The Pharma Innovation Journal 2022; SP-11(9): 1599-1602

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(9): 1599-1602

www.thepharmajournal.com
Received: 22-06-2022
Accepted: 25-07-2022

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Prediction of FAW infestation level in kharif maize

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Abstract
Maize also known as queen of cereals is having its utility because of its rich nutritive value along with its wide usability in industries. A recent study mentioned that 61% of global maize consumption is in the form of feed, whereas 17 and 22% is being utilized as food and in various industries, respectively. The increasing cropping area under maize, provides conditions conducive for flourishing of the insect pest population. One of the recently emerging and most damaging pest of maize is fall army worm (FAW). FAW is considered as an invasive species with great migration capabilities, however, it is an established fact that the entry and establishment of any invasive pest is majorly driven by favourable climatic conditions prevailing in the area. Present study aims to provide some regression models for prediction of FAW in maize in maize in 1-2 weeks in advance. The findings of present study revealed that preceding one week maximum temperature, wind speed and evaporation exhibited significant positive correlation with the FAW population and the prediction equation computed is $\hat{Y} = -10.54 + 0.03 X_1 + 0.56 X_2 + 0.24 X_3 - 0.14 X_4 - 0.02 X_5 - 0.75 X_6 - 0.01 X_7 + 0.46 X_8 + 0.79 X_9 - 0.05 X_{10}$ ($R^2=0.9265$). Whereas, for preceding two week wind speed exhibited significant positive correlation with the FAW population and the prediction model is $\hat{Y} = 6.37 + 0.00 X_1 + 0.00 X_2 + 0.24 X_3 - 0.05 X_4 - 0.11 X_5 - 1.10 X_6 - 0.01 X_7 + 0.66 X_8 + 0.66 X_9 + 0.46 X_{10}$ ($R^2 = 0.9047$).

Keywords: Fall army worm, maize, regression, population prediction model, weather parameters, crop age

Introduction

Maize also known as queen of cereals is having its utility because of its rich nutritive value along with its wide usability in industries. A recent study mentioned that 61% of global maize consumption is in the form of feed, whereas 17 and 22% is being utilized as food and in various industries, respectively. Further, it has been mentioned that 83% of the global maize production is used in feed, starch and biofuel industries, giving it a tag of global industrial crop (iimr.icar.gov.in). Due to its high demand and low input requirement, farmers are also becoming interested to shift from growing traditional crops towards maize cultivation, and is evident from its year by year growing acreage (Anonymous, 2021) [3]. Moreover, its photo-insensitive behavior makes it suitable for being grown in off seasons too. According to Anonymous (2020) [2] during 2019 the area, production and productivity for the maize crop in India was recorded as 9.2 million ha, 27.8 million metric tonne (MMT) and 2965 kg/ha, respectively. The production and productivity increased to the level of 16 and 5.42 times respectively in comparison to 1950-51, whereas area increased nearly by 3 times (iimr.icar.gov.in). The increasing cropping area under maize, provides the conducive conditions for flourishing of the insect pest population. One of the recently emerging and most damaging pest of maize is fall army worm (FAW) (*Spodoptera frugiperda* J.E. Smith, Lepidoptera: Noctuidae), which was first being reported from Karnataka in India (www.uahs.edu.in), and later from various parts of northern, central and southern India.

FAW is a very sturdy pest and is known to infest maize crop from vegetative to reproductive stage. The larvae prefers to feed upon the young soft portions of the plant, and during vegetative stage, scrapping and windowing is observed at lower densities, whereas at higher densities severe defoliation is noted. While during reproductive stage, larvae causes damage by feeding upon the tassels and boring in the cob causing the yield loss upto 50-80% on severe infestation (Gahatraj *et al*. 2020) [4].

