Journal of
Food Chemistry & Nanotechnology

https://doi.org/10.17756/jfcn.2025-s1-002

Research Article

Open Access

Weather-driven Pest Dynamics in Punjab: How Biodiversity and Climate Impact on Maize and Food Security

VK Sonawane, SK Gharde* and KS Ghodekar

Department of Entomology, Lovely Professional University, Punjab, India

***Correspondence to:**
SK Gharde
Department of Entomology,
Lovely Professional University,
Punjab, India.
E-mail: sgharde@rediffmail.com

Received: January 20, 2025
Accepted: April 29, 2025
Published: May 05, 2025

Citation: Sonawane VK, Gharde SK, Ghodekar KS. 2025. Weather-driven Pest Dynamics in Punjab: How Biodiversity and Climate Impact on Maize and Food Security. *J Food Chem Nanotechnol* 11(S1): S8-S14.

Copyright: © 2025 Sonawane et al. This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC-BY) (https://creativecommons.org/licenses/by/4.0/) which permits commercial use, including reproduction, adaptation, and distribution of the article provided the original author and source are credited.

Published by United Scientific Group

Abstract

The fall armyworm (FAW) (*Spodoptera frugiperda*) is a destructive pest, primarily affecting maize but also attacking crops like rice, sorghum, and cotton. It was first reported in India in 2018 in Karnataka, but it has since spread nationwide. This study, conducted at Lovely Professional University, Phagwara, Punjab, during 2023 - 2024, examined the effect of weather parameters such as (temperature, relative humidity (RH) and rainfall) on the population dynamics of key maize pests in Northwest India. Purposive sampling was used to monitor *S. frugiperda* populations, employing a diagonal sampling method where for *Chilo partellus* and *Sesamia inferens* destructive sampling techniques were used from 20 m × 20 m sampling units. Ten plants per sample unit (5 m × 5 m) were inspected weekly. FAW incidence peaked during the 26th and 27th standard meteorological weeks (SMW), while *C. partellus* was most abundant in the 29th and 27th SMW. *S. inferens* populations were highest in the 26th and 27th SMW. FAW was the most dominant species, causing slight to moderate damage (0 - 20%) to young leaves. The Shannon-Wiener diversity index (H') of 1.08 in 2023 and 1.07 in 2024 indicates moderate pest diversity, highlighting a stable pest community structure across the two years. This study identifies peak infestation periods for major pests of maize, enabling timely and targeted pest control. The dominance of FAW and weather-related pest dynamics offer crucial insights for developing region-specific integrated pest management (IPM) strategies. Timely pest management based on these insights can help farmers reduce crop losses and ensure sustainable maize production in Northwest India.

Keywords

Fall armyworm, Population dynamics, Integrated pest management, Diversity indices, Food security

Introduction

In addition to wheat and rice, maize (*Zea mays* L.) serves as an important carbohydrate-rich food source [1]. Native to Central America, maize has since been widely disseminated across tropical regions globally [2]. Maize production in India stands at around 38.09 million metric tons in 2023 [3], with major states like Karnataka, Madhya Pradesh, and Bihar contributing 45% of the nation significantly. Punjab, while traditionally dominated by wheat and rice, is focusing on maize due to its lower water requirement. The state's maize productivity is higher than the national average, attributed to the adoption of hybrid seeds and modern farming techniques [4]. Challenges include water scarcity, price volatility, and pest infestations, though government support for crop diversification helps boost maize cultivation. The invasion of plant pests is a major factor influencing the variability of maize production in India [5].

Plant pests are classified into three main categories: insect pests, viruses, and weeds [6]. Insect pests affecting maize include the spotted stem borer (*C. partellus*), cutworms (*Agrotis* sp.), shoot fly (*Atherigona* sp.), pink stem borer (*S. inferens*), and FAW (*S. frugiperda*) [7]. A recently identified invasive pest in India, *S. frugiperda*, generally called a FAW, has gained attention [8]. *S. frugiperda* J.E. Smith (Lepidoptera: Noctuidae) is a highly adaptable pest, feeding on more than 353 plant species from 76 families. Among its targets are vital crops belonging to the Poaceae, Fabaceae, Solanaceae, Asteraceae, Rosaceae, and Brassicaceae families [9, 10].

FAW larvae cause significant damage to maize crops, particularly through their leaf-boring behavior, which causes reduced photosynthetic efficiency leading to significant yield losses and economic damage for farmers. First-instar larvae begin feeding on the leaf tissue, consuming the mesophyll and leaving behind a translucent epidermal layer. Subsequently, the larvae bore into the whorl of rolled leaves, creating holes as the leaves unfolded. In later instars, the larvae inflict substantial damage, often defoliating the plant and leaving only the midribs and stems of maize crops [8, 11]. *S. frugiperda* can infest maize crops at both vegetative and generative stages, with more severe damage observed during the vegetative phase [12]. In 2018, FAW was first detected in India, where it initially infested maize fields in Karnataka [13]. It is anticipated that FAW will continue to spread globally. Wind dispersal, contamination of traded goods, transport via aircraft, and changing climate patterns are thought to contribute significantly to its expansion [14].

