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Impact of agrometeorological factors on the population dynamics of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) in maize

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Abstract
The field experiments for two consecutive years (2021 and 2022) were conducted at Entomology Farm, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-Jammu) to study the population dynamics of fall armyworm (larvae) in maize and the impact of agrometeorological factors on their population build-up. The results of the experiment depicted the commencement of fall armyworm (larvae) from 20th Standard Meteorological Week (SMW) in both the years of study (2021 and 2022). Two peak larval populations were recorded in the 25th SMW and 28th SMW in 2021 and the 26th SMW and 29th SMW in 2022. However, the lowest population was recorded in the 31st SMW in both years of experimentation. The correlation studies revealed that the mean maximum temperature had a non-significant negative correlation with the fall armyworm (larvae) population where a positive and highly significant correlation was recorded with the mean minimum temperature. Mean relative humidity (morning and evening), rainfall, and rainy days had a highly significant positive correlation with the larval population of fall armyworm. However, sunshine hours had a significant negative correlation with the fall armyworm population.

Keywords: Abiotic factors, fall armyworm, maize, correlation, regression

Introduction
Maize (*Zea mays* L.) is the third most important cereal crop after rice and wheat (Martin *et al.*, 2006) [8] owing to its versatility and per unit low cost of production (Tariq, 2010) [6]. This crop is affected by around 250 different insect pest species in the field and storage (Mathur, 1992) [9]. However, fall armyworm, being the most devastating pest of maize, causes an estimated yield loss of 8.3 million tonnes to 20.6 million tonnes per year (Day *et al.*, 2017) [3]. Fall armyworm (*Spodoptera frugiperda* Smith) (Noctuidae: Lepidoptera), an invasive pest from the Americas, was first recorded in India from Karnataka in July 2018 on maize crops (Sharanabasappa *et al*., 2018; Ganiger *et al*., 2018; Shylesha *et al.*, 2018) [14, 4, 15]. Owing to its rapid dispersal activity, the incidence of fall armyworm was soon reported in all the neighbouring states (Padhee and Prasanna, 2019) [11]. The damage is inflicted by the immature larvae which feed on the maize plant voraciously from first to last larval instars. Being a well-known long-distance migratory insect pest (Liu *et al.*, 2019) [7], the damage severity and population size of fall armywormsare severely affected byenvironmental factors (Becker, 1974) [2]. Temperature and rainfall are considered primary factors governing the occurrence, development, and survival of this insect pest. (Saminathan *et al.*, 2001; Priyanka *et al.*, 2018) [13, 12] As such, a complete understanding of the impact of agrometeorological factors on the population dynamics of this pest is crucial to chalk out appropriate management strategies (Anandhi *et al*., 2020) [1]. Keeping these facts in view, the present experiments were devised to examine the impact of various agrometeorological factors on the population dynamics of fall army worm.

Materials and Methods
Field experiments were conducted for two consecutive years (2021 and 2022) at Entomology Farm, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-Jammu) to evaluate the impact of different agrometeorological factors on the larval population build-up of fall armyworms.

The maize seeds were sown in a plot size of 10 x 10 m^2 spaced at 60 x 20 cm between rows and plants, respectively. The crop was raised as per the recommended package of practices of SKUAST-Jammu. The population build-up of fall armyworm (larvae) was recorded at weekly intervals from planting till harvesting of the crop. For sampling and monitoring, twenty-five plants were randomly selected, tagged, and analyzed for data recording. A population model was, thus, developed in which agrometeorological factors were used as predictor variables to explain the population fluctuation of the fall armyworm population. The required weekly data on different weather parameters *viz.* maximum and minimum temperature, morning and evening relative humidity, rainfall and rainy days and sunshine hours were collected from the Section of Agro-Meteorology, SKUAST-Jammu, and subjected to simple correlation studies and linear regression analysis for examining their impact on population dynamics of fall armyworm.

