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Role of abiotic factors and crop age on FAW infestation in maize

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Abstract
Due to climatic changes, numerous incidences of expanding the reach of insects, invasion of new faunal species are being recorded. One such invasion took place in India during 2018, which created a havoc for the maize growers in the country. This new invasive species was identified as fall army worm scientifically known as *Spodoptera frugiperda* J.E. Smith (Lepidoptera: Noctuidae), and can cause approximately 21-53% of yield loss as in maize crop. The infestation of this new insect in maize crop, drastically affected the maize production in India, which indirectly affected the maize based agro industries, thus hampering the economy to certain extent. Therefore, it becomes necessary to study the factors which can affect the FAW establishment and distribution. Therefore, present study is mainly focused upon the correlation studies of weather parameters with FAW larval population in maize crop during *kharif* and *rabi* seasons. Out of ten understudy independent factors (crop age and nine weather parameters), maximum and minimum temperature and evaporation had significant positive impact on FAW larval population, whereas morning and evening relative humidity, rainfall and rainy days exhibited significant negative correlation, during *kharif* season. While during *rabi* season, maximum and minimum temperature showed significant positive correlation with FAW larval population, whereas crop age, rainfall, rainy days and wind speed were found to be significantly negatively correlated.

Keywords: Fall army worm, maize, correlation, climate, weather parameters, crop age

Introduction
The green revolution which occurred during 1960's, achieved its major aim of attaining maximum productivity level and ensured the food security in India. During this period, farmers mainly focused on growing wheat and paddy, whereas again a shift in market demand is being seen for the millets, due to people becoming more health conscious. Therefore, again the interest of farming community is shifting towards the cultivation of other grains too. One such crop which is gaining popularity with the changing time is maize, due its wide demand and usability in culinaries and also as raw product for various industries. One of the major constraining factor in large scale cultivation of any crop is their infestation with the insect pests. Both, the growth of crop and establishment of pest are majorly governed by climatic conditions.

Globally, in recent times the world is facing a massive challenge of climate change which is impacting the existing flora and fauna of a region. Due to these changes, numerous incidences of expanding the reach of insects, invasion of new faunal species are being recorded. One such invasion took place in India during 2018, which created a havoc for the maize growers in the country. This new invasive species was identified as fall army worm scientifically known as *Spodoptera frugiperda* J.E. Smith (Lepidoptera: Noctuidae), which migrated from African region to Indian sub-continent and was first reported at the Shivamogga district of Karnataka (www.uahs.edu.in). Later, within very short span of time, the FAW spread its leg to other states of the country and has presently being reported majorly from Tamil Nadu, Andhra Pradesh, Maharashtra, Chhattisgarh, Madhya Pradesh and Orissa.

The FAW is being reported on maize crop from the very initial stage and pertains till maturity. In vegetative stage of the crop, it damages the leaves by scrapping, making pin sized holes, windowing, defoliating and damaging the whorl, whereas in reproductive stage it is known to bore inside the cob, feed upon the growing kernels and contaminating them with the frass (Acharaya *et al*., 2020) [1]. Biologically, FAW completes its life cycle in approximately 30-45 days, undergoing four different stages of metamorphosis *viz*. egg, larvae, pupae and adult stages, making it a holometabolic insect. Out of these stages only larval stage is responsible for the damage and can cause approximately 21-53% of yield loss in maize crop (www.cabi.org).

The infestation of this new insect in maize crop, drastically affected the maize production in India, which indirectly affected the maize based agro industries, thus hampering the economy to certain extent. Maize production in India accounted for 21.80 million tonnes from an acreage of 8.69 million hectare leading to the productivity of 2509 Kg/ha during 2017 (Tali, 2018) [8].

Thus, keeping in mind the important contribution of maize for development of agrarian community, it becomes necessary to study the factors which can affect the FAW establishment and distribution. One the major insect population driving factor is considered to be the climate or weather of the concerned region. Therefore, present study is mainly focused upon the correlation studies of weather parameters with FAW larval population in maize crop during *kharif* and *rabi* seasons, which delineates the contribution of a particular weather parameter upon the establishment of the pest in maize crop. The present findings will form the basis for the population dynamics studies and studies related with forecasting and model development for the prediction of FAW population.

Material and Method

Trial establishment

Maize crop was grown on a plot of size (30×15) m during *kharif* and *rabi* seasons of 2020-21, 2021-22 with the spacing of (60×20) cm. All the recommended agronomical practices were followed, except for the pest management measures, which ensured the creation of naturally conducive microclimate for pest establishment.