In addition to the FAW (*S. frugiperda*), maize crops in India are significantly impacted by other key insect pests, including the maize stem borer and the pink stem borer. Knowledge about the biodiversity of major pests of maize allows us to develop region-specific, sustainable pest management strategies, including the use of biocontrol agents and optimized pest monitoring that protect maize production, thereby enhancing food security and supporting the livelihoods of farmers in affected areas. Furthermore, the findings can provide valuable insights for local farmers and policymakers in Punjab, enabling them to formulate effective strategies and policies for the control of *S. frugiperda*. Through a comprehensive understanding of pest behavior, environmental influences, and effective pest management strategies, stakeholders can collaborate to reduce the negative effects of this invasive species on maize production.

Materials and Methods

Study area

Sampling took place in the research fields of Lovely Professional University, Phagwara, during the growing seasons of 2023 and 2024. Concurrently, laboratory investigations were conducted in the Department of Entomology. The research took place between May and September of both years.

Sampling

Sampling took place in the research fields of Lovely Professional University, Phagwara (31.2559° N, 75.7054° E), situated in the Trans-Gangetic plains agro-climatic zone, during the growing seasons of maize Kharif 2023 and Kharif 2024. Purposive sampling assessed FAW (*S. frugiperda*) on maize with a diagonal method and destructive sampling techniques, utilizing a larger sample unit of 20 m × 20 m, were applied to evaluate the stem borers (*C. partellus* and *S. inferens*) and sampling This involved plant dissection to examine the stems and count individual larvae, along with assessing damage by inspecting entry holes and frass. A total of 10 plants were observed in each sample unit (5 m × 5 m) at weekly interval from the total five replication were conducted. The plants were assessed in the field for infestation symptoms, attack severity, and *S. frugiperda* population density (Figure 1).

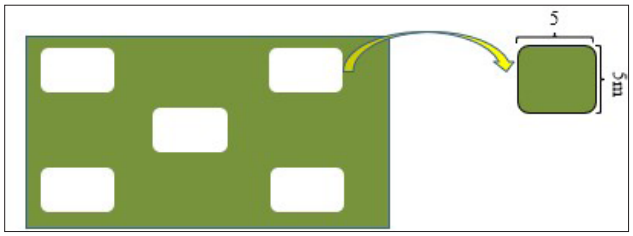


Figure 1: Sampling method of FAW.

Damage characteristics

Damage from pest attacks was assessed based on three primary factors: (i) attack behavior and visible symptoms; (ii) intensity of the infestation, and (iii) the number of damaged leaves per plant. Larval behavior and attack symptoms were observed directly on the infested maize plants. This included monitoring the laying of eggs, their placement, and the behavior of larvae from hatching until the pre-pupal stage. Specific attention was given to the plant parts targeted by the larvae and how they fed. Symptoms of infestation were identified on maize leaves, focusing on the type and extent of damage.

To evaluate attack intensity, the damage was quantified on a scale of 1 to 9, as outlined by Putrasamedja et al. [15], assessing the extent of injury caused by *S. frugiperda* on the maize plants.

$$I = \frac{\Sigma(n \times v)}{N \times Z} \times 100\% \quad (1)$$

Where, I is attack intensity, Z is the highest score (9), N is the number of plants observed, n is the number of plants that have a "*v*" value (crop damage), and v is the value (score) of crop damage based on the criteria in figure 2.

Attack categories were classified according to the severity of leaf damage and grouped into three plant age categories (weeks after planting (WAP)) (Table 1).

To assess the number of infected maize leaves per plant, observations were conducted on a random sample of 200 maize plants affected by *S. frugiperda* larvae in the field. The plants selected for observation were post-planting 6 weeks old post-planting, as they had nearly fully developed their leaves and were transitioning to the generative phase. The assessment consisted of determining the proportion of infected leaves to the total number of leaves on each maize plant.

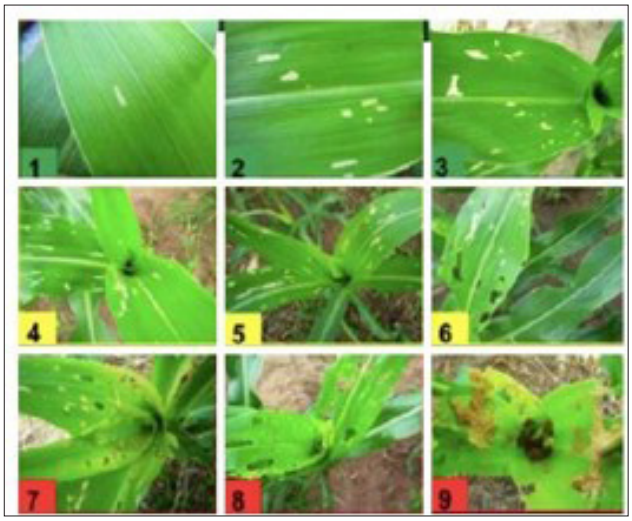


Figure 2: Davis and Williams scale value [14].