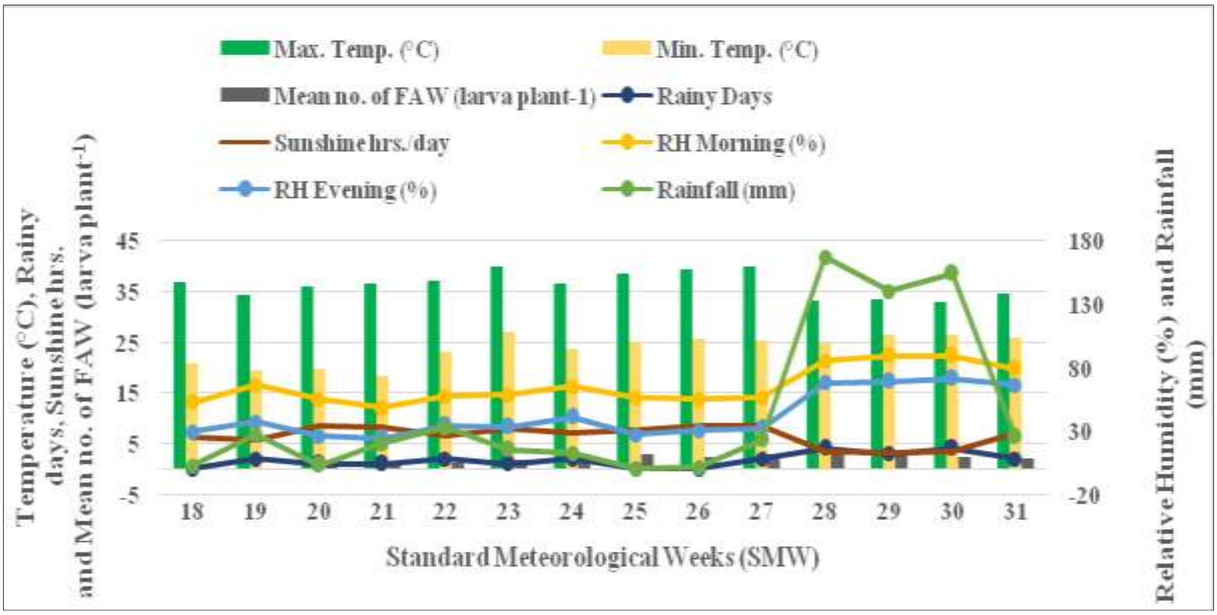
Results and Discussion

Population dynamics of fall armyworm (larvae)

The perusal of the data recorded on the population dynamics of fall armyworm revealed the commencement of larval population of fall armyworm (0.48 larvae $plant^{-1}$; 0,56 larvae $plant^{-1}$) from 20^{th} Standard Meteorological Week (SMW) in both the years of study (2021 and 2022), respectively. Further, the larval population gained a steady increase and the population reached its maximum in the 25^{th} SMW (2.92 larvae $plant^{-1}$) and 26^{th} SMW (3.04 larvae $plant^{-1}$) in 2021 and 2022, respectively. The population dynamics fluctuated afterward, increasing and decreasing at various instances, and a second peak of larval population was recorded in the 28^{th} SMW (2.92 larvae $plant^{-1}$) and 29^{th} SMW (3.04 larvae $plant^{-1}$) in 2021 and 2022, respectively. From weeks further, the larval population declined and reached a minimum in the 31^{st} SMW wherein a population of 2.04 and 2.36 larvae $plant^{-1}$ were recorded (Table 1-2). Kumbhar *et al*. (2022) [6] recorded the population build-up of fall armyworm (larvae) after the third week of sowing with a peak population in the 39^{th} SMW. Kalyan *et al*. (2019) [5] recorded the peak larval *S. frugiperda* population in the 33^{rd} SMW. The difference between the peak population weeks arises due to variations in the sowing period and different climatic conditions.