FAW is considered as an invasive species with great migration capabilities, however, it is an established fact that the entry and establishment of any invasive pest is majorly driven by favourable climatic conditions prevailing in the area (Timilsena *et al*., 2022) [8]. It has also been proven that the FAW population structure is mainly temperature and rainfall dependent (Murua *et al*. 2006) [5]. However, the timely adoption of the management practices needs to be done to check the establishing population, which can only be facilitated when some forecasting model based on the existing climatic conditions could be developed. Therefore, it becomes necessity for present time to develop some population prediction models for FAW in maize crop. Present study aims to provide some regression models for prediction of FAW larval population in kharif maize crop at least one to two weeks in advance which would help in the timely formulation of ecofriendly management approaches.

Material and Method

Trial establishment

For working out the regression equation the natural population of FAW larvae was being allowed to infest the maize crop grown on an acreage of 450 meter square during kharif seasons of 2020 and 2021 with the standard spacing of 60 cm × 20 cm. Any kind of pest management practices were avoided, for ensuring highest potential of natural infestation.

Data collection

Larval counts on the weekly basis were noted from twenty five randomly selected plants to yield standard meteorological week wise larval density/plant. The meteorological data used in present study for computing the regression model was procured from Agromet observatory established at JNKVV farm, Jabalpur**.**

Statistical Analysis

Correlation and multiple regression of crop age and preceding one and two week abiotic factors with the FAW larval population was calculated by using the undermentioned formulae as proposed by Sharma (2011) [6].

$$\text{Correlation 'r'} = \frac{\sum xy - \frac{\sum x . \sum y}{n}}{\{\sum_x 2 - ((\sum x)^2)\}\{\sum_y 2 - ((\sum y)^2)\}}$$

Regression $\hat{Y} = a + b_1X_1 + b_2X_2 + \dots + b_xX_x$ (R^2)

Where,
a = Intercept,
b_1, b_2, b_x = Regression coefficients.
X_1, X_2, X_x = Independent factors.
R^2 = Coefficient of multiple determination.
Test of significance 'r'

$$t = \frac{r}{\sqrt{1 - r^2}}\sqrt{n - 2}$$

Result

Regression studies for one week prior prediction of the FAW infestation level in kharif maize

During kharif 2020, 2021 and pooled data presented in table 1, the FAW population on maize was found to be significantly positively driven by maximum temperature (r = 0.64, 0.65 and 0.75, respectively) and wind speed (r = 0.66, 0.57 and 0.73, respectively). Further, it exhibited significant negative relationship with morning relative humidity (r = -0.52, -0.58 and -0.73, respectively). Whereas, crop age and bright sun shine hours exhibited negative and positive effect, respectively but were found to be non-significant, during the understudy period. Moreover, during kharif 2021 and pooled data, FAW population was negatively impacted by evening relative humidity (r = -0.69 and -0.65, respectively), rainfall (r = -0.57 and -0.52, respectively) and rainy days (r = -0.67 and -0.60, respectively), while during kharif 2020, non-significant negative correlation was observed among them. Evaporation exerted significant positive effect over the FAW population during kharif 2021 and pooled (r = 0.69 and 0.61, respectively), and was positively non-significant during kharif 2020. Similarly, minimum temperature showed significant positive impact only during kharif 2021 (r = 0.57), whereas during kharif 2020 and pooled, it was exhibited positive non-significant influence upon the FAW larval population.

Table 1: Correlation coefficients between independent factors (crop age and preceding one week weather parameters) and FAW larval population in kharif maize

Independent variables	Kharif		Pooled
	2020	2021	
Crop age (days)	-0.44	-0.46	-0.46
$T_{max.}$ (°C)	0.64**	0.65**	0.75**
$T_{min.}$ (°C)	0.34	0.57*	0.49
RH_{morn}	-0.52*	-0.58*	-0.73**
RH_{Eve}	-0.36	-0.69**	-0.65**
BSS (hrs.)	-0.19	0.43	0.27
Rainfall (mm)	-0.36	-0.57*	-0.52*
Rainy days (days)	-0.35	-0.67**	-0.60*
Wind Speed (km/hr)	0.66**	0.57*	0.73**
Evaporation (mm)	0.27	0.69**	0.61*

