual data points.

The covariates fitted in the models included the stink bug incidence in the corresponding weeks, mean maximum and minimum temperature, morning and evening RH and rainfall, all lagged at one week period. The significant predictors was mean maximum temperature (p = 0.0191), minimum temperature (p = 0.0012), morning RH (p = 0.0002) and rainfall (p = 0.0001) when the stink bug incidence of the corresponding week (Table 1). However, model × was the best model with the lowest SBC of 199.31. The different predictors that were fitted in the model × were stink bug incidence, maximum temperature, minimum temperature, evening RH, morning RH and rainfall. The highest litchi stink bug population observed during summer months, April (7.99), May (8.34), June (7.73) and July 2009 (5.87). The average of litchi stink bug population was the highest during summer (7.48) than winter (3.55). Earlier, Liu and Lai (8) and Boopathi *et al.* (2) reported that stink bug

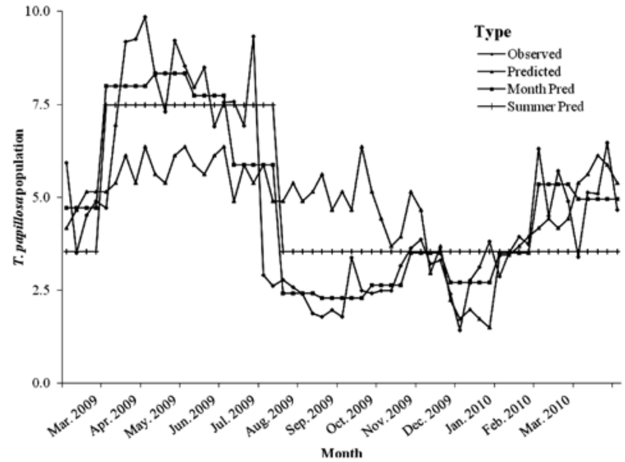

Fig. 1. Graphical representation of the observed, predicted, monthpred, summerpred of stink bug population in litchi.

Table 1. P-values and BIC of significant covariates of litchi stinkbug incidence in different ARIMAX models.

Model	Covariate	SE	t value	P value	AIC	BIC
I	*T. papillosa* population, Max.Temp	0.1301	-2.42	0.0191*	262.69	266.74
II	*T. papillosa* population, Min Temp	0.1239	-3.43	0.0012**	264.15	268.20
III	*T. papillosa* population, Max RH	0.1357	-1.11	0.2707ns	467.79	471.84
IV	*T. papillosa* population, Min RH	0.1240	-4.08	0.0002**	471.85	475.90
V	*T. papillosa* population, Rainfall	0.1083	-5.67	0.0001**	511.19	515.24
VI	*T. papillosa* population, Max Temp, Min Temp	0.2818	-0.34	0.7339ns	264.43	270.51
VII	*T. papillosa* population, Max Temp, Max RH	0.1559	3.57	0.0008**	457.09	463.16
VIII	*T. papillosa* population, Max Temp, Min RH	0.1972	0.12	0.9062ns	466.81	472.89
IX	*T. papillosa* population, Max Temp, Rainfall	0.1599	-1.01	0.3179ns	502.22	508.30
X	*T. papillosa* population, Max Temp, Min Temp. Max-RH, Min-RH, Rainfall	0.1322	-2.24	0.0291*	195.26	199.31