Table 1: Criteria for *S. frugiperda* attack.

Criteria	WAP		
	0 - 2	2 - 4	> 4
Slight	0 - 10	0 - 20	0 - 40
Moderate	10 - 20	20 - 40	40 - 60
Heaviness	20 - 40	40 - 60	60 - 75
Very heavy	40 - 85	60 - 85	75 - 85
No result	> 85	> 85	> 85
Economic threshold	15%	30%	50%

Attack percentage by *S. frugiperda* (%)

The percentage of FAW pest attacks was observed by calculating the number of affected plants at three elevation ranges: 0 - 250 meters, >250 - 500 meters, and > 500 meters above sea level, followed by analysis using a specific formula [16]:

$$P = \frac{a}{b} \times 100\% \quad (2)$$

Where, P is the percentage of infected plants, a is the number of affected plants, and b is the number of plants observed.

Assessing diversity indices of major lepidopteran pest of maize ecosystems

The collected specimens of *S. frugiperda*, *C. partellus*, and *S. inferens* were identified by carefully examining their morphological traits. We followed the guidelines provided by Dhillon and Hasan [17] for FAW [18], for maize stem borer [19], and for pink stem borer, using a stereo zoom light microscope to ensure accurate identification down to the species level. Now, when it came to measuring diversity, we started by calculating relative density. The percentage that shows the proportion of individuals of each species:

$$\text{Relative density (\%)} = \left(\frac{\text{Number of individuals of a species}}{\text{total number of individuals across all species}}\right) \times 100$$

Next, we assessed alpha diversity, which tells us how diverse the community is. For this, we used several well-known indices:

Simpson's diversity index

Quantifies the probability that two individuals chosen at random from a sample are from different species [20].

$$D = \frac{\sum n(n-1)}{N(N-1)} \quad (3)$$

Where, n represents the total number of individuals of a specific species and N denotes the total number of individuals across all species.

The Simpson's index of diversity is calculated by subtracting the Simpson's diversity index from 1. This index varies from 0 - 1, with higher values representing greater diversity within a given sample.

The Shannon-Wiener index (H') [21]

Provides a measure of uncertainty or randomness in species distribution.

$$H' = -\sum Pi \ln (Pi) \quad (4)$$

Where, Pi = S/N; S denotes the number of individuals of a specific species, N represents the total number of individuals in the sample, and ln indicates the natural logarithm (base e).

Pielou's evenness index (E1) [22]

Measures the distribution uniformity of individuals across different species.

$$E1 = \frac{H'}{\ln (S)} \quad (5)$$

Where, S refers to the total number of species present in the sample.

Margalef's richness index (Mg) [23]

It gives us a sense of how many species are present in relation to the total number of individuals.

$$Mg = \frac{(S-1)}{\ln .N} \quad (6)$$

Where, S represents the total number of recorded species, and N represents the sum of all individuals across these species.

Finally, we also considered the dominance index (D), which highlights the extent to which one or more species dominate the community

$$D = \sum\left(\frac{n}{N}\right)^2 \textbf{ or } D = \frac{(\sum n(n-1)}{N(N-1)} \quad (7)$$

Where, n represents the total number of individuals for a particular species, and N denotes the overall total of individuals across all species.

Data analysis

Weather data, including maximum and minimum temperature, rainfall, RH, and wind speed, were collected from the meteorological laboratory at Lovely Professional University, Phagwara, during the experimental period. Weekly averages of major pests of maize were calculated and correlated with weather parameters using Spearman rank correlation, performed in R software (using the Hmisc or corrplot package)

to evaluate the impact of weather factors on pest diversity. Additionally, multiple regression analysis was performed.

The attack intensity and percentage of *S. frugiperda*, along with various diversity indices, were calculated using Microsoft Excel 2019, and the results are presented below.

Results and Discussion

Incidence of major lepidopteran pest of maize during Kharif 2023 and Kharif 2024

In the Kharif season, studies on pest incidence (Figure 3) revealed that infestation of *S. frugiperda* on maize was noticed from 23rd SMW to 35th SMW, where incidence of *C. partellus* and *S. inferens* was reported from 24th SMW to 34th and 35th SMW, respectively, in Kharif 2023 and Kharif 2024. The peak infestation of *S. frugiperda* was observed during the 27th SMW in both Kharif 2023 and Kharif 2024, while *C. partellus* and *S. inferens* peaked during the 29th SMW in 2023 but shifted to the 27th SMW in 2024 (Figure 3). This shift in peak infestation during 2024 may be attributed to differences in weather conditions, maize phenology, or pest population dynamics between the two years. The current findings align with Reddy et al. [24], who reported that the incidence of *S. frugiperda* peaked during the second fortnight of July and was lowest in the second fortnight of October during the Kharif season. Similarly, Capinera et al. [25] noted the highest infestation in the third week of August in 45 day-old crops. The maximum infestation occurred at both vegetative and reproductive stages, suggesting that the larvae feed on both stages, as indicated by Pazhanisamy et al. [26].

