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Forecasting the incidence of jackfruit shoot and fruit borer *Diaphania caesalis* Walker (Pyralidae: Lepidoptera) in Jackfruit (*Artocarpus heterophyllus* Lam.) ecosystems

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Abstract

The shoot and fruit borer, *Diaphania caesalis* (walker) is a major pest of jackfruit, *Artocarpus heterophyllus* Lam. The influence of abiotic factors *viz.*, maximum and minimum temperatures, maximum and minimum relative humidity, wind speed and rainfall on *D. caesalis* damage in jackfruit was observed for three consecutive years (January 2013- December 2015). The percentage of fruit infestation was positively correlated with rainfall. In all the three years only rainfall induced the variability in total fruit infestation in the range of 77 to 97%. This information can be utilized to forewarn farmers about possible outbreak of the pest incidence, there by ensuing IPM strategies may be adopted to reduce a greater yield loss.

Keywords: *Diaphania caesalis*, IPM, prediction models, *Artocarpus heterophyllus,* forecasting

1. Introduction

The jackfruit (*Artocarpus heterophyllus* Lam.) is a tree species in the mulberry family (Moraceae) and is the largest tree-borne fruit. It is native to the Western Ghats of India and is known to spread from India to other tropical countries [5]. In India, the estimated area under jackfruit is about 67000 ha with an annual production of 1176000MT. In spite of vast cultivation and usage of jackfruit, it remains as an underutilized fruit species and needs urgent attention concerning pest management strategies.

Thirty nine species of insects are known to attack jackfruit in India [1]. Among them, shoot and fruit borer, *Diaphania caesalis* (Wlk.) is a major pest [16, 11]. The larva of *D. caesalis* is a voracious feeder, causes severe fruit damage [7, 14]. Khan and Islam (2004) [15] reported 27.44% damage by *D. caesalis* in jackfruit plantations in Bangladesh. There are no previous studies from India to quantify the damage of *D. caesalis*. The knowledge about relationship between a crop and its associated pest with regard to yield loss is an important aspect to determine IPM strategies.

The population dynamics of any pest species is usually affected by both biotic and abiotic factors [19]. Insect pests outbreak is greatly influenced by climatic factors i.e., rainfall, temperature and relative humidity [3, 13, 20]. The population dynamics of *D. caesalis* like any other species are liable to fluctuate according to the dynamic condition of prevailing environmental factors. The quantification of major mortality factors, both biotic and abiotic are necessary for reliable forecasting of insect populations. With an increasing frequency of extreme climatic changes, prediction of insect populations will be helpful for assessing a pest incidence. Insect-weather relationships can thus help in deciphering the role of different weather factors on insect populations. Mere knowledge of seasonal abundance and population build up trend may not be adequate to ensure timely management to tackle pest problems and prevent crop losses [4]. The forewarning models would be useful to predict the likely incidence of an insect pest, thereby helping in its timely management. In agriculture, in order to reduce yield loss pest outbreak prediction models help to decide timely intervention and avoid delay in IPM implementation [19]. Forecasting the peak abundance of pests in advance helps in timely management of crop pests. Hence a systematic survey for the periodical recording of percentage of crop loss caused by *D. caesalis* was done for three years (2013 to 2015).

In India, jackfruit is grown as a backyard crop and still not commercially exploited. Even though this fruit is considered as a staple food in some countries, information on the economics of jackfruit is scarce. It has not received much attention of researchers and is still considered as an under exploited fruit crop. Jackfruit is also known as the poor man's food, which can really contribute towards food security of the country. Cover sprays with insecticides cannot be recommended for the pest management of an underutilized crop like jackfruit. Therefore, this work is aimed at studying the relationship of abiotic factors with yield loss in jackfruit due to *D. caesalis,* so that appropriate management practices can be adopted in time to prevent crop loss.

2. Materials and Methods

2.1 Field Sites

A study was conducted in the jackfruit orchard at the Indian Institute of Horticultural Research (IIHR), Bengaluru (12° 8'N; 77° 35'E), India during January 2013 – December 2015. Trees of medium height (5-6 feet), between 12 and 20 years old and spaced at 10 m × 10 m apart, being pruned once in one or two years were selected for the study. The rain fed orchard was never sprayed with any pesticides, and the soil was fertilized with minerals and/or organic nutrients. The orchard was ploughed superficially twice or thrice a year to control weeds. The experiment was carried out in a randomized complete block design (RCBD).