**,* Significant at 0.01 and 0.05 levels; AIC = Akaike's information criterion; SBC = Schwarz's ayesian criterion

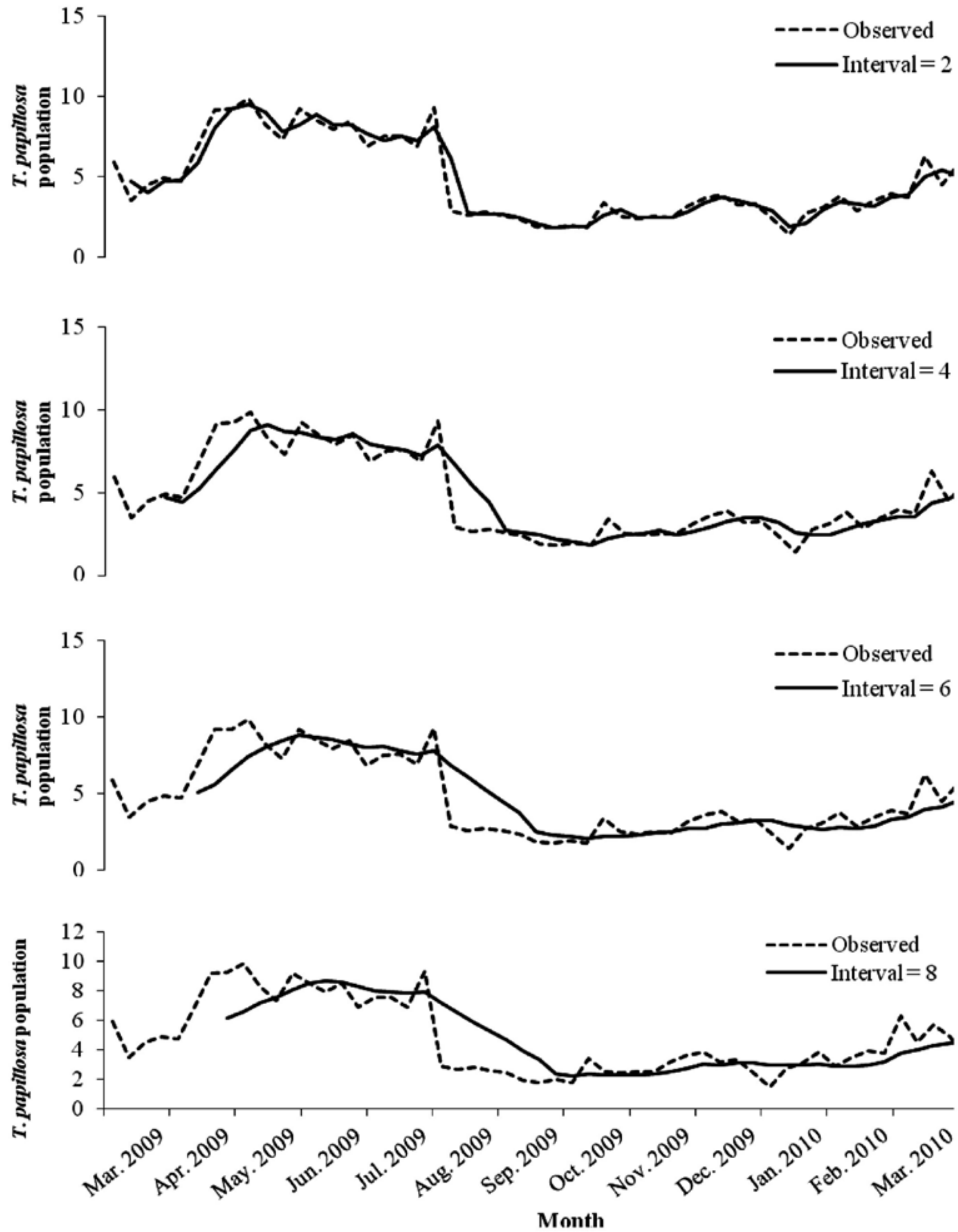

Fig. 2. Weekly litchi stinkbug population time series plot and 2, 4, 6 and 8 weeks moving average forecasts.

incidence found the highest during summer months than other seasons, which is in accordance with the present findings.

In exploring different prediction models by fitting covariates to the time series data, model × was found to be best model for predicting the stink bug incidence; all covariates were found significant except maximum RH. These covariates included the stink bug population in corresponding week, mean maximum and minimum temperature, maximum and minimum RH and rainfall. Meteorological factors such as temperature, humidity and rainfall are an important extrinsic factors that are directly associated with the development of stink bug. However, evening RH did not have any significant covariates as predictors of stink bug incidence. This can be explained by the fact that the stink bug incidence was rather low with less stink bug incidence in certain weeks, therefore, the stink bug incidence of the corresponding week was not a significant predictor, or at worst could lead to inaccurate prediction. Temperature was found as an important predictor for stink bug incidence.

Temperature affects the stink bug bionomics through the time required for developmental period decreases as temperature increases from 24° to 33°C. A decrease in temperature would have the opposite effect. All weather factors had a negative effect in the stink bug incidence. In all, using weather factors as predictors for stink bug incidence were different from one location to another; this pattern has been observed by several other studies.

This method is highly useful for estimating the incidence of stink bug and saves precious time by avoiding field observations. The knowledge of the spatial distribution of the stink bug would also deeply abet in the targeting the management measures. The prediction model based on the time series and weather factors were developed and showed different predictors.

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Received : June, 2017; Revised : September, 2017; Accepted : November, 2017