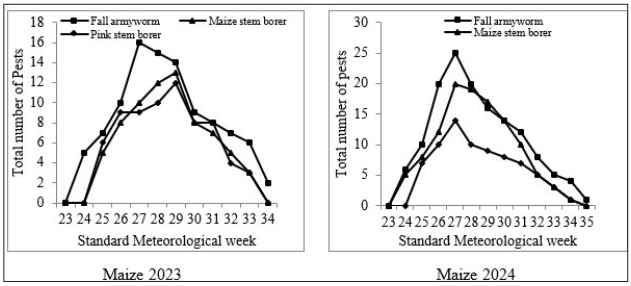


Figure 3: Diversity of major pests on maize during 2023 and 2024.

Influence of weather parameters on populations of *S. frugiperda*, *C. partellus* and *S. inferens* during Kharif 2023 and Kharif 2024

Influence of weather parameters on populations of *S. frugiperda*, *C. partellus*, and *S. inferens* during Kharif 2023 and Kharif 2024. The correlation between weather parameters and seasonal incident of *S. frugiperda*, *C. partellus*, and *S. inferens* on maize during Kharif 2023 and Kharif 2024 is presented in figure 4. The correlation studies indicated that the population of FAW (r = 0.38, 0.70*, 0.60*, and -0.30), *C. partellus* (r = 0.37, 0.61*, 0.58*, and -0.02), and *S. inferens* (r = 0.29, 0.62*, 0.62*, and -0.34) with maximum temperature, minimum temperature, RH, and rainfall, respectively, in Kharif 2023. Correlation values marked with an asterisk (*) denote significance at $p < 0.05$. Positive correlations observed with minimum temperature and RH indicate moderate to strong relationships, while

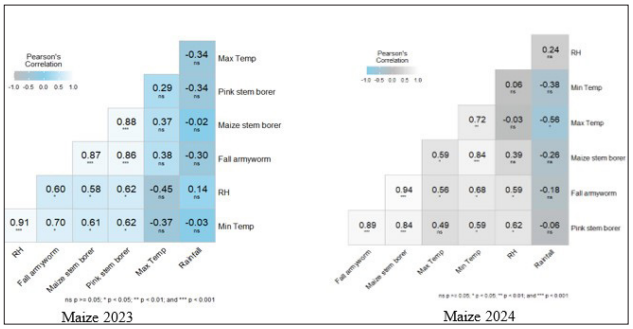


Figure 4: Correlation study between major pests of maize in 2023 and 2024 with weather factor.

negative correlations with rainfall suggest an inverse relationship with pest populations. However, during Kharif 2024, incidence of FAW (r = 0.56*, 0.68*, 0.59* and -0.18) *C. partellus* (r = 0.59*, 0.84***, 0.39 and -0.26), and *S. inferens* (r = 0.49, 0.59*, 0.62* and -0.06) with i.e., maximum temperature, minimum temperature, RH and rainfall, respectively. Reddy et al. [24] found a positive correlation between the larval population of *S. frugiperda* and minimum temperatures during the Kharif and Rabi seasons, while rainfall exhibited a negative correlation. These findings align with [27], which reported that *Spodoptera litura* incidence also had a negative correlation with rainfall in the Kharif season. Increased rainfall during rabi significantly influences *S. frugiperda* populations, consistent with Waddill et al. [28], who noted that *S. frugiperda* populations in tropical regions fluctuate with seasonal rainfall, reaching their lowest during dry periods. Furthermore, Sharma et al. [29] observed that both heavy and light rainfall significantly reduced early instar FAW populations, impacting the adult population. About abiotic factors, *S. inferens* larval populations showed a significant negative correlation with maximum (T_{max}) and minimum temperatures (T_{min}) on HKI 1128 (r = -0.4992, -0.5183) and HQPM 1 (r = -0.4872, -0.4717), respectively [30]. Multiple regression equations were developed to analyze the relationship between weather parameters (X) and the mean larval populations of *S. frugiperda*, *C. partellus*, and *S. inferens* on maize during the Kharif season of 2023 and 2024 (Table 2).

