Original Research Article

Seasonal incidence of fall armyworm, *Spodoptera frugiperda* (J. E. Smith) on sorghum

Abstract:

The study on seasonal incidence of fall armyworm was carried out during *kharif*, 2019 at Agricultural college farm, Bapatla. The oviposition of fall armyworm was observed from 34th SMW and reached its peak during 40th SMW (0.03 egg masses plant^{-1}). The larval population of fall armyworm was commenced during 35th SMW and increased gradually to a peak of 1.67 larvae plant^{-1} during 41st SMW. The maximum plant infestation (60.00%) and leaf damage severity rating (3.13) of fall armyworm was observed during 41st SMW. The peak activity of natural enemies was observed during 41st SMW which coincides with the larval population of fall armyworm. The correlation analysis indicated that eggmasses of fall armyworm was positively correlated with minimum temperature(r= 0.668) and wind speed (r= 0.529) while, the larval population showed significant positive correlation with maximum temperature (r= 0.029). The plant infestation caused by fall armyworm had shown significant negative correlation with maximum temperature (r= -0.633) (r= 0.678) and evening relative humidity (r= 0.664) whereas, the leaf damage severity rating exhibited significant positive correlation with evening relative humidity (r= 0.691). The multiple regression analysis revealed that the influence of weather parameters on the incidence of fall armyworm and natural enemies in sorghum ecosystem was more than 65% and 40%, respectively.

Key words: Fall armyworm, seasonal incidence, correlation, weather parameters, sorghum.

1. INTRODUCTION

Sorghum (*Sorghum bicolour* (L.) Moench) is an important staple food for more than 500 million people after wheat, rice, maize and barley in the world whereas in India, it occupied third place after rice and wheat in terms of production and utilization (Varaprasad and Staggenborg, 2011). It occupied an area of 4.96 m ha with an annual production of 4.80 MT in India during 2018-19 (FAO, 2018-19). The productivity of sorghum in India (967 kg ha^{-1}) was low compared to the world productivity (1408 kg ha^{-1}) due to abiotic and biotic stress. Among the biotic stresses, the insect pests and diseases are causing significant yield loss (Reddy and Patil, 2015).

It harbours nearly 150 species of insects in different agroecosystems of India (Sharma, 1993). Shoot fly, stem borer and sorghum midge has attained the major pest status in India and accounts to the yield loss of nearly 32 per cent in India (Nwanze *et al.*, 1995). The recently introduced pest, fall armyworm [*Spodoptera frugiperda* (J. E. Smith)] has become a great threat to cereal production in the world (Day *et al.*, 2017) and causing 16 per cent yield loss in sorghum (Abrahmas *et al.*, 2017). The pest status was not static on sorghum even though it is one of the preferred host for fall armyworm and it has been largely influenced by weather parameters like temperature, relative humidity and wind.

In view of the existing situation and importance of sorghum in India, there is a need for the development of economically viable and environmentally safe approach for successful management of fall armyworm. For this, the knowledge on population dynamics fall armyworm in sorghum is required but, the availability of literature on seasonal incidence of fall armyworm in India is scanty. Hence, the present investigation was carried out to find out the influence of weather parameters on incidence of fall armyworm and its natural enemies in sorghum.

2. MATERIALS AND METHODS

The field experiment on seasonal incidence of fall armyworm in sorghum was carried out during *kharif*, 2019 at Agricultural college farm, Bapatla. The sorghum variety (CSH-16) was sown during second week of August in an area of 400 m^2 with a spacing of 45× 15 cm. The crop was raised as per the agronomic recommendations of ANGRAU and the plot was kept under unprotected conditions throughout the crop growth period.

The observations on incidence of fall armyworm (No. of egg masses and larvae per plant), pest damage (Plant infestation and leaf damage severity) and population of natural enemies (Coccinellids, spiders and predatory bugs) were recorded on 30 randomly selected plants at weekly interval from 10 DAS to crop maturity.