2.2 Data Collection

Data on different weather variables were collected from the meteorological observatory at ICAR – IIHR experimental farm, Hesseraghatta. Out of 100 trees, 75 trees were selected at random for the study Weekly observations were made from the first Standard Meteorological Week (SMW) i.e first week of January to last week of December i.e. 48 SMW every year. The fruit damage was observed from 17th SMW (i.e. first week of May) to 36th SMW (last week of September) and was correlated with weekly averaged weather parameters.

Mature fruits were examined once a week from the selected trees. The fruits were categorized as damaged and undamaged by the presence or absence of borer hole and the percentage of infestation was calculated for each week independently. Thus the extent of infestation in every week was assessed from May to September each year. For the quantification of infestation, the following formula was used.

$$\text{Per cent borer Incidence} = \frac{\text{No of damaged fruits X100}}{\text{Total no of mature fruits}}$$

2.3 Forewarning Model

To develop a forewarning model for *D. caesalis*, the percentage of borer incidence on mature fruits in relation to weather parameters, i.e. rainfall (RF), maximum temperature (Tmax), minimum temperature (Tmin), morning relative humidity (% RH1), evening relative humidity (% RH2), evaporation (E) and wind speed (WS) at IIHR orchard during 2013 – 2015 was assessed. Each year, linear correlation coefficients were computed between the percent *D. caesalis* incidence in different weeks and a weekly mean value of each of the weather parameter, from the first week of May onwards until the maturity of fruit in September.

Multiple regression analysis was utilized to quantify contributions of various abiotic factors in fruit infestation. A linear multiple regression model was developed for each year independently, following the method of Snedecor and Cochran (1967) [21] to assess the percentage of fruit damage by *D. caesalis.* The percentage of fruit damage by the borer and weather parameters were analyzed using a stepwise regression. The model accuracy was confirmed by the value of the coefficient of determination (R^2). The model reliability was evaluated by comparing the observed and predicted percentage of damage by *D. caesalis* and the Root Mean Square Error (RMSE) was used to evaluate the regression model fitness [16]. The statistical analysis of the data was carried out using SPSS software (IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp 2012).

3. Results

3.1 Weather parameters and percentage fruit damage

The percentage of fruit damage by *D. caesalis* and the prevailing weather factors of different standard meteorological week (SMW) indicated that the mean pest population fluctuated significantly from last week of April to the first week of October during 2013 – 2015 (Figure 1). The fruits were damaged by *D. caesalis* from 17th SMW onwards. The pest population was increased from 18th SMW and fluctuated up to 36th SMW.

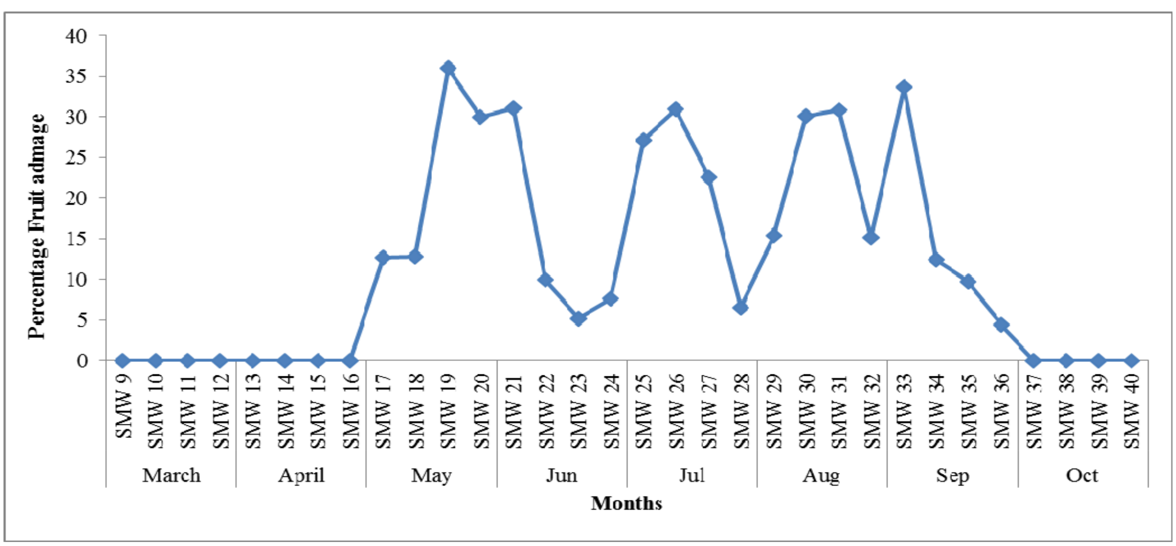

Fig 1: Percentage of fruit damage by *D. caesalis* in different standard meteorological weeks (SMW) during 2013 - 2015