Attack intensity of *S. frugiperda* during Kharif 2023 and Kharif 2024

Our observations indicate that the intensity of *S. frugiperda* attacks on Kharif maize in Punjab during 2023 and 2024 varied significantly, ranging from 4.5% - 44.1% (Figure 5). Attacks began in the second WAP with a "moderate" intensity of 16.20% per plant in 2023 and a "slight" intensity of 9% per plant in 2024. The lower initial attack intensity in 2024 may be attributed to factors such as changes in weather conditions, early pest management interventions, or variations in maize planting time, which could have influenced larval establishment and population dynamics. Attack intensity peaked at the fifth WAP, reaching 44.10% per plant in 2024. After this peak, intensity declined, recording "slight" levels of 33.30% and 32.40% per plant in 2023 and 2024, respectively, eventually dropping to "mild" levels of 5.40% and 4.50% per plant by the twelfth WAP. The attack intensity was higher in the year 2023 due to the weather conditions. The results suggest that *S. fru-*

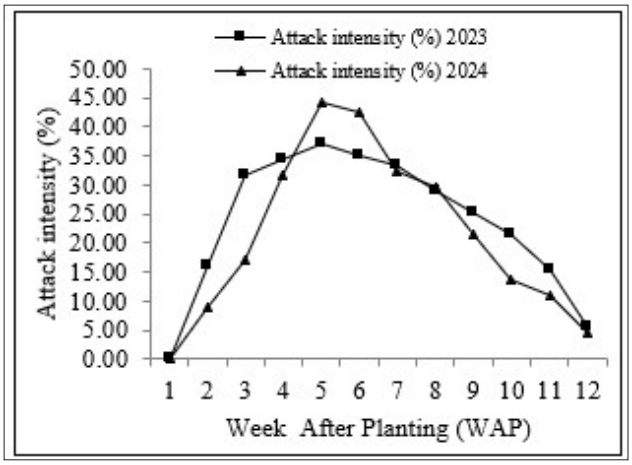


Figure 5: The intensity of *S. frugiperda* attacks on maize in Punjab during the years 2023 and 2024.

giperda larvae have significant destructive potential, adversely affecting maize productivity. Chimweta et al. [31] noted "very heavy" attack intensity at the fourth WAP, while Pathania et al. [32] highlighted that crop damage is influenced by plant vulnerability, pest density, and developmental stages. *S. frugiperda* damaging ability is significantly greater than that of other maize pests [33], with the most severe damage occurring during the vegetative phase [34, 35].

Determining the range of maize leaf damage inflicted by *S. frugiperda* Larvae per plant

The study revealed that *S. frugiperda* primarily attacks maize leaves at the shoots or growing points, with the number of affected leaves per plant ranging from 1 - 9 (Figure 2). The highest incidence of leaf damage was observed in the 4 - 6 leaves category (102 plants and 130 plants), followed by 1 - 3 leaves (58 plants and 42 plants), while the least damage occurred in the 7 - 9 leaves category (40 plants and 28 plants) during the Kharif seasons of 2023 and 2024. *S. frugiperda* targeted leaves located at various heights on the maize plant but notably preferred the younger, top leaves (Figure 6). This preference aligns with previous findings indicating that

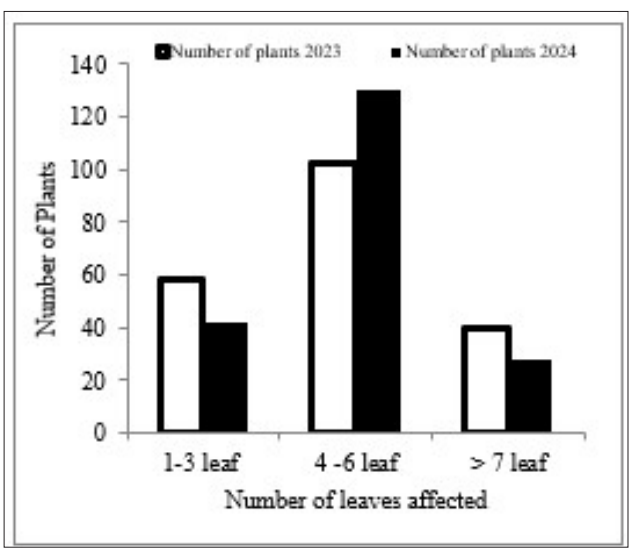


Figure 6: The range of the number of leaves attacked by *S. frugiperda* per plant during 2023 and 2024.

S. frugiperda larvae favor younger maize leaves due to their softer tissue and higher water content, which are less resistant to feeding compared to older leaves with thicker, more rigid cell walls.

Attack percentage of *S. frugiperda*

In areas below 250 meters above sea level, the highest recorded attack percentages were 27.57% and 33.20% per 25 m^2 plot, while in regions above 500 meters, the lowest were observed at 15.16% and 10.91%, during the Kharif seasons of 2023 and 2024 (Figure 7). This difference is attributed to the limited cultivation of maize in higher-altitude regions. The availability of host plants is a key factor influencing pest attacks, as the abundance and quality of food resources directly support insect population growth [31]. In addition to food, altitude and temperature also play crucial roles in limiting pest development by affecting insect physiology, distribution, and abundance [36-39]. Hoiss et al. [40] noted that temperature changes can reduce insect fecundity, leading to population declines. Furthermore, research suggests that higher altitudes slow insect reproduction, resulting in fewer generations and reduced species populations [41].

