Indian Journal of Ecology
Vol. 53, Issue 1, January-March 2026: 115-119
Journal homepage: http:/www.indianecol.org
DOI: https://doi.org/10.55362/IJE/2026/4766

Manuscript Number: 4766

Assessment of spatial distribution of fall armyworm, *Spodoptera frugiperda* (JE Smith) on maize (*Zea mays* L)

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Received: October 25, 2025 Revision Submitted: January 12, 2026 Accepted: February 10, 2026

***Abstract*:** Understanding insect spatial distribution patterns is fundamental to ecology, providing insights into community assembly, biodiversity maintenance and pest management strategies. The present study investigated the spatial patterns of larvae of fall armyworm on maize. The experiment was conducted at the Instructional farm, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan during Kharif 2019 and 2020.The larval population of *Spodoptera frugiperda* was recorded on sixty randomly selected plants at weekly interval. The data from original counts were arranged in frequency tables for fitting the different statistical parameters. Variance to mean ratio, exponent – K, patchiness index, clumping index, mean colony size, mean clump size, Iwao's patchiness regression and Taylor's power law were analyzed to test the dispersion behaviour of *S. frugiperda.* The result revealed that clumped or uniform or random distribution of *S. frugiperda* larvae in maize during both the year. The values of variance to mean ratio exceeded unity, the Lloyd's index was close to 1.0 and regression equation based on Taylor's Power law was computed as $\log S^2 = -0.507 + 1.398 \log \bar{x}$ and $\log S^2 = -0.141 + 1.108 \log \bar{x}$ in 2019 and 2020, respectively. All these values were indicated that the larvae of *S. frugiperda* showed clumped type of distribution in most of sampling date.

***Keywords*:** Clumped, Fall armyworm, Maize, Spatial distribution, *Spodoptera frugiperda.*

1. INTRODUCTION

Maize (*Zea mays* L) is an important cereal crop next to rice and wheat grown over a wide range of geographical and environmental conditions in India as compared to other cereal crops. Among various biotic factors, insect pests take a heavy toll of the crop thus bringing down crop yields. As many as 141 insect pests cause varying degrees of damage to the crop right from sowing till harvest (Reddy and Trivedi, 2008). The recently introduction of invasive fall armyworm, *Spodoptera frugiperda* (J.E. Smith) is of serious concern for maize cultivation due to its notorious and polyphagous behaviour. The pest was first reported in West Africa in late 2016 (Goergen et al., 2016) by early 2017, the pest invaded sub–Saharan Africa. Moreover, this pest has been spread to many Asian countries. In India, it was reported for the first time on maize from Shivamogga district in Karnataka during May-June 2018 (Sharanabasappa et al., 2018). However, the presence of the pest has been reported from most growing region of the country (Rakshit et al., 2019). The knowledge on the behavior pattern of *S. frugiperda* and its bio-ecology are of major importance for development of strategies to manage this pest (Sarmento et al., 2006). The study of spatial distribution of *S. frugiperda* in maize cultivation is essential to develop a plan of integrated pest management *viz.,* by identifying whether pests are aggregated, random, or uniform, managers can move away from uniform, blanket-spray approaches to targeted, site-specific interventions, thereby ensuring the optimization of sampling and control strategies (Farias et al., 2001). Keeping the above facts in view, the experiment is conducted to understand the spatial behavior of *S. frugiperda* in maize field at Udaipur district of Rajasthan state.

2. MATERIALS AND METHODS

2.1. Location & Sowing of Maize

The experiment was laid out at the Instructional Farm, Rajasthan College of Agriculture, MPUAT, Udaipur. Maize variety Pratap Makka-3 was sown in the prepared field on the 5th July, 2019 and 2nd July, 2020 with row to row and plant to plant spacing of 60 cm × 25 cm, respectively.

2.2. Observation

The population of fall armyworm, *S. frugiperda* was observed on 15 randomly selected plants in each replication (four replications). In all a total of 60 plants were observed to record the population of *S. frugiperda* at weekly interval.

Available online: March 13, 2026

2.3. Statistical Analysis

The data from original counts were arranged in frequency tables for fitting the different statistical parameters. Variance to mean ratio (Southwood, 1978), exponent – K (Lloyd, 1967), patchiness index (Lloyd, 1967), clumping index (David and Moore, 1954), mean colony size (Tanigoshi et al., 1975), mean clump size (Arbous and Kerrich, 1951), Iwao's patchiness regression (Iwao, 1968) and Taylor's power law (Taylor, 1961) were analyzed to test the dispersion behaviour of this pest. α and B which were obtained from the regression of the mean crowding against mean density refers to the basic component of dispersion and the pattern of distribution respectively (Iwao, 1968). The regression constants 'a' and 'b' of Taylor's power law also indicated the sampling parameter and the aggregation index respectively (Taylor, 1961). Different statistical analyses are used in spatial distribution to identify, quantify and interpret complex geographic patterns—such as clustering, dispersion or randomness—that simple visual mapping cannot explain.