The leaf damage severity was recorded by using the rating scale of Wiseman *et al.* (1966). 0- no damage, 1- small amount of pinhole-type injury, 2- several pinholes, 3-small amount of shot hole type injury with 1 or 2 lesions, 4- several shot hole type injuries and few lesions, 5- several lesions, 6-several lesions, shot hole injury and portions eaten away, 7-several lesions and portions eaten away and areas drying, 8- several portions of the whorl eaten away

Comment [C1]: The authors must justify the importance and its relation to Standard Meteorological Week in the study; at the same time they must strengthen and provide greater consistency. Likewise, it must include information on natural enemies and the impact on the presence of *Spodoptera frugiperda*.

Comment [C2]: It is well known that an imbalance in soil nutrition could cause abiotic problems that directly impact agronomic variables, including pests and diseases. However, the document makes little mention of the nutritional status of the soil and the most effective agronomic practices that could control the fall armyworm in the typical conditions of small farmers.

and areas drying, 9- the whorl completely eaten away and more areas drying or plant dead was used for rating the fall armyworm damage.

The data on various weather parameters (Maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, rainfall, rainy days and wind speed) during the entire crop growth period was collected from meteorological observatory, Agricultural College Farm, Bapatla. In order to determine the relationship between the weather parameters and incidence of fall armyworm and natural enemies, the mean population of pest and natural enemies were subjected to simple correlation analysis with weather parameters and multiple linear regression equations for pest and natural enemies population with weather parameters were formulated by using SPSS 16.0 software.

Comment [C3]: The authors must provide greater consistency with respect to the statistical program used; likewise, the methodology lacks bibliographic support; therefore, they should reinforce the relationship between climatic parameters and the incidence of fall armyworm

3. RESULTS AND DISCUSSION

3.1 Seasonal incidence of fall armyworm on sorghum:

The observation on seasonal incidence of fall armyworm and their natural enemies on sorghum were recorded from 34th SMW (Standard Meteorological Week) to 49th SMW (Table 1). The oviposition of fall armyworm was observed from 34th SMW (0.03 egg masses plant^{-1}) thereafter, it was increased gradually and attained the peak during 40th SMW (0.30 egg masses plant^{-1}). The results were in accordance with the reports of Shylesha and Sravika (2018) who reported that the maximum oviposition of FAW was noticed during 39th and 40th SMW in maize. The moths of FAW preferred to oviposit on 54 to 64 days old sorghum plants compared to 22 to 42 days old plants (Pitre *et al.*, 1983).

The larval population of FAW (0.37 larvae plant^{-1}) was noticed initially during 35th SMW then population increased gradually and attained the peak population of 1.67 larvae plant^{-1} during 41st SMW (59 DAS). The findings were in conformation with Paul and Deole (2020) who reported that the maximum larval population of FAW was observed during 39th and 40th SMW in maize. Kumar *et al.* (2020) observed the peak incidence of FAW during the first fortnight of November in maize.

Comment [C4]: The manuscript should strengthen the study on the effect of the spatial distribution of the armyworm larvae and the phenological stages of the crop; it is a limitation that can be observed in the methodology and results shown.

The infestation of FAW was observed from 35th SMW (16.67%) to 49th SMW (43.33%). The per cent infestation was more than 50 per cent from 40th SWM to 47th SWM however, the

peak infestation of 60.00 per cent was observed during 41st SWM (59 DAS). The findings were in line with the results of Wyckhuys and Neil (2006) who reported that the peak infestation of fall armyworm was noticed during the whorl stage of maize and the infestation was decreased gradually during post whorl stage of the crop. The maximum infestation of FAW on plants (53.89%) was observed at 66 days after seedling emergence in maize (Pinango *et al.*, 2001).

The leaf damage severity rating was low during the early crop growth period. Later, the damage of FAW on leaves increased with the increase in larval population. However, the maximum leaf damage severity rating of 3.13 was observed during 41st SMW (59 DAS) which was coincided with the peak population of larvae. Similarly, Chamberlin and All (1991) found that the leaf injury rating of fall armyworm on sorghum was low upto 43 days after planting later, it was increased at 51 and 58 days after planting. According to Macharia *et al.* (2019), the severity rating of fall armyworm in maize was very low up to 30 days after emergence (DAE) later, it was increased at 44 DAE and 58 DAE.