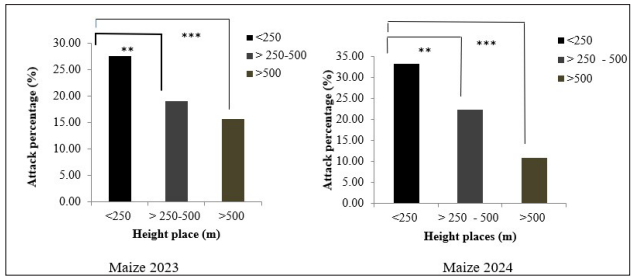


Figure 7: Elevation based variations in *S. frugiperda* attack rates in Punjab, India. (** and *** indicating significant differences).

Diversity of major pests

Arthropod pest biodiversity was assessed using five indices, with a total of 239 pests captured in Kharif 2023 and 329 in Kharif 2024 (Table 2).

Pest richness, as measured by the Menhinick and Margalef indices, showed no significant differences between Kharif 2023 and Kharif 2024. Likewise, diversity indices, including the Shannon-Wiener and Simpson's Index, revealed no major variations across the two years. Pest species dominance remained relatively stable, indicating a consistent pattern of species prevalence between the years (Table 3 and table 4).

Conclusion

The study at Lovely Professional University analyzed weather-related pest dynamics in maize, focusing on FAW (*S. frugiperda*). FAW peaked in the 26th and 27th SMW, with early instar larvae damaging the leaf epidermis and later instars causing more severe leaf and stem damage. Infestations started at 2 WAP, peaking at 4 WAP, with the highest attack rates (30.38%) occurring below 250 meters altitude. The H' of 1.08 (2023) and 1.07 (2024) highlighted significant pest diversity. A high diversity index indicates the presence of multiple pest species, necessitating diversified pest management approach-

Table 2: Multiple linear regression analysis was conducted on the mean larval numbers of *S. frugiperda*, *C. partellus*, and *S. inferens* (Y) in relation to weather parameters (X) in maize during Kharif 2023 and Kharif 2024 (n = 10).

Crop	Species	X1	X2	X3	X4	Multiple regression equation	R2	Fcal
Maize - 2023	*S. frugiperda*	0.23	0.167	0.03	-0.01	$Y= -13.696 + 0.225_{x1} + 0.167_{x2} + 0.027_{x3} - 0.006_{x4}$	0.98	68.61
	C. partellus	0.26	0.128	0.04	0.018	$Y= - 15.266 + 0.263_{x1} + 0.128_{x2} - 0.038_{x3} + 0.018_{x4}$	0.89	13.47
	S. inferens	0.17	-0.01	0.06	-0.02	$Y= -10.027 + 0.174_{x1} - 0.014_{x2} + 0.063_{x3} - 0.020_{x4}$	0.85	9.943
Maize - 2024	*S. frugiperda*	0.08	0.229	0.05	0	$Y= - 11.456 + 0.077_{x1} + 0.229_{x2} + 0.045_{x3} - 0.004_{x4}$	0.79	7.685
	C. partellus	0	0.344	0.03	-0.02	$Y= -10.591 + 0.004_{x1} + 0.344_{x2} + 0.025_{x3} - 0.018_{x4}$	0.82	9.221
	S. inferens	0.05	0.101	0.02	0.025	$Y= -5.830 + 0.049_{x1} + 0.101_{x2} + 0.024_{x3} + 0.025_{x4}$	0.72	5.173

Note: X1: Maximum temperature, X2: Minimum temperature, X3: RH, and X4: Rainfall.

Table 3: Abundance of major lepidopteran pest of maize from the Punjab.

Crop - maize	*S. frugiperda*	*C. partellus*	*S. inferens*	Total
2023	99	71	69	239
2024	141	114	74	329
Total	240	185	143	558

es to address potential threats from various pests effectively. These findings provide valuable insights for region-specific IPM strategies to minimize crop damage and enhance maize production in Northwest India.

Acknowledgements

None.

Conflict of Interest

None.