The formulae of different statistical measures as follow (1-9):

$$\text{Dispersion index} = \frac{\text{Variance}}{\text{Mean}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

A ratio of 1 indicates a random (Poisson) distribution, >1 indicates a clustered or over-dispersed distribution, and <1 indicates a uniform or under-dispersed distribution.

$$\text{Dispersion pattern (K)} = \frac{(\bar{x})^2}{s^2 - \bar{x}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, $\bar{x}$= mean density; s^2 = variance

$$\text{CV} = \frac{\sigma}{\bar{x}}\ x\ 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where, s = standard deviation; $\bar{x}$ = mean

$$\text{Mean Crowding Index (X)} = \bar{x} + \left(\frac{s^2}{\bar{x}} - 1\right) \quad \ldots\ldots\ldots\ldots (4)$$

$$\text{Llyod's Patchiness Index} = \frac{X}{\bar{x}} \quad \ldots\ldots\ldots\ldots (5)$$

Taylor's power law: This gives a relation between variance and mean.

$S^2 = a.x^b$…….(6) (Taylor, 1961) where 'a' is a constant depending upon experimental conditions and 'b' is the coefficient of contagion.

Iwao's patchiness index relates mean crowding (X*) to mean density as:

X*= α + βX (Iwao, 1968)……(7) where 'α' is the index of basic contagion and 'β' is the density contagiousness coefficient.

$$\text{Index of Clumping} = \frac{s^2}{\bar{x}} - 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Mean Colony Size = 1 + mean crowding…. (9)

3. RESULTS AND DISCUSSION

Spatial distribution: The statistical parameters for testing distribution pattern of *S. frugiperda* larvae are presented in Table 1 and 2 during *Kharif,* 2019 and 2020, respectively. The data revealed clumped, uniform and random larval distribution. The values of variance to mean ratio exceeded unity in most of the sampling occasions indicating a contagious type of distribution during both the year. However, on 29th, 37th, 38th and 39th SWM in 2019 and on 29th, 38th and 39th SWM in 2020, the distribution was observed to be uniform. The larval distribution pattern on 36th SMW and 37th SMW was random during 2019 and 2020, respectively. The mean crowding index ranged from 11.50 to 31.62 and 7.79 to 37.26 during 2019 and 2020, respectively. The Lloyd's index was close to 1.0 during both the year that also

Table 1. Distribution pattern of *S. frugiperda* on maize during *Kharif,* 2019

SMW	Mean density ($\bar{x}$)	Variance (S^2)	Variance to mean ratio ($S^2/\bar{x}$)	Dispersion pattern (K)	Co-efficient of variation (CV)	Mean crowding index (X)	Lloyd's patchiness index ($X/\bar{x}$)	Index of clumping (IDM)	Mean colony size (C)	Pattern of distribution
29	16.00	4.67	0.29	-22.59	0.14	15.29	0.96	-0.71	16.29	U
30	29.50	45.67	1.55	53.83	0.23	30.05	1.02	0.55	31.05	C
31	31.25	42.92	1.37	83.71	0.21	31.62	1.01	0.37	32.62	C
32	11.50	16.33	1.42	27.36	0.35	11.92	1.04	0.42	12.92	C
33	12.50	16.33	1.31	40.76	0.32	12.81	1.02	0.31	13.81	C
34	25.50	46.33	1.82	31.21	0.27	26.32	1.03	0.82	27.32	C
35	12.75	18.92	1.48	26.36	0.34	13.23	1.04	0.48	14.23	C
36	20.25	20.92	1.03	615.09	0.23	20.28	1.00	0.03	21.28	R
37	22.25	14.92	0.67	-67.51	0.17	21.92	0.99	-0.33	22.92	U
38	19.00	15.33	0.81	-98.45	0.21	18.81	0.99	-0.19	19.81	U
39	12.00	6.00	0.50	-24.00	0.20	11.50	0.96	-0.50	12.50	U

U- Uniform; C- Clumped; R- Random; (x̄) mean of 15 plants

indicated clumped type of distribution. The Iwao's patchiness regression was computed as X* = – 0.328 + 1.022 x in 2019 (Figure 1) and X* = -0.229 + 0.956 x in 2020 (Figure 3). The index of basic contagion (a) was negative which indicated that aggregation was of individuals rather than colonies. The density contagiousness coefficient were b = 1.022 1st year, being greater than unity suggested that the colonies were over dispersed. The regression equation based on Taylor's Power law was computed as log S^2 = – 0.507 + 1.398 log $\bar{x}$ and log S^2 = – 0.002 + 1.072 log $\bar{x}$ in 2019 and 2020 respectively (Fig. 2 & 4). The value of the index of aggregation (b) were more than unity in both the year, thus confirmed the aggregate nature of distribution.