During the fruiting period of jackfruit (February - October) *D. caesalis* recorded four distinct fruit damage peaks every year. *D. caesalis* caused the highest damage during the 19th SMW (36.06%), 26th SMW (40.12%) and 30st SMW (31.2%) in 2013, 2014 and 2015 respectively.

3.2 Forewarning Model

The correlation between present fruit damage and weather parameters indicated a positive correlation between the fruit infestation and rainfall in all the three years 2013 (r=0. 93), 2014 (r=0. 88) and 2015 (r=0. 98). There was no significant relationship between other weather factors and fruit infestation (Table: 1).

Table 1: Relationship between *Diaphania caesalis* infestation and weather parameters during 2013-15.

Years	RF	T_{Max}	T_{Min}	R_{H1}	R_{H2}	E	WS
2013	0.94^{**}	-0.18^{NS}	0.31^{NS}	-0.41^{NS}	-0.11^{NS}	0.19^{NS}	0.31^{NS}
2014	0.88^{**}	-0.28^{NS}	0.42	-0.04^{NS}	0.13^{NS}	-0.35^{NS}	-0.15^{NS}
2015	0.99^{**}	0.10^{NS}	0.37	-0.06^{NS}	-0.02^{NS}	0.08^{NS}	-0.35^{NS}

** Correlation is significant at the 0.01 level
NS Not significant

Weather parameters contributed the variability in total infestation of 94.30 (R^2 = 0.943), 82.90 (R^2=0.829) and 97.90% (R^2=0.979) in 2013, 2014 and 2015 respectively. Rainfall alone could make the variability in percentage fruit damage of 88.10 (R^2 = 0.881), 78 (R^2 = 0.78) and 97.40% (R^2 = 0.974) during 2013, 2014 and 2015, respectively (Table 2).

Table 2: Forecasting models for *Diaphania caesalis*

Year	Model type	Statistical model	R2	RMSE
2013	Full regression model (All weather parameters)	$y=150.32 + 5.29X_1 - 2.20 X_2 - 3.08X_3 - 0.91X_4 + 0.50X_5 + 4.13X_6 + 0.007X_7$	94.30%	6.32
	Optimized model	$y = 1.658 + 5.17X_1$	88.10%	7.46
2014	Full regression model (All weather parameters)	$y = 45.728 + 3.737X_1 – 0.773X_2 - 2.015X_3 + 0152X_4 + 0.295X_5 – 1.137X_6 + 0.567X_7$	82.90%	9.50
	Optimized model	$y = 5.105 + 4.009X_1$	78%	8.81
2015	Full regression model (All weather parameters)	**y =** $59.067 + 4.846X_1 -0.307X_2 -1.274X_3 – 0.266X_4 -0.018X_5 – 0.769X_6 + 0.124X_7$	97.90%	3.12
	Optimized model	$y = 4.684 – 0.181 X_1$	97.40%	2.80
Combined (2013-2015) Model		$Y=52.811+4.572 X_1-1.711 X_3$	88.6%	2.51

Where: Y =Percentage damage by *D. caesalis,* X1= Rainfall (mm), X2= minimum temperature (°C), X3= maximum temperature (°C), X4= Morning Relative humidity (%) at 8.00 am, X5= Evening Relative humidity (%) at 5.00 pm, X6 = evaporation, X7= wind speed.

4. Discussion

In order to establish sustainable pest management strategies, it is essential to know the percentage of damage in different months of cropping season and its relationship with various climatic factors. The percentage of fruit damage by *D. caesalis* followed similar trend every year. The percentage of jackfruit damage by *D. caesalis* in different standard meteorological weeks during the study period indicated that no damage was noticed during March-April and September-October. The fruit damage was more at the onset of rainfall as reported by Hasyim *et al*. (2008) [12], who reported that the number of flies and moths caught in pheromone traps was directly linked to rainfall.