* Significant at 5%, ** Significant at 1%

The multiple regression equations computed for one week prior prediction of FAW infestation level in maize crop during kharif season with ten independent factors (*i.e.* crop age and nine preceding 1 week weather parameters) were as follows:

a) Kharif 2020

$\hat{Y}$= - 24.76 + 0.01 X_1 + 0.43 X_2 + 0.53 X_3 - 0.03 X_4 + 0.01 X_5 - 0.86 X_6 - 0.01 X_7 + 0.38 X_8 + 0.33 X_9 + 060 X_{10} (R^2 = 0.9532)

b) Kharif 2021

$\hat{Y}$= - 49.06 + 0.01 X_1 + 0.09 X_2 + 0.83 X_3 + 0.33 X_4 - 0.08 X_5 + 0.07 X_6 - 0.01 X_7 - 0.01 X_8 + 0.73 X_9 + 0.50 X_{10} (R^2 = 0.8508)

c) Pooled

$\hat{Y}$= - 10.54 + 0.03 X_1 + 0.56 X_2 + 0.24 X_3 - 0.14 X_4 - 0.02 X_5 - 0.75 X_6 - 0.01 X_7 + 0.46 X_8 + 0.79 X_9 - 0.05 X_{10} (R^2 = 0.9265)

Where,
X_1 = crop age, X_2= T_{max}, X_3 = T_{min}, X_4 = RH_{morn}, X_5 = RH_{eve}, X_6 = BSS, X_7 = rainfall, X_8 = rainy days, X_9 = Wind speed, X_{10} = Evaporation.
The coefficient of determination (R^2) for the above mentioned equations were 0.9532, 0.8508 and 0.9265 during kharif 2020, 2021 and pooled data, respectively, which implicated that the understudy independent factors (preceding 1 week weather parameters and crop age) contributed about 95.32, 85.08 and 92.65% variation in the FAW larval population in maize.

Regression studies for two week prior prediction of the FAW infestation level in kharif maize

The correlation coefficients presented in table 2, defines the relationship between FAW larval population in kharif maize with different weather parameters (preceding 2 week) and crop age. It delineates that wind speed and evaporation had significant positive influence on the FAW larval population during kharif 2021 (r = 0.52 and 0.75, respectively) and pooled (r = 0.52 and 0.52, respectively), while morning relative humidity exhibited negative significant impact only during pooled (r = -0.51). Further, maximum and minimum temperature of preceding two weeks had positive impact on the FAW larval population, but were found to be non-significant. While crop age, evening relative humidity, BSS, rainfall and rainy days of preceding two weeks had non-significant negative influence on the FAW larval population.

Table 2: Correlation coefficients between independent factors (crop age and preceding two week weather parameters) and FAW larval population in kharif maize.

Independent variables	Kharif		Pooled
	2020	2021	
Crop age (days)	-0.44	-0.46	-0.46
$T_{max.}$ (°c)	0.46	0.40	0.50
$T_{min.}$ (°C)	0.18	0.24	0.18
$RH_{morning}$	-0.46	-0.39	-0.51*
$RH_{Evening}$	-0.38	-0.47	-0.50
BSS (hrs.)	-0.50	0.11	-0.19
Rainfall (mm)	-0.10	-0.43	-0.22
Rainy days (days)	-0.21	-0.35	-0.34
Wind Speed (km/hr)	0.49	0.52*	0.75**
Evaporation (mm)	0.35	0.52*	0.52*

* Significant at 5%, ** Significant at 1%

The multiple regression equations for the estimation of FAW infestation in maize crop during kharif season with ten independent factors (*i.e.* crop age and nine preceding 2 week weather parameters) were as follows:

a) Kharif 2020

$\hat{Y}$= - 6.17 - 0.04 X_1 - 0.17 X_2 + 0.65 X_3 + 0.08 X_4 - 0.09 X_5 - 0.80 X_6 + 0.00 X_7 + 0.32 X_8 + 0.25 X_9 + 0.21 X_{10} (R^2 = 0.9073)

b) Kharif 2021

$\hat{Y}$= - 17.14 + 0.00 X_1 + 0.67 X_2 - 0.30 X_3 + 0.12 X_4 - 0.07 X_5 - 0.79 X_6 - 0.02 X_7 + 0.39 X_8 + 0.46 X_9 + 0.23 X_{10} (R^2 = 0.6999)

c) Pooled (kharif)