Data collection

Twenty five random plants were selected from the experimental plot from which the number of larvae present on the plants were counted and recorded at weekly interval. For observations related to meteorological parameters, data was obtained from Agromet observatory located at JNKVV farm, Jabalpur.

Statistical Analysis

Correlation and regression of the abiotic factors and crop age on FAW larval population were worked out as proposed by Sharma (2011) [7].

Result

Correlation of weather parameters and crop age with the FAW larval population during *kharif* season

During *kharif* 2020, maximum and minimum temperature had significant positive impact on the larval population (r = 0.71 and 0.53, respectively, whereas morning and evening relative humidity, rainfall and rainy days were found to have significant negative influence on the FAW larval population, (r = -0.54, -0.60, -0.52 and -0.55, respectively). Further, bright sun shine hours, wind speed and evaporation exhibited non-significant positive, while crop age had non-significant negative impact on the FAW larval population, but were found to be non-significant (Table 1).

Similar trend was observed during *kharif* 2021, maximum and minimum temperature and evaporation exhibited significant positive influence on the larval population (r = 0.64, 0.83 and 0.60 respectively), whereas morning and evening relative humidity and rainfall were found to be significantly negatively correlated with the FAW larval population (r = -0.61, -0.57 and -0.51, respectively). Further, bright sun shine hours and wind speed exhibited positive, whereas crop age and rainy days showed negative impact on larval population, but were found to be non-significant (Table 1).

On analyzing the pooled data of the *kharif* season, it can be inferred that maximum and minimum temperature and evaporation exhibited significant positive effect on FAW larval population (r = 0.76, 0.77 and 0.51 respectively), whereas morning and evening relative humidity, rainfall and rainy days were found to be significantly negatively correlated with the FAW larval population (r = -0.70, -0.65, -0.56 and -0.54, respectively). Further, bright sun shine hours and wind speed exhibited positive influence, while crop age expressed negative correlation, but were found to be non-significant (Table 1).

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

Independent variables	*Kharif* 2020		*Kharif* 2021		Pooled	
	r	b_{yx}	r	b_{yx}	r	b_{yx}
Crop age (days)	-0.16	-	-0.47	-	-0.46	-
$T_{max.}$ (°C)	0.71**	0.07	0.64**	0.08	0.76**	0.08
$T_{min.}$ (°C)	0.53*	0.10	0.83**	0.10	0.77**	0.10
$RH_{morning}$	-0.54*	0.03	-0.61*	0.03	-0.70**	0.03
$RH_{Evening}$	-0.60*	0.03	-0.57*	0.04	-0.65**	0.04
BSS (hrs.)	0.38	-	0.39	-	0.48	-
Rainfall (mm)	-0.52*	0.04	-0.51*	0.13	-0.56*	0.05
Rainy days (days)	-0.55*	0.79	-0.40	-	-0.54*	0.85
Wind Speed (km/hr)	0.45	-	0.26	-	0.40	-
Evaporation (mm)	0.39	-	0.60*	0.75	0.51*	0.66

r = correlation coefficient, b_{yx} = regression coefficient, * Significant at 5%, ** Significant at 1%

Correlation of weather parameters and crop age with the FAW larval population during *rabi* season

During *rabi* 2020-21, maximum and minimum temperature exhibited significant positive influence upon the larval population (r = 0.66 and 0.60, respectively), whereas, crop age, morning relative humidity, rainfall, rainy days and wind speed were found to have significant negative impact on the FAW larval population (r = -0.65, -0.54, -0.64, -0.54 and -0.51, respectively). Further, evaporation exhibited non-significant positive correlation (r = 0.39), while evening relative humidity and bright sun shine hours had negative impact of the larval population, but were found to be non-significant (Table 2).

During *rabi* 2021-22, maximum temperature exhibited significant positive influence on the larval population (r = 0.55), whereas, crop age, rainfall, rainy days and wind speed were found to be significantly negatively correlated with the FAW larval population (r = -0.58, -0.58, -0.65 and -0.56, respectively). Further, minimum temperature and evaporation exhibited positive correlation, whereas morning and evening relative humidity and bright sun shine hours had negative impact on the larval population, but were found to be non-significant (Table 2).

From pooled data of *rabi* season, it can be inferred that the maximum and minimum temperature exhibited significant positive influence (r = 0.61 and 0.58, respectively), whereas, crop age, rainfall, rainy days and wind speed were found to be significantly negatively correlated with the FAW larval population (r = -0.62, -0.70, -0.66 and -0.63, respectively). Further, evaporation exhibited positive effect, whereas morning and evening relative humidity and bright sun shine hours had negative impact on the larval population, but were found to be non-significant (Table 2).

