The Pharma Innovation Journal 2022; SP-11(10): 971-975

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(10): 971-975

www.thepharmajournal.com
Received: 23-08-2022
Accepted: 26-09-2022

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Studies on the population dynamics of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) on maize in relation to weather parameters

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Abstract
The studies on "Population dynamics and management of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) on *rabi maize*" was carried out under field conditions during *Rabi* 2020-21 at Agricultural Research Farm, Tirhut College of Agriculture, Dholi, Muzaffarpur, which is a sub-campus of Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar. The experimental outcome revealed that number of larval population and percent leaf damage of fall armyworm was started from 3rd standard week of January to the third week of May. The peak activity of fall armyworm was observed in 12th SMW of March 2021 with mean larval population and percent mean leaf damage of (4.8 larvae/plant) and (46.0% of percent leaf damage/plant) respectively, with the corresponding maximum temperature (35.6 °C), minimum temperature (17.7 °C), R.H. (%) at 07 (85.4%) and 14 hrs (46.2%), and rainfall (0.0 mm). The correlation analysis depicted that both larval population and percent leaf damage of fall armyworm, *Spodoptera frugiperda* were positively correlation with maximum temperature (°C) ($r = 0.492^*$) and ($r = 0.498^*$), respectively, and minimum temperature (°C) was positively correlation but no significant effect was observed on both larval population and percent leaf damage ($r = 0.001$) and ($r = 0.020$), and relative humidity (%) at 7 hours and 14 hours were negatively correlation and no significant effect on both larval population and percent leaf damage of *S. frugiperda*, ($r = -0.225$, $r = -0.277$) and ($r = -0.401$, $r = -0.414$), respectively, but rainfall was negatively correlation and significant effect on both larval population and percent leaf damage of fall armyworm ($r = -0.475^*$) and ($r = -0.533^*$) respectively.

Keywords: Fall armyworm, maize, fortnight, SMW

Introduction
Maize (*Zea mays* L.) is the important cereal crops after wheat and rice. In India maize is grown in wide area under different agro-climatic conditions. It is third most important cereal after wheat and rice. Fall armyworm is the most serious insect causing 57.6% to 58% of yield losses (Cruz *et al.*, 1999) [1] and also due its is polyphagous (Goergen *et al.*, 2016) [3] and cosmopolitan nature (Wiseman *et al.*, 1966) [11], fall armyworm was going to damage more than 186 plant species of 42 different families, *viz*., Poaceae (35.5%), Fabaceae (11.3%), Solanaceae (4.3%), Asteraceae (4.3%), Rosaceae (3.7%), Chenopodiaceae (3.7%), Brassicaceae and Cyperaceae (3.2%) are important families which are affected by fall armyworm attack (Casmuz *et al*., 2017) [2]. Keeping in view of the importance of maize crop, and the economic losses caused by the fall armyworm during *rabi* season, the present study aimed to study the population dynamics of fall armyworm in relation to weather parameter to know the seasonal distribution, and its activity, polyphagous nature, host and habitat finding behavior in relation to fluctuation in abiotic weather parameters, and take precaution measures to avoid the outbreak of pest during cropping season

Materials and Methods
A field experiment was conducted at research farm Tirhut College of Agriculture, Dholi (Muzaffarpur), a campus of Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur), Bihar during rabi 2020-21 to assess the number of larvae and percent leaf damage per ten randomly selected plants in relation with climatological weather parameters. In this experiment Shaktiman-5 (QPM) hybrid variety was preferred as the test variety and sowing of maize crop was taken on 5th January 2020-21 in an area of 100 m^2 and record the observations by selecting 10 random plants at 7th days intervals starting from 7th days after sowing to till harvest. During this field trial, except plant protection measures, all prescribed agronomic practices were taken to grow the healthy crop.