The distribution pattern of *S. frugiperda* was contagious corroborated the findings of Melo et al. (2006), Farias (2001), Rios et al. (2014), Meena et al. (2019) and Hutasoit et al. (2020). The incidence of larvae of *S. frugiperda* in maize can show different distribution patterns: 'binomial-negative' or 'aggregated' when larvae are small, random, which is the most frequently reported and uniform (Melo et al., 2006). Farias (2001) observed that *S. frugiperda* showed aggregated distribution for the small caterpillars (high population density) in the field whereas, had random distribution of the large ones (low population density) showing more dispersed population of older larvae. Rios et al. (2014) reported that the aggregation indices

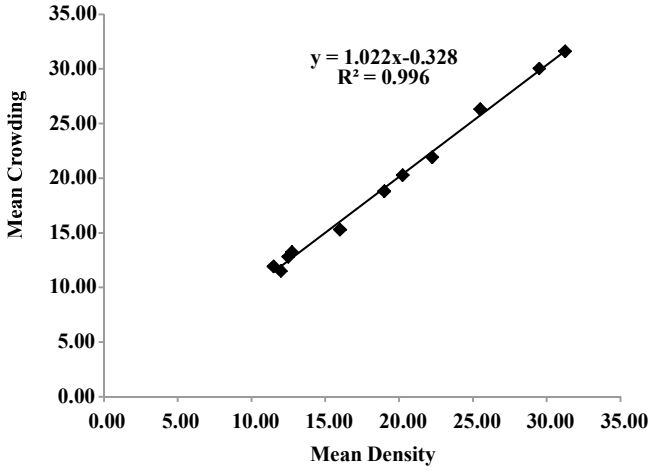

Figure 1. Iwao's Regression for mean crowding and mean density of *S. frugiperda* on maize during *Kharif* 2019

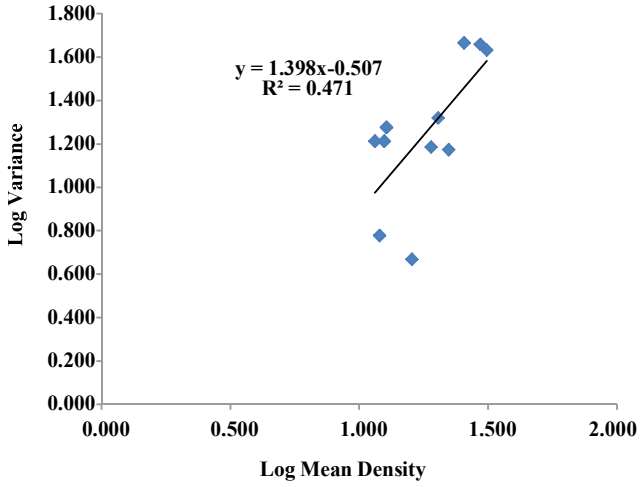

Figure 2. Regression of log variance on log mean density for *S. frugiperda* on maize during *Kharif*, 2019

Table 2. Distribution pattern of *S. frugiperda* on maize during *Kharif,* 2020

SMW	Mean density ($\bar{x}$)	Variance (S^2)	Variance to mean ratio ($S^2/\bar{x}$)	Dispersion pattern (K)	Co-efficient of variation (CV)	Mean crowding index (X)	Lloyd's patchiness index ($X/\bar{x}$)	Index of clumping (IDM)	Mean colony size (C)	Pattern of distribution
29	20.25	4.25	0.21	-25.63	0.10	19.46	0.96	-0.79	20.46	U
30	33.25	55.58	1.67	49.50	0.22	33.92	1.02	0.67	34.92	C
31	36.25	50.92	1.40	89.60	0.20	36.65	1.01	0.40	37.65	C
32	37.00	46.67	1.26	141.62	0.18	37.26	1.01	0.26	38.26	C
33	19.25	28.92	1.50	38.33	0.28	19.75	1.03	0.50	20.75	C
34	7.50	9.67	1.29	25.96	0.41	7.79	1.04	0.29	8.79	C
35	19.50	27.00	1.38	50.70	0.27	19.88	1.02	0.38	20.88	C
36	8.50	9.67	1.14	61.93	0.37	8.64	1.02	0.14	9.64	C
37	21.25	20.92	0.98	-1354.69	0.22	21.23	1.00	-0.02	22.23	R
38	22.25	16.92	0.76	-92.82	0.18	22.01	0.99	-0.24	23.01	U
39	14.50	9.67	0.67	-43.50	0.21	14.17	0.98	-0.33	15.17	U

