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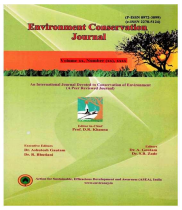

Forewarning of insect incidence based on weather variables for management of cropping practices in Sugarcane

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ABSTRACT

The early shoot borer, top borer, root borer, internode borer are major insect occurs in most of the sugarcane growing areas of the Gujarat and cause extensive damage to the sugarcane crop, which leads to losses in the crop yield. The weather discrepancies acting an important role in development of sugarcane insect and pest. The proper management of cropping practices may leads to overcome on it. Therefore it need to develop weather based approaches for forewarning the insect incidence which helps to farmers takes timely control measures to reduce the damage and yield losses due to this borer complex. Current study, relationship between insects incidence with weekly average weather parameters has been workout by using Karl-Pearson's correlation approach on the 18 years of the data (2000-01 to 2017-18) in the Navsari district. The some of the weather variables were found significantly correlated with insect incidence. The multiple linear regression (MLR) and discriminant function analysis approach were adopted for statistical forewarning of the insect incidence. It was observed that MLR technique found better than discriminant function analysis for forecasting of insect incidence for forewarning of early shoot borer at 90 DAP and top shoot borer incidence at 5th month of crop season respectively.

Introduction

Sugarcane is main source of sugar in India. Sugarcane is predominantly grown in tropical and subtropical regions. Sugarcane is main source of raw material for the production of white sugar, jaggery and *khandsari*. Sugar industry is second largest agro based industry in India after textile industry. The Sugarcane cultivation and Sugar industry in India plays a vital role in socio-economic development of rural areas by mobilizing rural resources and generating higher income and employment opportunities. Gujarat is the sixth largest sugarcane producing state in India with a production of 11.61 Million tonnes and account for about 3.21% of total sugarcane production in a country. In Gujarat, area under sugarcane is more than 1.65 lakh hectares of land (Anonymous, 2020). A sugarcane crop is sensitive to the climate, irrigation, fertilizers, soil type, diseases, insects-pest, varieties, and the harvesting time. The sugarcane crop is attacked by a varied range of insect pests all through its plant stages (Williams *et al.,* 1969). The early shoot borer, top borer, root borer, internode borer are major insect additively cause considerable damage to the sugarcane crop,

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which results in yield losses. The weather based forewarning provides information about the time and severity of outbreak of this borer infestation of sugarcane. Insect-pest monitoring data along with corresponding weather data is crucial to improve insect-pest forewarning models and provide forecasts for operational use. Understanding the nature of this combined interaction needs an inter-disciplinary approach to identify critical components needed to develop management tools to address the pest and disease concerns of a farmer. Notwithstanding many years of implementation of pest management strategies, some pests remain difficult to manage and their dynamics are still largely unpredictable, with sometimes dramatic yield reduction (Kiritani, 2006; Gregory *et al.*, 2009).

The several efforts have been attempted to study the relation between insect-pest incidence, weather parameters and yield losses. Srivastava (2002) has also been attempted to forecast the frequency and intensity of occurrence of insect-pests and diseases of various crops like cotton, grain sorghum, wheat, corn, soybean, alfalfa, peanuts, dry beans, potato, millets, tomato, sugarcane etc. Paswan *et al.* (2017) studied relationship between borer incidence and weather parameters and developed forewarning models for borers of sugarcane under Bihar agro ecosystem. Deb and Bharpoda (2017) studied relationship and found the impact of meteorological factors on population of major insect pests in tomato under middle Gujarat conditions. Chattopadhyay *et al.* (2019) studied the effect of weather parameters on the population dynamics of *Spodoptera litura* in soybean and cotton during kharif season using six years pest data. It was shown that incidence of *S.litura* in soybean and cotton can be predicted well in advance using the observed relationship of the pest with weather parameters as well as weather forecast. Mohankumar *et al.* (2020) studied the seasonal incidence of phytophagous mite pests on different varieties of sugarcane crop. Laterally with this Priya and Suresh (2009), Kumar *et al.* (2014), Sattar *et al.* (2014), Marcari *et al.* (2015) and Kumar *et al.* (2015) developed forecast models based on agro-meteorology for forecasting of yield and quality of sugarcane crop. The advanced techniques were adopted by Laxmi and Kumar (2011), and Hossain and Abdulla (2015) and Dubey *et al.* (2018) for forecasting sugarcane yield.