Larval Population

Larval observation was recorded by observing the number of larvae present per 10 randomly selected plants in an area of $100m^2$, and plant damage, presence of frass, excreta on whorl of plant were also considered as presence of larvae and mean of larval population was worked out at weekly interval and correlation was studied with meteorological variables such as temperature °C (max., min), R.H (%) at (07 hrs, and 14 hrs) and total rainfall (mm).

The Mean larval population of fall armyworm was calculated as follows

$$\text{Mean Larval Population} = \frac{\text{Number of larvae}}{\text{10 randomly slelected plants}} \dots (1)$$

Percent leaf damage

Percent leaf damage was observed by counting the total number of fresh damaged leaves on top 5 leaves by selecting 10 random plants and mean percent leaf damage was worked out at weekly interval and effect of weather parameters on percent leaf damage was studied by correlating observations with meteorological variables by using 'IBM-Statistical Package for the Social Science' software (IBM-SPSS Statistics version 20).

The percent leaf damage was calculated by using below formula

$$\text{Percent leaf damage} = \frac{\text{Number of damage leaves}}{\text{Total number of leaves}} \text{ x } 100 \dots (2)$$

Results and Discussion

The observations on population dynamics of mean larval population of fall armyworm, *S. frugiperda* present per 10 randomly selected plants and percent leaf damage by selecting fresh damaged leaves on top 5 leaves by selecting 10 random plants have been summarized in Table 1 and depicted in fig.1 and fig.2. The corresponding maximum and minimum temperature (°C), R.H. (%) at 07 and 14 hours, and total rainfall (mm) during experiment was 29.9 °C, 15.5 °C, 86.2 %, 57.8 % and 0.21 mm, respectively.

In the present study the larval population and percent leaf damage of fall armyworm, *S. frugiperda* was ranges from (0.0 to 4.8 larvae per plant) and (0.0% to 46%) respectively. The activity of fall armyworm larvae was first recorded from 3rd standard meteorological week (SMW) of (19 January 2021) with lowest mean larval population of 0.8 larvae per plants and percent leaf damage of 6.0% with the corresponding minimum, maximum temperature (°C), relative humidity (%) at 07 and 14 hours and rainfall (mm) of 8.0 °C, 17.3 °C, 94.7%, 70% and 0.0 mm respectively. The present investigation was strongly supported by Kumar *et al.*, (2020), who observed the lowest incidence of larval population fall armyworm, during *Rabi* season.

The maximum incidence of fall armyworm was observed in the 12th standard mean week (SMW) of 23 March 2021 with the larval population of (4.8 larva per plant) with the percent leaf damage of (46.0%) and the corresponding minimum and maximum temperature were (°C) of (17.7 °C and 35.6 °C), relative humidity (%) at morning and evening hours were (85.4% and 46.2%) with rainfall of (0.0mm). The present experimental outcomes close proximity with the Meagher and Nagoshi (2004) [6], who reported maximum peak activity of fall armyworm was observed in the month of March and also line with the Huang *et al*., (2020) [4], who observed the infestation and distribution of FAW increasing from January to March month. In the present experiments larval population was increases with increase in temperature. The present findings similar with Wood *et al*., (1979) [12], who reported increase in soil temperature during late winter influences emergence of adult moth.

The population of fall armyworm and percent leaf damage started to declining slowly from 15th SMW of 12 April 2021 (3.8 larvae/plant), and (percent leaf damage 36.0%) to 20th SMW of 17 May 2021(0.6 larvae/plant), and (percent leaf damage 2.0%) respectively, with the corresponding minimum and maximum temperature (°C) and relative humidity (%) at 7 hrs and 14 hrs and rainfall of (17.3 °C, 35.2 °C, 72.1%, 38.2% and 0.0 mm) and (21.4 °C, 33.9 °C, 88.0%, 62.8% and 2.61 mm) respectively. In the present experiment population of fall armyworm was declining in the month of April, it may be due to age of plant, as age of plant increases the preference of larvae for feed as well as adult moth for oviposition was reduces due to incompatibility of host. The present studies was close proximity with the Mitchell *et al.*, (1974) [7], who observed the distribution of eggs and larvae of fall armyworm differed based on phenological stage of maize.

