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Seasonal incidence and influence of weather factors on the incidence of *Spodoptera frugiperda* (J.E. Smith) on maize

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Abstract
Field experiments were carried out to study the seasonal incidence of Fall armyworm, *Spodoptera frugiperda* on maize during *rabi* 2019 and *summer* 2020 and the observations were taken at weekly intervals. The study revealed that the incidence of FAW started in 38th MSW (0.52 larvae / plant) and the population increased gradually and reached the peak in 44th MSW (1.20 larvae/ plant) which coincided with the maximum per cent infestation (53.72%) in *rabi* 2019. The incidence of FAW in *summer* 2020 started from 8th MSW (0.69 larvae / plant), reached the peak in the 12th MSW (1.69 larvae/ plant), which coincided with the maximum per cent infestation (58.33%). Correlation analysis in *rabi* season revealed that larval population and infestation showed a significant positive correlation with the evening relative humidity (r= 0.727) while maximum temperature, minimum temperature and rainfall exhibited negative association with larval incidence and infestation of *S. frugiperda*. During summer season, the correlation analysis showed a positive correlation with maximum temperature (r= 0.675) while minimum temperature, morning humidity, evening humidity and rainfall showed a negative correlation.

Keywords: Seasonal incidence, correlation, rabi, summer, maize, fall armyworm

Introduction
Maize, *Zea mays* L (Family: Poaceae) is the most adaptable crop having wider acceptability under varied agro- climatic conditions. Universally, maize is known as "Queen of cereals" because of its high genetic yield potential among the cereals and third important cereal crops next to wheat and rice in the world (Kumar *et al.*, 2020) [7]. It is a high yielding crop of considerable commercial and industrial value, as many goods are made from its grains. However, maize production is generally hampered by abiotic and biotic stresses such as insect pests, diseases, soil nutrients and unstable temperature (Tefera *et al.*, 2011) [16]. Regarding the insect pests, over 40 species were recorded as pests attacked maize crop in different growth stages and four species of moth group including cutworms, stem borers, earworms and armyworms were considered as the major pests which caused serious damage to maize worldwide (Capinera, 2008) [3].

The fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) is a polyphagous pest, native to tropical and subtropical regions of the United States causing a huge infestation throughout the Southeast and along the Atlantic coast during 1970s. In recent years, *S. frugiperda* has been reported its first detection in Southern India during 2016 (CABI, 2018) [1]. The recently introduced pest fall armyworm, *S. frugiperda* is of serious concern due to its polyphagous nature. It has good ability to travel and disperse long distance annually, during the summer months may be the key reason for its rapid spread (Mallapur *et al*., 2018) [18]. In addition to its characteristics, widespread on several crop species and higher reproductive potential caused a serious impact not only on the economic and food security but also particularly hard to control (Prasanna *et al*., 2018) [11].

For the development of an adequate management strategy with minimum pesticide use, requires basic knowledge on population dynamics of insect pests. From a pest management viewpoint, the population dynamic is very important to know the most susceptible stage of the pest and would be the most opportune periods to apply the control option by following the integrated pest management (IPM) concepts (Price *et al*., 2011) [12]. The study demonstrates the variation of *S. frugiperda* population as well as their relationship with the influence of factors such as temperature, humidity and the rainfall in the maize field trial. The information will give a valuable guideline of when is the most susceptible period and provides a better option to control this insect.

Materials and Methods

The present investigation was conducted at Experimental farm, Agricultural College and Research Institute, Madurai situated between latitude 9.54º N and longitude 78.54º E. The area is semiarid with a mean annual rainfall of 890 mm and 147 meters from above mean sea level. Field trials were carried out during *rabi* 2019 and *Summer* 2020 to study the seasonal incidence of fall armyworm, *S. frugiperda*. The TNAU maize hybrid COH (M)-6 was sown with a spacing of 60 x 25 cm. All common standard agronomic cultural practices were followed in the experimental field except plant protection measures. In each season, beginning from 15 days after sowing (DAS), the observations were made on larval population and per cent infestation at weekly intervals.