Looking to the scope and importance of the forewarning of insect incidence in relation to weather variable, the current study was carried out to develop statistical forewarning model for predicting insect incidence well in advanced for effective management cropping practices in sugarcane.

Material and Methods

The study was conducted in Navsari district of south Gujarat. The Navsari is located at 20.95˚ N 72.93˚ E. In completion of the objective of the development of forewarning of insect incidence the weather data were collected from the Nodal officer (IMD project), Dept. of Agril. Engineering, NMCA, NAU, Navsari for the year 1991 to 2016. The different weather parameters were considered *viz.* weekly average maximum temperature, weekly average minimum temperature, the total weekly rainfall, weekly average morning relative humidity (RH-I), weekly average evening relative humidity (RH-II). The study utilized the past data (2000-01 to 2017-18) on per cent incidence of early shoot borer (60 and 90 DAP) and top borer (5th month and 7th month of crop season) which were collected from annual reports (Entomology) of Main Sugarcane Research Station, Navsari Agricultural University, Navsari.

Statistical data analysis

In present investigation analysis of data was carried out by using following different kind of statistical tools.

Association of insect-pest incidence with weekly weather parameters

The relationship between incidence of early shoot borer and top shoot borer (Y_i) with weekly average weather parameters (X_i) were studied by using Karl-Pearson's correlation coefficient (r) approach. The significance of correlation coefficient was tested by t-test statistics at 5 or 1 per cent level of the significance.

$$r = \frac{\sum_{i=1}^{n}(X_i-\bar{X})(Y_i-\bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i-\bar{X})^2 \sum_{i=1}^{n}(Y_i-\bar{Y})^2}} \quad (1)$$

Statistical forewarning models

The statistical forewarning models were developed using multiple linear regression (MLR) and

discriminant function analysis approach (Sisodia *et al.*, 2014 and Garde *et al.,* 2020). The weakly weather variables were utilized for development of weather indices (Agrawal *et al.,* 2007; Garde *et al.,* 2015). The forewarning model was developed using observed weekly weather variables as explanatory variable and per cent incidence of insect as response variable. The form of the developed model is as follow:

- Model 1

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots + \beta_n X_n + e \quad (2)$$

Where,
Y is per cent insect incidence
$\beta_0, \beta_1, \beta_2, \ldots, \beta_n$ are regression coefficients
X_i is the average effect of the ith weather variable in each year (i=1, 2,..., n).
e is the error term

Further MLR model was developed using weather indices as independent variable and per cent incidence as dependent variable through stepwise regression method.

- Model 2

$$Y = A_0 + \sum_{i=1}^{p} \sum_{j=0}^{1} a_{ij} Z_{ij} + \sum_{i \neq i\prime=1}^{p} \sum_{j=0}^{1} a_{ii\prime j} Z_{ii\prime j} + cT + e \quad (3)$$

Where,
Y is observed per cent insect incidences
A_0 is the intercept
$Z_{ij} = \sum_{w=1}^{m} r_{ij}^{j} X_{iw}$ and
$Z_{ii\prime j} = \sum_{w=1}^{m} r_{ii\prime j}^{j} X_{iw} X_{ii\prime w}$ are the weather indices
a_{ij} and $a_{ii'j}$ are the regression coefficients
p is the number of weather variables to be used
c is the regression coefficients of trend variable
T is the trend variable
e is the error term