References

1. Shah TR, Prasad K, Kumar P. 2016. Maize-a potential source of human nutrition and health: a review. *Cogent Food Agric* 2(1): 1166995. https://doi.org/10.1080/23311932.2016.1166995
2. Edmeades GO, Trevisan W, Prasanna BM, Campos H. 2017. Tropical Maize (*Zea mays* L.). In Genetic Improvement of Tropical Crops. Springer, pp 57-109.
3. Production Volume of Maize India FY 2010-2024. [https://www.statista.com/statistics/1140254/india-production-volume-of-maize/#statisticContainer] [Accessed May 05, 2025]
4. Punjab Agricultural University. 2020. Annual Report on Agricultural Statistics in Punjab.
5. Directorate of Plant Protection, Quarantine & Storage 2021. Impact of Pests on Major Crops in India, with Focus on Maize (ICAR Report). [https://icar.org.in] [Accessed May 05, 2025]
6. Huesing JE, Prasanna BM, McGrath D, Jeffers D, Bohn MO. 2018. Insect pests of maize: a global perspective on the biology and management of key pests. *Ann Rev Entomol* 63: 85-99.
7. Deshmukh SS, Kalleshwaraswamy CM, Asokan R, Swamy HM, Maruthi MS, et al. 2018. First report of the fall armyworm, *Spodoptera frugiperda* (J E Smith) (Lepidoptera: Noctuidae), an alien invasive pest on maize in India. *Pest Manag Horticult Ecosys* 24(1): 23-29.
8. Montezano DG, Sosa-Gómez DR, Specht A, Roque-Specht VF, Sousa-Silva JC, et al. 2018. Host plants of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas. *Afr Entomol* 26(2): 286-300.
9. Kansiime MK, Mugambi I, Rwomushana I, Nunda W, Lamontagne-Godwin J, et al. 2019. Farmer perception of fall armyworm (*Spodoptera frugiperda* JE Smith) and farm-level management practices in Zambia. *Pest Manag Sci* 75(10): 2840-2850. https://doi.org/10.1002/ps.5504
10. Fall Armyworm Control Methods and Symptoms. Agrifarming. [https://www.agrifarming.in/fall-armyworm-control-methods-and-symptoms] [Accessed May 05, 2025]
11. Prasanna B, Huesing JE, Eddy R, Peschke VM. 2018. Fall Armyworm in Africa: A Guide for Integrated Pest Management.
12. Ganiger PC, Yeshwanth HM, Muralimohan K, Vinay N, Kumar ARV, et al. 2018. Occurrence of the new invasive pest, fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), in the maize fields of Karnataka, India. *Curr Sci* 115: 621. https://doi.org/10.18520/CS/V115/I4/621-623
13. Goergen G, Kumar PL, Sankung SB, Togola A, Tamò M. 2016. First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (J E Smith) (Lepidop tera, Noctuidae), a new alien invasive pest in West and Central Africa. *PLoS One* 11: e0165632. https://doi.org/10.1371/journal.pone.0165632
14. Davis F, Williams W. 1992. Visual Rating Scales for Screening Whorl Stage Corn for Resistance to Fall Armyworm (No. Technical Bulletin 186). Mississippi State University, USA.
15. Putrasamedja S, Setiawati W, Lukman L, Hasyim A. 2016. The appearance of several onion clones and their relationship with the intensity of attack by plant pests. *J Hort* 22: 349.
16. Silva DM, Bueno AD, Andrade K, Stecca CD, Neves PM, et al. 2017. Biology and nutrition of *Spodoptera frugiperda* (Lepidoptera: Noc-

Table 4: Diversity indices of major lepidopteran pest of maize collected from two different years (Kharif 2023 and Kharif 2024).

Year	Host	No. of species	Shannon-Wiener diversity index (H')	Simpson index	E1	Mg	D
2023	Maize	3	1.08	0.66	0.78	0.36	0.35
2024	Maize	3	1.07	0.65	0.77	0.34	0.35

tuidae) fed on different food sources. *Sci Agric* 74: 18-31. https://doi.org/10.1590/1678-992X-2015-0160