The natural incidences of FAW were correlated with weather parameters. The data on weather parameters *viz.*, maximum temperature (Cº), minimum temperature (Cº), morning and evening relative humidity (RH) and rainfall were recorded daily at Meteorological unit, AC&RI, Madurai. The mean weather data that prevailed on that week were observed and presented as meteorological standard week (MSW) to workout correlation studies. The data were analysed by correlation between weather parameters and larval population and per cent infestation. The observations on larval population (No. of larvae/plant) and per cent plant infestation were recorded. Larval population was observed by counting the number of larvae present per plant. The per cent plant infestation was observed and calculated using Davis and Williams (1992) [4] method. The data collected were subjected to Pearson's correlation coefficient and regression analysis by SPSS software at $P \leq 0.05$.

Results and Discussion

The weekly recorded observations on larval population, per cent infestation and weather parameters such as maximum temperature, minimum temperature, morning RH, evening RH and rainfall for the season *rabi* and *summer* were statistically analysed and the mean values were tabulated and presented in Table 1 & 2.

During *rabi* season, the incidence of *S. frugiperda* was noticed from 38th MSW (4th week of September) with minimum population of 0.52 larvae/plant and the population reached its peak during 42nd MSW (4th week of October) with the maximum population of 1.20 larvae/plant. After the peak, the overall incidence gradually declined and lasted up to nine weeks with the larval population of 0.41 larvae/plant at 46th MSW (4th week of December) on maize. The per cent infestation during *rabi* season was minimum (23%) on 38th MSW (4th week of September) and reached its peak on 42nd MSW (4th week of October) observed with 53.32% infestation. The incidence declined and lasted up to nine weeks with 25.31% infestation (46th MSW - 4th week of December).

The larval population, per cent infestation during *summer* 2020 observed were tabulated and given in the Table 2. During *summer* season, the population incidence of *S. frugiperda* was noticed from 8th MSW (3rd week of February) with minimum population of 0.69 larvae/plant and the incidence reached its peak during 12th MSW (2nd week of March) with the maximum population of 1.69 larvae/plant. After the peak, the overall incidence gradually declined and lasted up to nine weeks with the larval population of 0.78 larvae/plant at 16th MSW (2nd week of April). The data on per cent infestation was minimum (30.23%) of8th MSW (3rd week of February) and reached its peak on 12th MSW (2nd week of March) observed up to nine weeks of maize crop with 31.00% infestation during 16th MSW (2nd week of April).

Table 1: Seasonal Incidence of *Spodoptera frugiperda* in maize ecosystem during *rabi* 2019

Meterological Standard Week (MSW)	Rabi season			Weather parameters				
	Larval Population	Infestation (%)	Leaf Damage score	Max. Temp. (ºC)	Min. Temp. (ºC)	Morning RH	Evening RH	Rainfall
38	0.52	23.14	3.0	34.43	15.09	91.71	56.00	27.70
39	0.59	30.35	3.2	32.63	15.17	88.00	50.86	84.00
40	0.67	38.29	3.6	33.71	15.51	87.86	50.43	0.00
41	0.74	47.01	4.1	32.09	15.37	91.14	56.14	7.80
42	1.20	53.32	4.5	31.51	14.54	92.86	63.14	21.13
43	0.92	49.83	4.3	31.59	14.13	90.71	57.71	16.87
44	0.42	44.09	3.9	33.23	14.57	93.00	53.71	18.50
45	0.38	35.18	3.3	32.14	15.00	90.57	55.14	1.80
46	0.41	25.31	3.2	31.51	14.97	87.14	45.86	3.00

Table 2: Seasonal Incidence of *Spodoptera frugiperda* in maize ecosystem during *Summer* 2020

Meterological Standard Week (MSW)	Summer season			Weather parameters				
	Larval Population	Infestation (%)	Leaf Damage score	Max. Temp.	Min. Temp.	Morning RH	Evening RH	Rainfall
8	0.69	30.23	4.9	34.03	13.96	83.29	41.29	0.00
9	0.88	34.67	5.0	34.73	14.13	84.00	40.86	0.00
10	0.96	42.75	5.3	37.30	14.66	86.29	41.14	0.00
11	1.18	53.72	5.8	37.20	14.44	85.29	36.71	0.00
12	1.69	58.33	6.2	37.74	15.14	86.71	38.43	0.00
13	1.31	54.11	5.9	37.37	16.46	71.71	41.00	0.00
14	1.11	49.83	5.2	38.09	15.09	76.29	38.00	0.60
15	0.97	41.33	4.9	37.43	14.60	83.00	39.50	0.83
16	0.78	31.00	4.7	38.56	16.30	76.00	37.29	0.00