The Discriminant function analysis was attempted to develop forewarning model using weighted weather indices. Total fifteen weighted indices were considered. Two discriminant score have been obtained from these weighted weather indices. Two discriminant score along with trend were used to develop the model through stepwise regression technique (Agrawal *et al.,* 2012, Garde *et al.*, 2015, Kumari *et al.*, 2017). The form of the developed model is as follow:

- Model 3

$$Y = \beta_0 + \beta_1 ds_1 + \beta_2 ds_2 + \beta_3 T + \varepsilon \quad (4)$$

Where
Y is sugarcane yield (t/ha)
β_i are regression coefficient, i =0,1,2,3
ds_1 and ds_2 are discriminant scores,
T is the trend variable
ϵ is error term assumed to follow $N(0, \sigma^2)$
The comparison of developed forewarning models were done with help of Adj. R^2, Forecast error %, Mean Absolute Percentage error (MAPE) and Root mean Square error (RMSE).

Results and Discussion

Association of insect incidence with weekly weather parameters

The association between insect incidence and weekly weather parameter were observed. It was observed the significant correlation coefficient between early shoot borer incidence at 60 DAP (Days after transplanting) and weekly average weather parameters *viz*. morning relative humidity (7th SMW) and evening relative humidity (6th SMW). It was indicated that relative humidity was found to profoundly influence the borer infestation. At 90 DAP, the significance of correlation coefficient were observed between early shoot borer incidence and morning relative humidity (5th SMW) and evening relative humidity (3rd, 12th and 13th SMW). It is also observed rainfall during 60-90 DAP was observed to reduce borer infestation though the association was not significant. The significance of correlation coefficient was observed between top shoot borer incidence at 5th month after transplanting and maximum temperature (2nd and 17th SMW), minimum temperature (19th and 20th SMW). It observed that the association between mean temperature and the pest seems to be dominated by minimum temperature. At 7th month, the significant correlation coefficient were observed between top shoot borer incidence and weekly average maximum temperature (11th SMW), minimum temperature (11th, 19th and 27th SMW), and morning relative humidity (29th and 30th SMW).

Forewarning model: MLR using weekly weather variables

The forewarning models were developed using MLR techniques with weekly weather variables for per cent incidence of early shoot borer (ESB) at 60 and 90 days after transplanting (DAP) and top shoot borer (TSB) at 5th month & 7th month. The observed resulted were presented in Table 1 along with adj. R^2. No variable were found significant in forewarning model for top shoot borer at 7th month. It was observed from the Table 1 that Model-1.1 have high value of adjusted R^2 (32.2) and low RMSE (0.45). The value of MSE, RMSE and MAPE ranges from 0.11 to 0.80, 0.33 to 0.90 and 17.75 to 22.25, respectively. It indicated that none of the models were found suitable for Forewarning insect incidence, therefore study utilized modified approach for forewarning insect incidence.

Forewarning model: MLR using weekly weather indices

Further model was developed by taking weather indices as independent variable for per cent incidence of early shoot borer (ESB) at 60 and 90 DAP and top shoot borer (TSB) at 5th month & 7th month. Stepwise multiple regression technique was used to obtain significant weather variables. The obtained forewarning model equations are presented in Table 2. It was observed from the Table 2 that Model-2.2 show high value of adjusted R^2 (74.7 %) and acceptable RMSE (0.69) than Model-2.1. Thus Model-2.2 found suitable for forewarning early shoot borer incidence at 90 DAP ($Y = 1.237 + 0.001\ Z_{251}$). The interaction between minimum temperature and morning relative humidity showed impact on incidence of ESB at 90 DAP. It was also found from Table 2 that Model-2.3 found suitable for forecasting of top shoot borer at 5th month with respect to high value of adjusted R^2 (88.9) and RMSE (0.72) ($Y = 9.583 + 0.026Z_{41} - 0.046T$). The weighted morning relative humidity (Z_{41}) and weighted average interaction between maximum temperature and morning relative humidity (Z_{141}) along with trend T have significant effect on top shoot borer incidence. Similar results for morning relative humidity were observed by Paswan *et al.* (2017) for top shoot borer of sugarcane in Bihar.