17. Dhillon MK, Hasan F. 2017. Morphological changes in *Chilo partellus* (Swinhoe) undergoing diapause. *J Entomol Zool Stud* 5(3): 1658-1661.
18. Soujanya PL, Sekhar JC, Karjagi CG, Ratnavathi CV, Venkateswarlu R, et al. 2023. Role of morphological traits and cell wall components in imparting resistance to pink stem borer, *Sesamia inferens* Walker in maize. *Front Plant Sci* 14: 1167248. https://doi.org/10.3389/fpls.2023.1167248
19. Simpson EH. 1949. Measurement of Diversity.
20. Shannon CE. 1949. Communication in the presence of noise. *Proceedings IRE* 37(1): 10-21. https://doi.org/10.1109/JRPROC.1949.232969
21. Pielou EC. 1966. The measurement of diversity in different types of biological collections. *J Theor Biol* 13: 131-144. https://doi.org/10.1016/0022-5193(66)90013-0
22. Margalef R. 1973. Information theory in ecology. In Royal Academy of Sciences and Arts of Barcelona.
23. Kumar NV, Yasodha P, Justin CG. 2020. Seasonal incidence of maize fall armyworm *Spodoptera frugiperda* (JE Smith) (Noctuidae; Lepidoptera) in Perambalur district of Tamil Nadu, India. *J Entomol Zool Stud* 8(3): 1-4.
24. Reddy KJ, Kumari K, Saha T, Singh SN. 2020. First record, seasonal incidence and life cycle of fall armyworm, *Spodoptera frugiperda* (JE Smith) in maize at Sabour, Bhagalpur, Bihar. *J Entomol Zool Stud* 8(5): 1631-1635.
25. Capinera JL. Fall Armyworm, *Spodoptera frugiperda* (Insecta: Lepidoptera: Noctuidae). [http://edis.ifas.ufl.edu/in255]. [Accessed May 05, 2025]
26. Pazhanisamy M, Senthilkumar M, Sathyaseelan V. 2019. Seasonal incidence of leaf eating caterpillar, *Spodoptera litura* (Fabricius) in groundnut ecosystem during Kharif season. *Plant Arch* 19(2): 3351-3354.
27. Mitchell ER, McNeil JN, Westbrook JK, Silvain JF, Lalanne-Cassou B, et al. 1991. Seasonal periodicity of fall armyworm, (Lepidoptera: Noctuidae) in the Caribbean basin and northward to Canada. *J Entomol Sci* 26(1): 39-50. https://www.doi.org/10.18474/0749-8004-26.1.39
28. Waddill VH, Mitchell ER, Denton WH, Poe SL, Schuster DJ. 1982. Seasonal abundance of the fall armyworm and velvetbean caterpillar (Lepidoptera: Noctuidae) at four locations in Florida. *Flo Entomol* 65(3): 350-354. https://doi.org/10.2307/3494308
29. Sharma H, Jaglan MS, Yadav SS. 2017. Population dynamics of pink stem borer, Sesamia inferens (Walker) on maize as influenced by weather conditions. *J Appl Nat Sci* 9(4): 1975 -1980. https://doi.org/10.31018/jans.v9i4.1476
30. Supartha IW, Susila IW, Sunari AA, Mahaputra IF, Yudha IK, et al. 2021. Damage characteristics and distribution patterns of invasive pest, *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) on maize crop in Bali, Indonesia. *Biodiversitas J Biol Diversity* 22(6): 3378-3389. https://doi.org/10.13057/biodiv/d220645
31. Chimweta M, Nyakudya IW, Jimu L, Bray Mashingaidze A. 2020. Fall armyworm [*Spodoptera frugiperda* (J.E. Smith)] damage in maize: management options for flood-recession cropping smallholder farmers. *Int J Pest Manag* 66(2): 142-154. https://doi.org/10.1080/09670874.2019.1577514
32. Pathania M, Verma A, Singh M, Arora PK, Kaur N. 2020. Influence of abiotic factors on the infestation dynamics of whitefly, *Bemisia tabaci* (Gennadius 1889) in cotton and its management strategies in NorthWestern India. *Int J Trop Insect Sci* 40: 969-981. https://doi.org/10.1007/s42690-020-00155-2
33. Food and Agriculture Organization of the United Nations and CAB International. 2019. Community-Based Fall Armyworm (*Spodoptera frugiperda*) Monitoring, Early Warning and Management, Training of Trainers Manual.
34. Suby SB, Soujanya1 PL, Yadava P, Patil J, Subaharan K, et al. 2020. Invasion of fall armyworm (*Spodoptera frugiperda*) in India: nature, distribution, management and potential impact. *Curr Sci* 119(1): 44-51.
35. Dhar T, Bhattacharya S, Chatterjee H, Senapati SK, Bhattacharya PM, et al. 2019. Occurrence of fall armyworm *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) on maize in West Bengal, India and its field life table studies. *J Entomol Zool Stud* 7: 869-875.
36. Badenes-Perez FR, Gershenzon J, Heckel DG. 2014. Insect attraction versus plant defense: young leaves high in glucosinolates stimulate oviposition by a specialist herbivore despite poor larval survival due to high saponin content. *PLoS One* 9(4): e95766. https://doi.org/10.1371/journal.pone.0095766
37. Bhusal K, Bhattarai K. 2019. A review on fall armyworm (*Spodoptera frugiperda*) and its possible management options in Nepal. *J Entomol Zool Stud* 7(4): 1289-1292.
38. Shi P, Zhong L, Sandhu HS, Ge F, Xu X, et al. 2012. Population decrease of *Scirpophaga incertulas* Walker (Lepidoptera Pyralidae) under climate warming. *Ecol Evol* 2(1): 58-64. https://doi.org/10.1002/ece3.69
39. Du Plessis H, Schlemmer ML, Van den Berg J. 2020. The effect of temperature on the development of *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Insects* 11(4): 228. https://doi.org/10.3390/insects11040228
40. Hoiss B, Krauss J, Potts SG, Roberts S, Steffan-Dewenter I. 2012. Altitude acts as an environmental filter on phylogenetic composition, traits and diversity in bee communities. *Proc R Soc B Biol Sci* 279(1746): 4447-4456. https://doi.org/10.1098/rspb.2012.1581
41. Zhang W, Zhao F, Hoffmann AA, Ma CS. 2013. A single hot event that does not affect survival but decreases reproduction in the diamondback moth, *Plutella xylostella*. *PLoS One* 8(10): e75923. https://doi.org/10.1371/journal.pone.0075923