Increasing of larval population and percent leaf damage was observed in 3rd SMW of 19 January 2021(0.8 larvae/ plant), and (percent leaf damage 6.0%) with corresponding minimum temperature of (8.0 °C) and maximum temperature (17.3 °C) and relative humidity at 7 hrs (94.7%) and 14 hrs (70.0%) and rainfall of (0.0 mm) to the 8th SMW of 23 February 2021(3.6 larvae/plant), and (percent leaf damage 34.0%) with the corresponding minimum temperature (12.1 °C) and maximum temperature (31.0 °C) and relative humidity at 7 hrs (93.7%) and 14 hrs (67.0%) and rainfall of (0.0 mm), and it may be due to suitability of host for feeding and oviposition and again larval population and percent leaf damage was decreases from 9th SMW of 2 March 2021 (2.6 larvae/plant), and (percent leaf damage26.0%) respectively, and again increased in 10th SMW of 9 March 2021 (4.2 larvae/plant), and (percent leaf damage 38.0%) and decreased in 11th SMW of 16 March 2021 (3.0 larvae/plant), and (percent leaf damage 30.0%), and at the end of cropping season there was no incidence of fall armyworm was observed.

Table 1: Population dynamics of fall armyworm, *S. frugiperda* (larval population) of maize in relation to weather parameters during *Rabi*, 2020-21

Month	Date of Observation	SMW	Mean Larval Population	Percent Leaf Damage	Temperature (°C)		Relative Humidity (%)		Total Rainfall (mm)
					Max.	Min.	07:00 hrs	14:00 hrs	
Jan	12-01-2021	2	0.0	0.0	15.7	13.4	95.8	69.4	0.0
	19-01-2021	3	0.8	6.0	17.3	08.0	94.7	70.0	0.0
	26-01-2021	4	1.8	16.0	19.8	08.6	94.2	72.5	0.0
Feb	02-02-2021	5	2.2	20.0	21.5	07.1	94.1	76.6	0.0
	09-02-2021	6	2.4	24.0	25.0	09.4	90.4	79.0	0.0
	16-02-2021	7	2.8	32.0	26.4	11.3	92.8	82.7	0.0
	23-02-2021	8	3.6	34.0	31.0	12.1	93.7	67.0	0.0
March	02-03-2021	9	2.6	26.0	29.3	14.6	84.1	58.7	0.0
	09-03-2021	10	4.2	38.0	32.9	15.1	90.4	55.4	0.0
	16-03-2021	11	3.0	30.0	30.4	15.1	91.8	66.5	0.0
	23-03-2021	12	4.8	46.0	35.6	17.7	85.4	46.2	0.0
	30-03-2021	13	4.2	44.0	35.2	17.7	81.1	39.4	0.0
April	06-04-2021	14	4.6	40.0	36.3	16.9	84.2	38.7	0.0
	12-04-2021	15	3.8	36.0	35.2	17.7	72.1	38.2	0.0
	19-04-2021	16	3.4	32.0	35.8	20.6	75.1	47.4	0.0
	26-04-2021	17	3.0	28.0	35.2	19.7	80.4	39.2	0.11
May	03-05-2021	18	1.4	22.0	34.1	20.8	73.5	36.5	0.0
	10-05-2021	19	1.0	10.0	32.8	21.5	73.5	44.4	0.48
	17-05-2021	20	0.6	02	33.9	21.4	88.0	62.8	2.61
	24-05-2021	21	0.0	0.0	35.1	21.6	89.2	64.8	1.1