Kumar *et al.* (2020) [7] found that *S. frugiperda* in maize are minimum at second fortnight of November 2019 with 31, 21, 34 and 31 per cent infestation at Perambalur, Veppanthattai, Alathur and Veppur blocks of Perambalur district

respectively. The incidence of *S. frugiperda* in our studies was similar to the findings of Sonawane *et al.* (2020) [14] who reported that the infestation of *Earias vitella* (Fabricius) was started in the 33rd MSW (Middle of August) with an average larval population 0.4 larvae/plant and during last picking 43rd MSW it was 3.9 larvae/ plant. Peak incidence noticed with 5.2 larvae/ plant during 41st MSW. The findings of present study are in accordance with Palanisamy *et al.* (2019) [9], who reported maximum population, per cent infestation of *Spodoptera litura* (Fabricius) on groundnut was observed during 13th MSW with 3.80 larva per meter row and 60.1% infestation respectively. Similar observations were also noticed by Hanamat *et al.* (2013) [5] who stated that the seasonal incidence of *S. litura* on groundnut started from 7th meteorological standard week (MSW) with 3.20 per cent leaf damage and reached its peak during 11th MSW with 19.50 per cent leaf damage and declined thereafter. The present findings are contrary to Jakhar *et al.* (2016) [6] who reported that the *Helicoverpa armigera* (Hubner) incidence started in 40th MSW with 0.95 larvae/plant and peak incidence of 1.75 larvae/plant in 43th MSW, there after its population started declining and was nil on 51th week. Over all that season, the mean incidence of *H. armigera* was 0.97 larvae/plant in pigeon pea.

Overall, the results indicated that incidence of *S. frugiperda* was observed minimum from 38th to 46th MSW on *rabi* 2019, when compared to *summer* 2020 with maximum incidence was noticed from 8th MSW to 16th MSW. The results are in accordance with Caniço *et al.* (2020) who reported that the dry season, the percentage of maize infested by *S. frugiperda* ranged from 60 to 82.76%, while in the rainy season, the values ranged from 14.18 to 34.25%.

The influence of weather parameters on *S. frugiperda* larval incidence in maize during *rabi* 2019 and *summer* 2020 are tabulated and presented in Table 3. The result of correlation study on larval incidence revealed that the evening R.H. (r = 0.727*) showed significant positive association with the larval incidence while Morning R.H (r = 0.331) and Rainfall (r = 0.050) exhibited positive association with the larval population of *S. frugiperda* during *rabi* 2019. The larval population of FAW was negatively correlated with maximum temperature (r = -0.393) and Minimum temperature (r = -0.378) during *rabi* 2019. During *summer* 2020, the correlation study on larval incidence showed that the maximum temperature (r = 0.777*) exhibited significant positive association while minimum temperature (r = 0.665) and Rainfall (r = 0.328) exhibited positive association with larval incidence of *S. frugiperda*. The larval population of *S. frugiperda* found negatively correlated with Morning RH (r = -0.390) and Evening RH (r = -0.434) during *summer* 2020.

Correlation observed between weather parameters and S. *frugiperda* infestation in maize during *rabi* 2019 and *summer* 2020 is given in Table 4. The result of correlation study on per cent infestation revealed that the evening RH (r = 0.685*) showed significant positive association while Morning R.H (r = 0.546) exhibited positive association with the per cent infestation of *S. frugiperda* during *rabi* 2019. The per cent infestation of FAW was negatively correlated with maximum temperature (r = -0.452) and minimum temperature (r = -0.484) and rainfall (r = -0.216) during *rabi* 2019. During *summer* 2020, the correlation study on per cent infestation showed that the maximum temperature (r = 0.307) exhibited significant positive association while minimum temperature (r = 0.151) exhibited positive association with per cent infestation of *S. frugiperda*. The per cent infestation of *S. frugiperda* found negatively correlated with morning RH (r = - 0.078) and evening RH (r = -0.155) and rainfall (r = -0.111) during *summer* 2020.