U- Uniform; C- Clumped; R- Random; ($\bar{x}$) mean of 15 plants

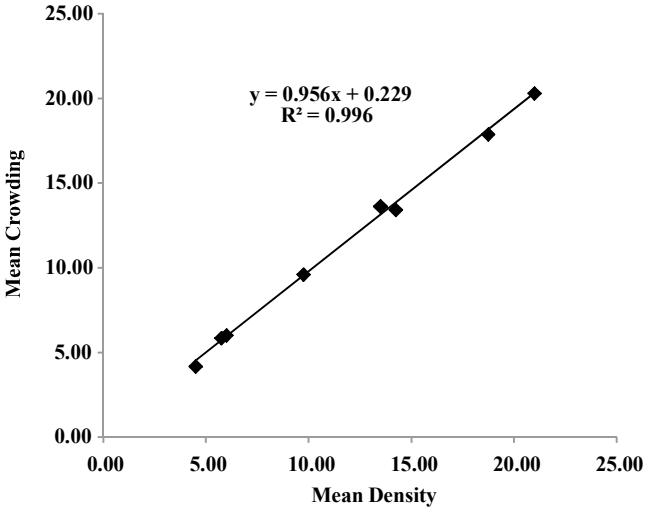

Figure 3. Iwao's Regression for mean crowding and mean density of *S. frugiperda* on maize during *Kharif* 2020

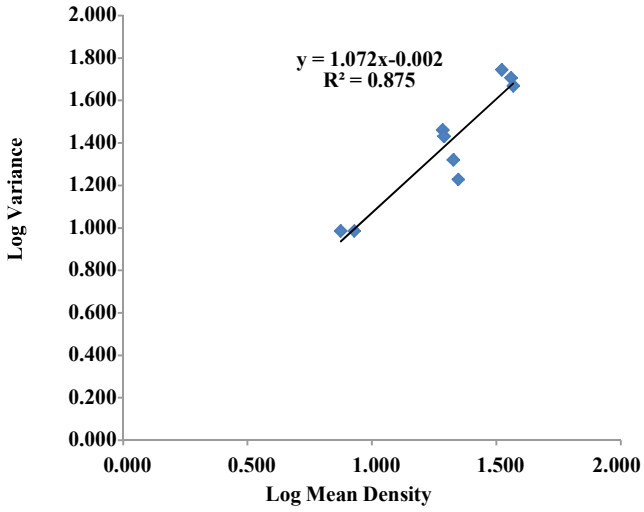

Figure 4. Regression of log variance on log mean density for *S. frugiperda* on *Kharif* maize 2020

(variance/mean ratio, Morisita's index, Green's index and Exponential k of a negative binomial distribution) indicated aggregate distribution for both small and large caterpillars. Meena et al. (2019) reported that the spatial distribution pattern of *S. frugiperda* larvae was uniform or close to random, rather than aggregated. Hutasoit et al. (2020) reported that the spatial distribution of *S. frugiperda* and result revealed that the intercept of regression values was greater than 0 and the regression slope value was around one, this indicated that armyworms spread in groups.

4. CONCLUSION

The study revealed that larvae of *S. frugiperda* had clumped, random and uniform type of distribution in different SMW. However, the values of variance to mean ratio exceeded unity and the Lloyd's index was close to 1.0 in most of SMW, which indicated that clumped type of distribution pattern was more prominent. Understanding these patterns is crucial for predicting pest spread and designing effective, region-specific control methods.

Acknowledgments

Authors express sincere thanks to the Head, Department of Entomology; Dean, Rajasthan College of Agriculture and Director of Research, MPUAT, Udaipur for providing necessary facilities and encouragement for research. Special thanks are extended to the staffs of the Instructional Farm, RCA, Udaipur for their assistance in field experiment and data collection.

Author's Contributions

KC Ahir, MK Mahla, S Ramesh Babu and B Singh prepared the initial manuscript draft and compilation of manuscript. All authors contributed to data entry, statistical analysis and figure preparation.

Conflict of Interest

The authors declare no conflict of interest.

Data availability

All data is present in the paper.

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