3.2 Seasonal incidence of natural enemies on sorghum

The coccinellids *viz*., *Cheilomenes sexmaculata* (Fab.), *Coccinella transversalis*(Fab.), *Brumoides suturalis* (Fab.) and *Cycloneda sanguinea* (L.) were observed from 35th SMW to 48th SMW. The peak population was noticed during 41st SMW (0.43 coccinellids plant^{-1}). The results were in agreement with the findings of Ankita *et al.* (2020) who reported that the activity of coccinellids was observed during the first week of August however, the maximum activity of coccinellids was noticed during the fourth week of September in maize.

Comment [C5]: It should strengthen the seasonal incidence of natural enemies and sorghum, at the same time with the climatic variables evaluated and consider the dissertation and discussion with updated antecedents and references, especially with scientific articles located in Q1 and Q2.

The population of spiders was low during the initial crop growth period *i.e.* up to 45 DAS (39th SMW). Later, the population was raised and attained the peak population of 0.90 spiders plant^{-1} during 41st SMW. The results were in coherence with the findings of Sidar *et al*. (2017) who recorded the incidence of spiders on maize from 32nd SMW to 44th SMW but, the peak population was noticed during 39th SMW.

The population of predatory bugs such as *Rhynocoris fuscipes* (Fab.), *Orius* sp. and *Eocanthecona furcellata* (Wolff) was observed from 35th SMW to 47th SMW. The maximum

population of 0.26 predatory bugs plant^{-1} was recorded during 41st SMW. The present observations were in line with the findings of Shylesha and Sravika (2018) who reported that the peak population of predatory bugs was observed from 38th SMW to 40th SMW in maize. The incidence of *E. furcellata* in maize was noticed during the 36th SMW and the peak population was observed during the 40th SMW (Keerthi *et al*., 2020).

Comment [C6]: The discussions should be reviewed and the following characteristics will have to be considered: Generally, the authors make the comparison of the results obtained from the research with that of other authors, but they do not make the dissertation of the same. It is necessary to emphasize that the dissertation is essential. The dissertation must consider the authors mentioned in the background.

3.3 Correlation between weather parameters and incidence of fall armyworm and natural enemies in sorghum

The correlation studies worked out between the weather parameters and population of FAW (Egg masses, larval population, per cent plant infestation, leaf damage severity rating) and their natural enemies revealed that the oviposition of FAW had significant positive correlation with the minimum temperature (r= 0.668) and wind speed (r= 0.529) However, the population showed non-significant positive correlation with other abiotic factors. This observation was in agreement with findings of Kundra *et al*. (2020) who reported that the ovipoistion of shoot fly had significant and positive correlation with the evening RH and rainfall in little millet (Table 2).

The larval population showed significant positive correlation with maximum temperature (r = 0.029) and non-significant positive correlation with minimum temperature (r= 0.383), morning RH (r= 0.222), evening RH (r= 0.274), and wind speed (r= 0.362) however, it showed non significant negative correlation with precipitation (r= -0.192) and no. of rainy days (r= -0.200). The results were in agreement with the findings of Paul and Deole (2020) who found the existence of non significant positive correlation between the larval population of FAW in maize and the weather parameters like minimum temperature and morning RH. According to Barrios *et al.* (2019), the larval population of *S. frugiperda* was positively correlated with the relative humidity in maize ecosystem.

The per cent plant infestation of fall armyworm showed significant positive correlation with morning RH (r = 0.678) and evening RH (r = 0.664) however, it had negative correlation with the maximum temperature (r= -0.633). The results were in partial coherence with Pazhanisamy *et al*. (2019) who observed the significant positive correlation between leaflet damage of *S. litura* in groundnut and relative humidity and non significant positive correlation

with the minimum temperature. However, the leaflet damage exhibited negative correlation with maximum temperature, wind speed and rainfall. The leaf damage severity of fall armyworm showed significant and positive correlation with evening RH (r = 0.691) and negative correlation with the maximum temperature (r= -0.237). The results were partially in coherence with the findings of Dar *et al*. (2019) who observed the significant positive correlation between the pest damage index caused by *Tetranychus turkestani* in mulberry and weather parameters like maximum temperature, minimum temperature and relative humidity.