Table 3: Correlation between weather parameters and weekly observations on larval population of *Spodoptera frugiperda* during *rabi* 2019

Rabi season (2020)	Weather parameters				
	Max. Temp. (ºC)	Min. Temp. (ºC)	Morning RH	Evening RH	Rainfall
Larval population	-0.393	-0.378	0.331	0.727*	0.050
Infestation	-0.452	-0.484	0.546	0.685*	-0.216

The findings of present study are in accordance with Palanisamy *et al.* (2019) [9] who reported the incidence recorded from 7th MSW to 13th MSW on groundnut exhibited negative association with R.H (r = -0.427), while maximum temperature (r = 0.366), Minimum temperature (r = 0.028) and rainfall (r = 0.581) exhibited positive association with mean larval population of *S. litura.*

Table 4: Correlation between weather parameters and weekly observations on larval population of *Spodoptera frugiperda* during *rabi* 2019

Summer season (2020)	Weather parameters				
	Max. Temp. (ºC)	Min. Temp. (ºC)	Morning RH	Evening RH	Rainfall
Larval population	0.777*	0.665	-0.390	-0.434	0.328
Infestation	0.307	0.151	0.078	-0.155	-0.111

Jakhar *et al.* (2016) [6] found that the *H. armigera* incidence started in 40th MSW and the population of *H. armigera* had significant and negative correlation with maximum temperature (r = -0.524) and non-significant and negatively correlated with minimum temperature (r = -0.710) in pigeonpea. Similar results were noticed by Yadhav *et al.* (2015) [17] who observed that larvae of *S. litura* in blackgram were noticed for the first time during 36th standard week with scanty population of 0.27 larvae/m^2 and highest population of 3.83 larvae/m^2 exhibited non- significant negative correlation with rainfall and wind velocity while temperature (minimum and maximum), relative humidity (morning and evening) and sunshine showed a non-significant positive correlation. The results obtained are in concurrence with the reports of Sharma and Franzaman (2000) [13] who found that the incidence of *Maruca vitrata* (Fabricius) on pigeonpea started from September reaching its first peak during middle October and moderately significant correlation was obtained between *M. vitrata* and sunshine hours and evening relative humidity (RH-II) with correlation coefficients (r) being 0.656 and -0.609, respectively. Pated *et al.* (2008) [10] observed peak infestation of pink stem borer, *Sesamia inferens* (Walker) on wheat (0.54 and 0.75 per cent white ears) during 10th and 12th standard weeks of 2005-06 and 2006-07 exhibited that maximum temperature (r = -0.5513 and r = - 0.4049), rainfall (r = - 0.0652 and r = - 0.4055) and sunshine hours (r = -0.0949 and r = - 0.4940) were negatively correlated with stem borer infestation. Present findings are more or less in line with Sreekanth *et al.* (2015) [15] who reported that morning and evening relative humidity showed significant positive correlation and minimum temperature showed significant negative correlation on the larval population of *M. vitrata* in rice fallow black gram.

Conclusion

The study suggests that, the population incidence and per cent infestation of *S. frugiperda* recorded during *rabi* 2019 was minimum when compared with the *summer* 2020. During *rabi* 2019, the incidence started from 38th MSW (4th week of September) and attained peak activity at 42nd MSW (4th week of October) and retained up to 46th MSW (4th week of December) which was having significant association with evening RH while morning RH and rainfall were positively correlated.

Minimum temperature and maximum temperature had negative association with incidence. During summer 2020, the incidence started from 8th MSW (3rd week of February) and attained peak activity at 12th MSW (2nd week of March) and retained up to 16th MSW (2nd week of April) and had positive association with maximum and minimum temperature whereas morning and evening relative humidity and rainfall exhibited negative association. Therefore, temperature plays a major role in biology of *S. frugiperda.*

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