Mean of 10 plants
SMW Standard Mean Week

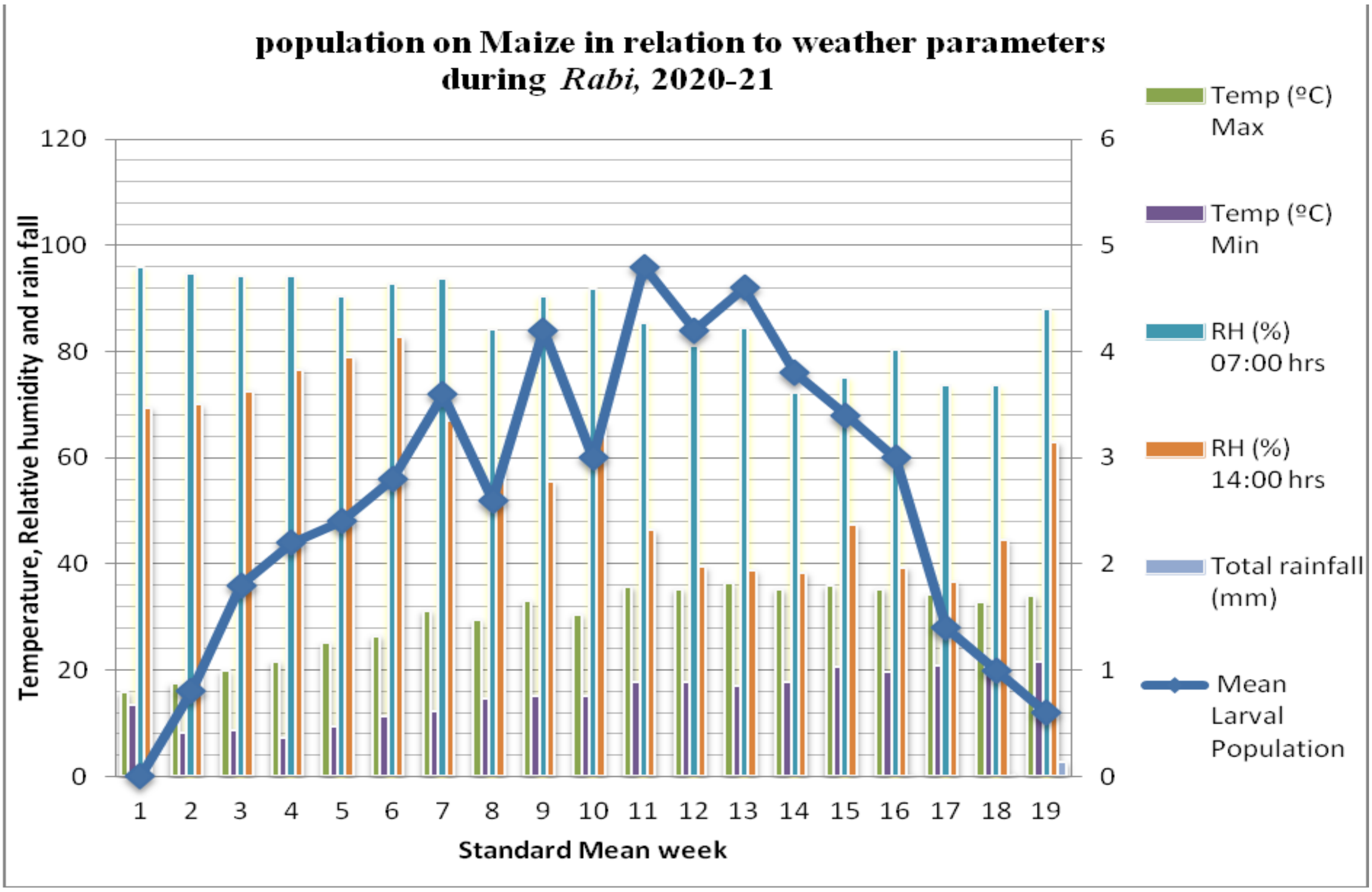

Fig 1: Population dynamics of fall armyworm, *S. frugiperda* (larval population) of maize in relation to weather parameters during *Rabi*, 2020-21