The coccinellid population showed significant positive correlation with no. of rainy days (r= 0.022) and negative correlation with evening RH (r= -0.008). The population of spiders showed significant positive correlation with no. of rainy days (r= 0.021) and maximum temperature (r= 0.033). Whereas, the predatory bugs showed significant positive correlation with the maximum temperature (r= 0.033). The present findings were in close conformity with the findings of Ahirwar *et al.* (2015) who stated that the non significant positive correlation associated between the population of natural enemies (Coccinellids, spiders and predatory bugs) in soybean and abiotic factors like maximum temperature and minimum temperature.

3.4 Multiple linear regression analysis

The contribution of weather variables *viz*., maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, rainfall, rainy days and wind speed on the incidence of fall armyworm egg masses, larvae, coccinellids, spiders and predatory bugs on sorghum was 75.77, 65.91, 41.86, 43.64 and 44.52 per cent, respectively (Table 3). Similarly, Kumar *et al*. (2020) reported that the abiotic factors were responsible for the 76%, 74%, 64% and 71% variation in the incidence of larval population of fall armyworm in the maize fields of Perambalur, Veppanthattai, Alathur and Veppur blocks of Tamil Nadu, respectively. The overall impact of abiotic factors on the incidence of natural enemies like spiders, coccinellids and chrysopids in potato was 26.60, 35.90 and 39.90 per cent, respectively (Natikar *et al*., 2018). The influence of weather parameters on the incidence of predatory bugs *viz*., *E. furcellata* and *R. fuscipes* on pigeonpea was 81.90 and 69.60 per cent, respectively (Chakravarty *et al*., 2017).

Comment [C7]: It is not specified what it refers to with biotic factors, it is necessary to discuss it based on climatic variables; be these the maximum temperature, minimum temperature, morning relative humidity, etc.

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Table 1. Seasonal incidence of fall armyworm and its natural enemies on sorghum during *kharif,* 2019

SMW	Crop stage	Fall armyworm*				No. of natural enemies plant^{-1} *			Weather parameters						
		No. of egg masses plant^{-1}	No. of larvae plant^{-1}	Plant infestation (%)	Leaf damage severity rating	Coccinellids	Spiders	Predatory bugs	Max. temp (˚C)	Min. temp. (˚C)	Relative humidity (%)		Rainfall (mm)	No. of rainy days	Wind speed (kmph)
											8:30 AM	5:30 PM			
34	10 DAS	0.03	0.00	0.00	0.00	0.00	0.00	0.00	33.75	25.67	82.57	67.42	5.20	1	1.86
35	17DAS	0.06	0.37	16.67	0.37	0.16	0.06	0.03	34.88	25.75	76.71	70.57	14.70	3	1.76
36	24DAS	0.10	0.67	26.67	0.90	0.20	0.10	0.03	32.52	25.94	81.14	64.00	2.50	0	1.93
37	31DAS	0.20	0.20	36.67	1.23	0.30	0.16	0.06	35.12	26.30	77.42	69.85	133.00	2	1.90
38	38DAS	0.13	0.60	43.33	1.53	0.06	0.00	0.00	31.64	25.40	85.85	82.57	28.60	3	1.79
39	45DAS	0.20	0.77	46.67	1.90	0.10	0.10	0.10	30.40	25.45	86.14	82.28	54.50	3	1.87
40	52DAS	0.30	1.33	53.33	2.67	0.20	0.43	0.13	32.35	25.70	86.00	77.00	0.50	0	2.10
41	59DAS	0.23	1.67	60.00	3.13	0.43	0.90	0.26	32.28	25.38	85.85	77.14	5.70	0	2.06
42	66DAS	0.16	0.30	56.67	2.90	0.26	0.53	0.16	30.07	24.45	86.14	84.71	114.60	6	1.93
43	73DAS	0.10	0.40	53.33	2.57	0.00	0.00	0.00	29.84	24.27	86.85	80.71	73.50	2	1.64
44	80DAS	0.06	0.80	53.33	2.00	0.06	0.10	0.06	30.28	24.22	85.42	80.57	78.90	3	1.76
45	87DAS	0.03	0.73	50.00	1.80	0.16	0.13	0.06	32.47	23.94	85.00	70.71	0.00	0	1.74
46	94DAS	0.03	0.57	53.33	1.30	0.13	0.13	0.03	31.32	23.48	86.28	75.71	0.20	0	2.00
47	101DAS	0.00	0.37	50.00	0.97	0.10	0.10	0.03	30.62	22.02	88.28	76.42	13.80	1	1.24
48	108DAS	0.00	0.10	46.67	0.60	0.06	0.06	0.00	30.18	22.01	86.85	75.57	0.20	0	1.86
49	115DAS	0.00	0.03	43.33	0.00	0.00	0.03	0.00	29.90	20.70	85.40	68.90	0.20	0	1.90