Table 2: Correlation coefficients recorded between independent factors (crop age and weather parameters) and FAW larval population in *rabi* maize

Independent variables	*Rabi* 2020-21		*Rabi* 2021-22		Pooled	
	r	b_{yx}	r	b_{yx}	r	b_{yx}
Crop age (days)	-0.65**	0.03	-0.58**	0.03	-0.62**	0.03
$T_{max.}$ (°C)	0.66**	0.04	0.55*	0.04	0.61*	0.04
$T_{min.}$ (°C)	0.60*	0.09	0.49	-	0.58*	0.10
$RH_{morning}$	-0.54*	0.01	-0.12	-	-0.39	-
$RH_{Evening}$	-0.37	-	-0.17	-	-0.31	-
BSS (hrs.)	-0.28	-	-0.40	-	-0.41	-
Rainfall (mm)	-0.64**	-0.88	-0.58*	-0.34	-0.70**	-0.77
Rainy days (days)	-0.54*	-5.14	-0.65**	-2.15	-0.66**	-8.82
Wind Speed (km/hr)	-0.51*	0.52	-0.56*	0.73	-0.63**	0.61
Evaporation (mm)	0.39	-	0.25	-	0.29	-

r = correlation coefficient, b_{yx} = regression coefficient, * Significant at 5%, ** Significant at 1%

Discussion and Conclusion

Crop age was found to be significantly and non-significantly negatively correlated with the FAW larval population in maize during *rabi* and *kharif* season, respectively. Regression coefficient reveals that with every unit increase in crop age during *rabi* season the larval population decreased to the tune of 0.03.

Maximum and minimum temperature exhibited significant positive influence during both the seasons. Further, with every unit increase in maximum and minimum temperature, there was an increase in the larval population to the tune of 0.08 and 0.10, respectively during *kharif*, whereas during *rabi*, it increased to the tune of 0.10. Present finding is similar to the findings of Murua *et al*. (2006) [5], Kumar *et al*. (2020) [4], Anandhi *et al*. (2020) [3], Reddy *et al*. (2020) [6] and Ahmad and Ibrahim (2021) [2], as they reported significant positive impact of temperature on FAW population with correlation coefficients ranging from 0.32 to 0.72.

Morning and evening relative humidty exhibited significant and non-significant negative impact during *kharif* and *rabi* season, respectively. Further, with every unit increase in morning and evening relative humidity, a decrease in the larval population to the tune of 0.03 and 0.04, respectively was sought. The findings of Kumar *et al*. (2020) [4], Reddy *et al*. (2020) [6] and Ahmad and Ibrahim (2021) [2] corroborates with the present findings, as they reported negative impact of relative humidity on the FAW larval population. The correlation coefficient between relative humidity and FAW population reported by Kumar *et al*. (2020) [4] was -0.67.

Bright sunshine hours exhibited positive and negative effect during *kharif* and *rabi* season, respectively, but were found to be non-significant. Similar findings have been reported by Reddy *et al*. (2020) [6], as they reported positive correlation of bright sunshine hours with the FAW population during *kharif* season. No literature is available for defining the relationship between these two during *rabi* season.

Rainfall and rainy days showed significant negative correlation with the FAW infestation during both the seasons. Further, every unit increase in rainfall and rainy days lead to a decrease in FAW population to the tune of 0.05 and 0.85, respectively, during *kharif*, whereas during *rabi*, it was to the tune of 0.77 and 8.82, respectively. Similar findings have been reported by Murua *et al*. (2006) [5], Kumar *et al*. (2020) [4], Anandhi *et al*. (2020) [3] and Reddy *et al*. (2020) [6], as they found significant negative impact of rainfall upon the FAW population with the correlation coefficient ranging from -0.36 to -0.83.

Wind speed had non-significant positive impact over the FAW population during *kharif* season, whereas during *rabi* season, it had significant negative impact and with every unit increase it decreased the larval population to the tune of 0.61.

Evaporation exhibited significant and non-significant positive impact during *kharif* and *rabi* seasons, respectively. Further, during *kharif* with every unit increase in evaporation the larval population increased to the tune of 0.66.

From the above treatise, it can be concluded that the growth and development of FAW larvae in maize during *kharif* season was positively driven by maximum and minimum temperature and evaporation, whereas morning and evening relative humidity, rainfall and rainy days had detrimental effect on the population.

Similarly during *rabi* season, maximum and minimum temperature contributed to the increase of FAW larval population, whereas crop age, morning and evening relative humidity, rainfall, rainy days and wind speed contributed in reducing the population.

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