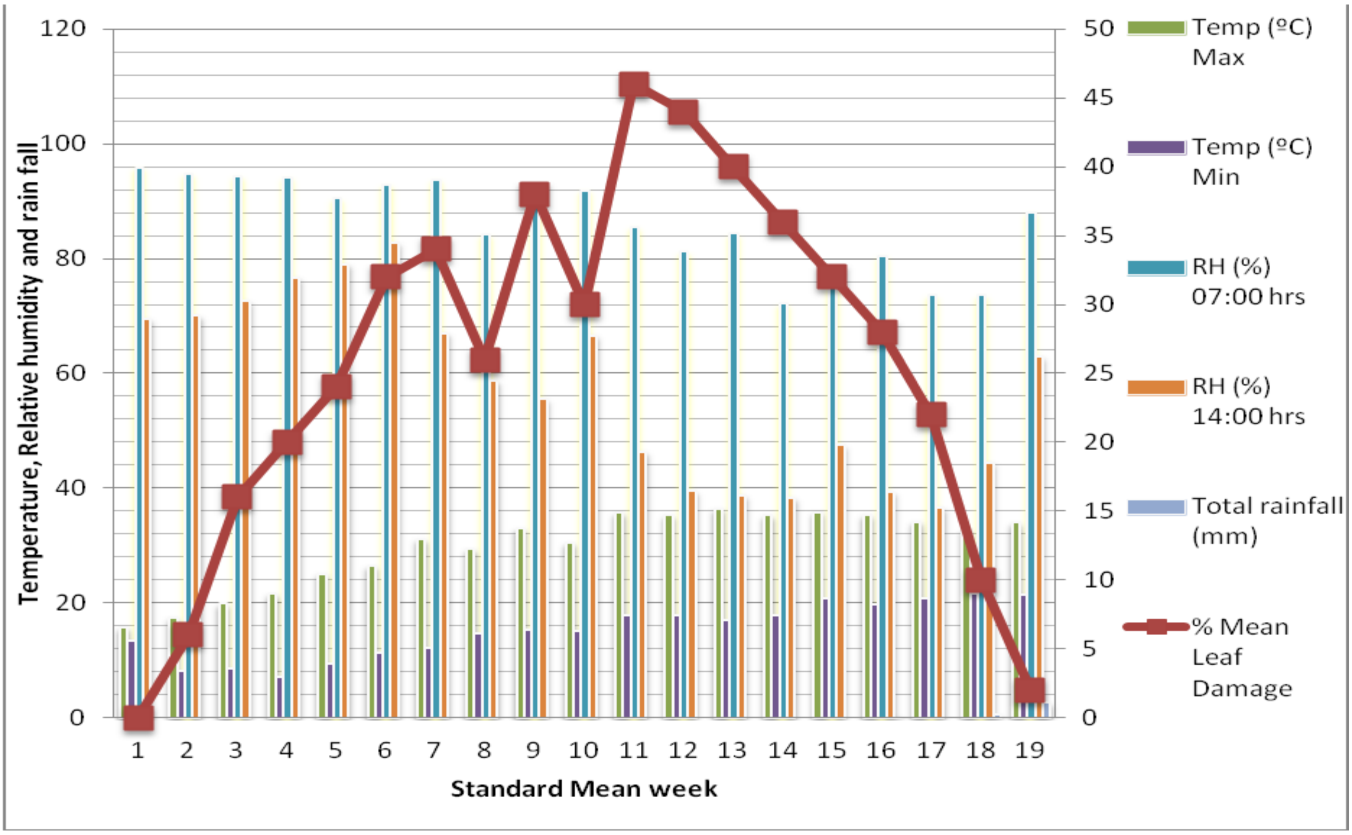

Fig 2: Population dynamics of fall armyworm, *S. frugiperda* (larval population) of maize in relation to weather parameters during *Rabi*, 2020-21

Influence of weather factors on mean larval population and percent mean leaf damage of *S. frugiperda* on *Rabi* maize during 2020-21

The analysis of correlation between weather factors on larval population and percent leaf damage of *S. frugiperda* from 2nd SMW of 12 January 2021 to 21th SMW of 24 May 2021 has been depicted in Table 2. The observed data on larval population and percent leaf damage in Table 2 clearly indicated that both larval population and percent leaf damage were positively correlation with maximum temperature (°C) and significant effect on the both larval population and percent leaf damage of fall armyworm (r = 0.492*) and (r = 0.498*), respectively.