Table 1: Population Dynamics of Fall Armyworm (FAW) on Maize in 2021

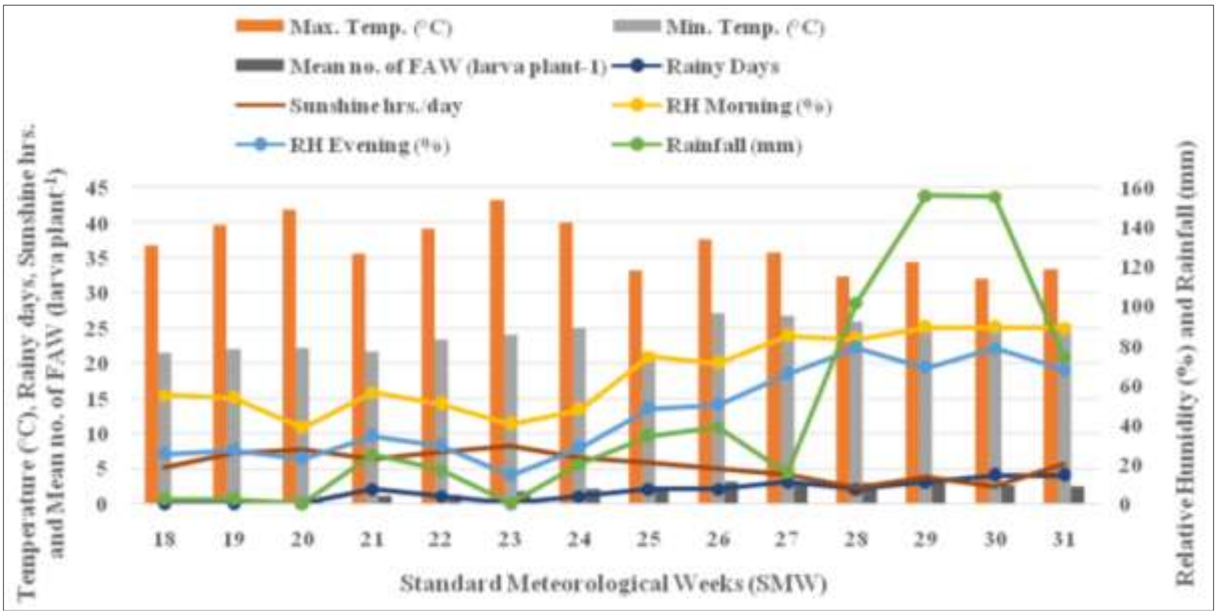
Standard Meteorological Weeks (SMW)	Mean no. of FAW (Larva $plant^{-1}$)	Temperature		Relative humidity		Sunshine (hours/day)	Rainfall (mm)	Rainy day
		Max T (°C)	Max T (°C)	Morning (%)	Evening (%)			
18	0.00	36.7	20.9	52.0	29.0	6.2	2.0	0
19	0.00	34.3	19.5	66.0	37.0	5.6	27.0	2
20	0.48	35.9	19.7	55.0	26.0	8.5	2.8	1
21	0.92	36.4	18.3	48.0	24.0	8.3	20.2	1
22	1.08	36.9	23.0	57.0	34.0	6.6	32.6	2
23	1.64	39.8	26.9	58.0	33.0	8.0	15.0	1
24	2.64	36.6	23.5	65.0	41.0	7.0	12.6	2
25	2.92	38.3	24.9	56.0	27.0	7.6	0.0	0
26	2.36	39.4	25.5	55.0	30.0	8.5	1.0	0
27	2.88	39.7	25.4	56.0	32.0	8.6	23.0	2
28	2.92	33.0	24.8	85.0	68.0	3.5	167.0	4
29	2.52	33.5	26.3	89.0	69.0	3.2	140.0	3
30	2.44	32.8	26.4	89.0	71.0	3.5	154.0	4
31	2.04	34.4	25.9	79.0	66.0	7.2	25.2	2



Graph 1: Graphical representation of Population Dynamics of Fall Armyworm (FAW) on Maize in 2021