Forewarning model: using discriminant function analysis

The discriminant function analysis techniques was adopted for development of models for forewarning the incidence of early shoot borer at 60 and 90 DAP, top shoot borer at 5th and 7th month. The obtained forewarning model equations are given in Table 3. The Table 3 revealed that Model-3.1 indicated that 79.1 per cent variation in early shoot borer incidence at 60 DAP was accounted by ds_2 and T ($Y = 1.504 + 0.158ds_2 + 0.094T$) and found low RMSE (0.75) which indicated appropriate forewarning model for early shoot borer. Similarly, the Model-3.3 indicated 54.1 per cent variation in top shoot borer incidence at 5 month was accounted by ds_1. ($Y = 1.545 + 0.111ds_1$) and lower RMSE (0.73) which showed suitable forewarning model for top shoot borer. The similar statistical approach was carried out by Agrawal *et al.* (2012) in Kanpur and similar result were observed for wheat yield.

Table 1: Forewarning model equations for insect incidence using weekly weather variables

Models	Model 1	Model equation	Adj.R^2
ESB (60DAP)	Model-1.1	$Y = 4.859 - 0.095\ X_5$	32.2
ESB_(90DAP)	Model-1.2	$Y = 1.662 + 0.055\ X_3$	26.1
TSB_(5 Month)	Model-1.3	$Y = 12.009 - 0.131\ X_4$	25.9

Table 2: Forewarning model equations for insect incidence using weather indices

Model	Model 2	Model equation	Adj.R^2
ESB(60DAP)	Model-2.1	$Y = 4.872 + 0.038\ Z_{51}$	53.9
ESB(90DAP)	Model-2.2	$Y = 1.237 + 0.001\ Z_{251}$	74.7
TSB(5Month)	Model-2.3	$Y = 9.583 + 0.026Z_{41} - 0.046T$	88.9
TSB(7Month)	Model-2.4	$Y = 11.315 + 0.001\ Z_{141} - 0.088T$	79.6

Table 3: Forewarning model equations for insect incidence using Discriminant Function

Model	Model 3	Model equation	Adj. R^2
ESB(60DAP)	Model-3.1	$Y = 1.504 + 0.158ds_2 + 0.094T$	79.1
ESB(90DAP)	Model-3.2	$Y = 1.753 - 0.032ds_1$	75.7
TSB(5Month)	Model-3.3	$Y = 1.545 + 0.111ds_1$	54.1
TSB(7Month)	Model-3.4	$Y = 2.778 - 0.122T$	43.4

There are several studies on forewarning of insect and pest using weather variables by adopting different statistical methods for different crops has been discussed by Agrawal and Mehta (2007). But limited work has been carried out on the forewarning of insect incidence particularly in sugarcane crop based on weather variables using similar statistical approaches. The overall comparison of the all above developed models it was observed that multiple linear regression approach found better than discriminant function analysis for forewarning of insect incidence. The Model-2.2 found suitable for forewarning of early shoot borer at 90 DAP with R^2 =74.7% and *RMSE*=0.69. Similarly, Model-2.3 found appropriate for forewarning top shoot borer incidence at 5th month of crop season with R^2 =88.9% and *RMSE*=0.52.

Conclusion

Farmers are mainly worried about the current disease and insect-pest severity data, preferably for their localities to support their decision making in crop protection. The current study suggested there is a scope for using other methods to develop predictors that could be used in forecasting models for reliable and dependable forecast. The forewarning models can be helpful in inspiring the farmer to organize and use their own resources in order to gather the benefits. The study showed multiple linear regression approach found better than discriminant function analysis for Forewarning of insect incidence. The study revealed that some of the weather variables were significantly correlated with insect incidence. It is required further studies pertaining to climate change driven changes in serious insect-pests of crops and planning and development of adaptive strategies needs to be undertaken to lessen the yield losses and safeguard the food security of nation.

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Conflict of interest

The authors declare that they have no conflict of interest.

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