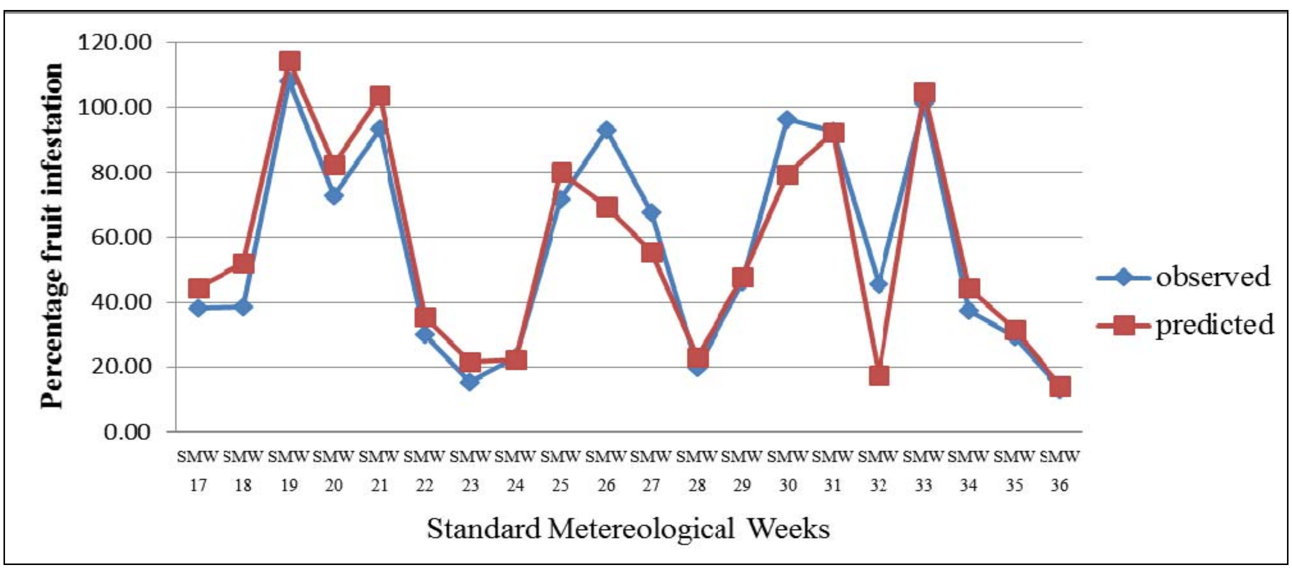

Fig 2: Actual and predicted levels of *Diaphania caesalis* infestation in different standard meteorological weeks (SMW) during 2013-15

Samuthiravelu, *et al* (2010) [22] have observed that the frequency of leaf webber, *Diaphania pulverulentalis* increased at increased relative humidity and rainfall. The model developed in the present study (Y=52.811+4.572 X1-1.711 X3), indicated that rainfall could be used in forecasting of *D. caesalis* damage. Furthermore, rainwater entering in to the fruit which causes rotting of fruits could be a reason for more damage of jackfruit during rainy season. Our observations are similar to those of Caloran and Ferino [2], who reported that the increase of various lepidopteron pest populations was highest during rainy periods. Rahmathulla *et al*. (2012) [18] reported that low temperature with high humidity during rainfall was favourable for breeding and multiplication of *D. pulverulentalis*. Emura *et al* (1974) [6] and Guarneri (2002) [10] also reported similar kind of observation on population dynamics of different insect pests.
The Knowledge on the relationship between pest and abiotic factors are key factors in constructing an effective integrated pest management program for any insect pest. Most of the systems of forecasting insect pest outbreak based on weather parameters [8, 9], which was also utilized in this study. The study provided an accurate forecast of infestation period of the pest. The significance of the model was less or no residual values between observed and predicted values (figure 2). Using this model, it would be possible to provide necessary forecasts of *D. caesalis* infestation in jackfruit ecosystem.

Fig 3: *Diaphania caesalis* damage on mature jackfruits

5. Conclusion

A study was conducted to know the impact of various abiotic components on the incidence of *D. caesalis* on jackfruit. Among different climatic factors, only rainfall had a significant positive correlation with the incidence of *D. caesalis*. Hence rainfall could be a valuable indicator of the variability in jackfruit borer infestation and can be utilized to make appropriate forecasting to minimize more loss of yield.

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