$\hat{Y}$= 6.37 + 0.00 X_1 + 0.00 X_2 + 0.24 X_3 - 0.05 X_4 – 0.11 X_5 – 1.10 X_6 - 0.01 X_7 + 0.66 X_8 + 0.66 X_9 + 0.46 X_{10} (R^2 = 0.9047)

Where,
X_1 = crop age, X_2= T_{max}, X_3 = T_{min}, X_4 = RH_{morn}, X_5 = RH_{eve}, X_6 = BSS, X_7 = rainfall, X_8 = rainy days, X_9 = Wind speed, X_{10} = Evaporation.

The coefficient of determination (R^2) for the above mentioned equations were computed as 0.9073, 0.6999 and 0.9047 during kharif 2020, 2021 and pooled data, which implicated that the understudy independent factors (preceding 2 week weather parameters and crop age) contributed about 90.73, 69.99 and 90.47% variation in the FAW larval population in maize.

Discussion and Conclusion

Maximum temperature, wind speed and evaporation of preceding one week exhibited significant positive impact on the FAW population, whereas morning and evening relative humidity, rainfall and rainy days had significant negative correlation. Crop age, minimum temperature and bright sunshine hours of preceding 1 week had no significant impact on the FAW population. The findings of Anandhi *et al*. (2020) [1] are in conformity with the present findings as they reported significant positive and negative correlation with the maximum temperature and rainfall, respectively, and non-significant correlation with minimum temperature of preceding one week weather data.

Further, multiple regression analysis of the pooled data for preceding one week weather data and crop age as independent factors on the dependent variable i.e. FAW larval population in maize was $\hat{Y}$= - 10.54 + 0.03 X_1 + 0.56 X_2 + 0.24 X_3 - 0.14 X_4 - 0.02 X_5 - 0.75 X_6 - 0.01 X_7 + 0.46 X_8 + 0.79 X_9 - 0.05 X_{10} (R^2=0.9265), where, X_1 = crop age, X_2= T_{max}, X_3 = T_{min}, X_4 = RH_{morn}, X_5 = RH_{eve}, X_6 = BSS, X_7 = rainfall, X_8 = rainy days, X_9 = Wind speed, X_{10} = Evaporation.

Similar result have been obtained by Sunitha *et al*. (2021) [7], as they developed the prediction equation by using multiple regression method with high R^2 value (0.6591).

Wind speed of preceding two week exhibited significant positive correlation with the FAW larval population, whereas rest of the independent factors were found to be non-significant. Similar findings has been claimed by Sunitha *et al*. (2021) [7], as they also found positive correlation of wind speed with the FAW population. Moreover, not much literature is available with respect to two week prior weather data based correlation and regression studies for FAW in maize. Further, two week prior prediction model obtained from multiple regression approach was $\hat{Y}$= 6.37 + 0.00 X_1 + 0.00 X_2 + 0.24 X_3 - 0.05 X_4 – 0.11 X_5 – 1.10 X_6 - 0.01 X_7 + 0.66 X_8 + 0.66 X_9 + 0.46 X_{10} (R^2 = 0.9047), where, X_1 = crop age, X_2= T_{max}, X_3 = T_{min}, X_4 = RH_{morn}, X_5 = RH_{eve}, X_6 = BSS, X_7 = rainfall, X_8 = rainy days, X_9 = Windspeed, X_{10} = Evaporation.

From the above findings, it can be concluded that among meteorological factors, maximum temperature, wind speed, and evaporation of preceding one week were responsible for increase in FAW population in kharif maize, whereas preceding one week morning and evening relative humidity, rainfall and rainy days had deteriorating effect upon the FAW population.

Further, wind speed and evaporation of preceding two week also contributed to the increasing population of FAW.

Acknowledgement

We owe our sincere thanks to NAHEP-CAAST, JNKVV, Jabalpur for providing us the resources needed for the conduction of this trial.

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