Minimum temperature (°C) was positively correlation but no significant effect was observed on both larval population and percent leaf damage (r = 0.001) and (r = 0.020), and relative humidity (%) at 7 hours and 14 hours were negatively correlation and no significant effect on both larval population and percent leaf damage of *S. frugiperda,* (r = -0.225, r = -0.277, and r = -0.382) and (r = -0.401, r = -0.414), respectively, but rainfall was negatively correlation and significant effect on both larval population and percent leaf damage of fall armyworm (r = -0.475*) and (r = -0.533*), respectively.

When data on mean larval population of *S. frugiperda* was subjected to (MLR) multiple linear regression analysis, 85.0 percent (R^2 =0.8573) of larval population was significant and positively influenced by maximum temperature, and significant and negatively influenced by rainfall, whereas, relative humidity (RH %) at 7 hours and 14 hours, non significant and negatively association with larval population of fall armyworm. Minimum temperature was found to be non significant and positively association with larval population of fall armyworm.

When data on percent mean leaf damage of *S. frugiperda* was subjected to (MLR) multiple linear regression analysis, 86 percent (R^2 =0.8649) of percent leaf damage was significant and positively influenced by maximum temperature, and rainfall was non significant and negatively influenced on percent leaf damage, whereas, relative humidity (RH %) at 7 hours and 14 hours were non significant and negatively correlation with percent leaf damage. Minimum temperature was non significant and positively influenced on percent leaf damage of fall armyworm.

The relationship of weather factors with fall armyworm larval population and percent leaf damage was observed in the present studies are close proximity with Kumar *et al.*, (2020), who observed the larval population of fall armyworm was positively correlation with maximum temperature (r = 0.72), and negatively correlation with both relative humidity (-0.5473) and rainfall (-0.5874) in Perambalur, district of Tamil nadu during *Rabi*, 2019. The present findings were line with the Yang *et al.*, (2021) [13], who reported that larval population density of fall armyworm was positively and significantly correlation with temperature also supported by Murua *et al.*, (2006) [8], who observed temperature was significantly affect the density of fall armyworm and similar results was obtained by Reddy *et al.* (2020) [9], who observed the maximum temperature was positively correlation on fall armyworm infestation and also observed the relative humidity was negatively correlation with *S. frugiperda* infestation. Relative humidity at evening was negatively affect the larval development and oviposition behaviour of *Spodoptera litura* Thanki *et al.*, (2003) [10].

Table 2: Correlation coefficient matrix and regression equation between meteorological variables with larval population and percent leaf damage of fall armyworm

Weather parameter	Mean Larval Population	% Mean Leaf Damage
Max. Temperature (X_1)	0.492*	0.498*
Min. Temperature (X_2)	0.001^{NS}	0.020^{NS}
RH. 07 00 hrs (X_3)	-0.225^{NS}	-0.277^{NS}
RH. 14 00 hrs (X_4)	-0.401^{NS}	-0.414^{NS}
Total rainfall (mm) (X_5)	-0.475*	-0.533*

*Correlation is significant at the 0.05 level (2-tailed).

Multiple regression equation for larval population of FAW

y=-3.168 + 0.280(X_1) - 0.306(X_2) + 0.053(X_3) - 0.042(X_4) - 0.713(X_5)

R^2 value= 0.8573

Multiple regression equation for percent leaf damage of FAW

y= -25.463+2.629(X_1) - 2.502(X_2) + 0.292(X_3) - 0.228(X_4) - 9.909(X_5)

R^2 Value: 0.8649

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