Table 2: Population Dynamics of Fall Armyworm (FAW) on Maize in 2022

Standard Meteorological Weeks (SMW)	Mean no. of FAW (larva plant^{-1})	Temperature		Relative humidity		Sunshine (hours/day)	Rainfall (mm)	Rainy day
		Max T (°C)	Min T (°C)	Morning (%)	Evening (%)			
18	0.00	36.8	21.5	55.0	25.1	5.1	2.0	0
19	0.00	39.6	21.9	53.4	26.9	7.1	2.0	0
20	0.56	41.8	22.1	38.3	22.7	7.6	0.0	0
21	0.96	35.6	21.6	56.3	34.0	6.3	24.8	2
22	1.24	39.1	23.3	50.3	29.1	7.3	16.8	1
23	1.72	43.2	24.0	40.0	14.0	8.2	0.0	0
24	2.00	40.0	25.0	47.3	27.9	6.5	20.0	1
25	2.44	33.2	21.4	74.4	47.9	5.8	34.0	2
26	3.04	37.6	27.0	71.0	49.9	4.9	38.6	2
27	2.84	35.7	26.7	84.9	65.6	4.1	15.2	3
28	2.96	32.4	25.9	83.0	78.9	2.2	101.4	2
29	3.04	34.4	25.4	89.1	68.6	3.8	155.8	3
30	2.64	32.0	25.7	89.1	78.4	2.4	155.4	4
31	2.36	33.3	25.5	88.7	67.6	5.7	74.2	4



Graph 2: Graphical representation of Population Dynamics of Fall Armyworm (FAW) on Maize in 2022

Correlation and regression analysis

The pooled data on the correlation and regression analysis between the agrometeorological factors and the population dynamics of fall armyworm revealed that the mean maximum temperature had a non-significant negative correlation with the fall armyworm (larvae) population where a positive and highly significant correlation was recorded with the mean minimum temperature. Mean relative humidity (morning and evening), rainfall, and rainy days had a highly significant positive correlation with the larval population of fall armyworm. However, sunshine hours had a significant negative correlation with the fall armyworm population (Table 3). The pooled data on linear regression equation (Y=a+bx) for fall armyworm (larvae) was found to be $Y=0.841-0.467X_1+2.526X_2+0.10X_3-0.039X_4+1.124X_5+0.607X_6+0.418X_7$. The corresponding correlation coefficient (R_2) value was worked out to be 0.701. The overall impact of agrometeorological factors on the population build-up of fall armyworm (larvae) was recorded at 70.1 percent (Table 4). Our results are in agreement with Anandhi *et al*. (2020) [1] who recorded a nonsignificant correlation of maximum temperature with the fall armyworm population. This could be attributed to the increase in natural enemies activities due to favourable microclimate owing to the lowering of maximum temperature. Mitchell *et al*. (1991) [10] recorded a tendency of variation in *S. frugiperda* populations with changes in rainfall. Kumbhar *et al*. (2020) [6] recorded a positive correlation of maximum temperature, minimum temperature, morning relative humidity, and evening relative humidity and a negative correlation of sunshine hours with the fall armyworm population, which supports our findings.

Table 3: Pooled correlation of fall armyworm (larvae) in maize crop in relation to weather factors in 2021 and 2022

Insect pest	Temperature		Relative humidity		Sunshine (hours/day)	Rainfall (mm)	Rainy day
	Max T (°C)	Min T (°C)	Morning (%)	Evening (%)			
Fall armyworm (larvae)	-0.296	0.785**	0.611**	0.629**	-0.392*	0.519**	0.563**

*Significant at 0.01 level, **Significant at 0.05 level

Table 4: Regression equation and co-efficient of multiple determination (R_2) of fall armyworm (larvae) in relation to weather factors in maize crop during 2021 and 2022

Insect Pest	Linear Regression Equation	Multiple correlation (R)	Co-efficient of determination (R_2)	Co-efficient of variation (%)
Fall armyworm (larvae)	$Y=-0.841-0.467X_1+2.526X_2+0.101X_3-0.039X_4+1.124X_5+0.607X_6+0.418X_7$	0.837	0.701	70.1

Where, Y=Mean number of fall armyworm (larvae), X_1=Maximum temperature (°C), X_2=Minimum temperature (°C), X_3=RH morning (%), X_4=RH evening (%), X_5=Sunshine hours, X_6=Rainfall (mm), X_7= Rainy days

Conclusion

Fall armyworm is a highly devastating pest in the maize ecosystem wherein significant damage is inflicted by the larval population till harvesting of the crop. The weather parameters play a significant role in the population build-up of this pest wherein temperature, relative humidity, rainfall, and rainy days have an important role to play. Henceforth, this pest requires careful vigilance during the entire cropping period of maize to devise appropriate and timely pest management programs to limit pest population build-up and sustain crop productivity.

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Conflict of Interest

Authors declare no conflict of interest.

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