SMW: Standard Meteorological Week DAS: Days After Sowing *Mean of 30 observations

Table 2. Correlation between the weather parameters and incidence of fall armyworm and its natural enemies on sorghum during *kharif*, 2019

S. No.	Pest/ Natural enemies	Particulars	Correlation coefficient (r)						
			Max. temp. (˚C)	Min. temp. (˚C)	Relative humidity (%)		Rainfall (mm)	No. of rainy days	Wind speed (kmph)
					8:30 AM	5:30 PM			
1	Fall armyworm	Egg masses	0.219	0.668**	-0.081	0.331	0.334	0.198	0.529*
2		Larval population	0.029**	0.383	0.222	0.274	-0.192	-0.200	0.362
3		Plant infestation (%)	-0.633**	0.341	0.678**	0.664**	0.187	0.036	0.023
4		Leaf damage severity rating	-0.237	0.344	0.328	0.691**	0.429	0.325	0.214
5	Natural enemies	Coccinellids	0.405	0.453	-0.266	-0.008*	0.195	0.022*	0.417
6		Spiders	0.033*	0.230	0.157	0.262	0.063	0.021*	0.463
7		Predatory bugs	0.033*	0.329	0.130	0.336	0.162	0.135	0.439

*Significant at 5 per cent level** Significant at 1 per cent level

Table 3 Multiple linear regression between the weather parameters and population of fall armyworm and its natural enemies in sorghum during *kharif*, 2019

S. No.	Pest/ Natural enemies	Particulars	Multiple linear regression with abiotic factors	R^2
1	Fall armyworm	Egg masses	$Y= -2.1107+0.0085X_1+ 0.0317X_2+0.0041X_3+ 0.0074X_4 +0.0006 X_5 -0.0217 X_6 +0.1486 X_7$	0.7577
2		Larval population	$Y= -5.9166- 0.033X_1+0.1795X_2 -0.017X_3 +0.061 X_4-0.0019 X_5-0.1918 X_6 +0.1952X_7$	0.6591
3	Natural enemies	Coccinellids	$Y= -3.3657+ 0.0550X_1-0.0031X_2+ 0.0126X_3+0.0048 X_4+0.0009X_5-0.0139 X_6+0.2100 X_7$	0.4186
4		Spiders	$Y= -10.254+0.119X_1- 0.016X_2 + 0.063X_3+ 0.005X_4+0.001 X_5 +0.011 X_6+0.643X_7$	0.4364

5		Predatory bugs	$Y= -2.7158+0.0272X_1+ 0.0032X_2 + 0.0159 X_3+0.0023X_4+0.0003 X_5 +0.0027 X_6+0.1635 X_7$	0.4452

X_1 - Maximum temperature (^{0}C), X_2 - Minimum temperature (^{0}C), X_3 - Morning relative humidity (%),X_4 - Evening relative humidity (%), X_5 - Rainfall (mm), X_6- No. of rainy days, X_7– Wind speed (kmph).