Print ISSN : 0972-8813
e-ISSN : 2582-2780

[Vol. 23(3) September-December 2025]

Pantnagar Journal of Research

(Formerly International Journal of Basic and Applied Agricultural Research ISSN : 2349-8765)

G.B. Pant University of Agriculture & Technology

Pantnagar, U.S. Nagar; Uttarakhand, Website : gbpuat.res.in/PJR

PANTNAGAR JOURNAL OF RESEARCH

Vol. 23(3) September-December, 2025

CONTENTS

Lagged effects of weather variables on *Helicoverpa armigera* (Hübner) larval population during rabi season

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ABSTRACT: The present study investigated the seasonal dynamics of *Helicoverpa armigera* larval population in relation to weekly meteorological variables during the rabi seasons of 2023-24 and 2024-25. Weekly larval density per plant was recorded and examined in relation to mean temperature, relative humidity, rainfall and sunshine hours. Larval population remained negligible during early winter but increased sharply from the 10th SMW onward, attaining peak densities of 8.500 larvae/plant in 2023-24 and 8.200 larvae/plant in 2024-25. To quantify weather–population relationships, Poisson generalized linear models with lagged weather variables were employed. During 2023-24, temperature at one-week lag showed a highly significant positive effect (β = 0.263; $p = 0.001$), indicating nearly a 30% increase in expected larval density per 1 °C rise, while sunshine at one-week lag was also significant (β = 0.247; $p = 0.044$). In contrast, during 2024-25, sunshine at one-week lag exerted the strongest influence (β = 0.797; $p < 0.001$), corresponding to more than a two-fold increase in larval abundance per additional sunshine hour, whereas temperature at two-week lag showed a significant negative effect (β = -0.236; $p = 0.032$). Relative humidity and rainfall exhibited weak or inconsistent associations in both seasons. The findings highlight the importance of antecedent thermal and solar conditions in regulating *H. armigera* larval population dynamics and provide insights useful for weather-based pest management strategies.

Keywords: *Helicoverpa armigera*, lagged Poisson GLM, larval density, pest-weather relationship, population dynamics

Chickpea (*Cicer arietinum* L.) ranks as the third most significant pulse crop globally, following dry beans and peas. The global average annual chickpea cultivation area is approximately 14 million hectares, resulting in a productivity of 1221.8 Kg/ha, with Asia contributing 88 percent of the cultivated area and 84 percent of the total production (FAO, 2022). In the Indian context, chickpeas are cultivated across 10.00 million hectares, yielding an annual production of 11.91 million tons, which corresponds to an average yield of 1192 kg per hectare (Agricultural Statistics at a Glance, 2022). The states of Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Karnataka and Andhra Pradesh collectively represent 91% of the total production and 90% of the area dedicated to chickpea cultivation (Golla, 2017).

The primary constraints impeding the enhancement of chickpea productivity include insect pest infestations from the pod borer, *H. armigera*, the beet army worm, *Spodoptera exigua*, in addition to other pests and climatic conditions (Chen *et al.,* 2011). Out of these *Helicoverpa* as a key insect pest of chickpea having caused an estimated loss of US$325 million. The pest is notorious and causes damage ranging from 30 to 40 per cent to about 90 per cent if not managed timely (Balraj *et al.,* 2025). In Pantnagar it causes substantial yield loss and 100% pod damage in chickpea if not managed timely (Jaba *et al.,* 2017). Weather parameters play a crucial role in regulating the population dynamics of insect pests by influencing their survival, development, reproduction and dispersal (Dharavath *et al.,* 2021; Huang, 2021; Chitralekha *et al.,* 2024; Devi *et al.,* 2024; Singh *et al.,* 2024; Demirel and Akgul, 2025; Srivastav *et al.,* 2025; Alok *et al.,* 2022).

The Generalized Linear Model (GLM) therefore presents a viable alternative for addressing such skewness, as it facilitates a cohesive application to various prevalent statistical methodologies. The classical linear model is predicated upon the assumption that the errors conform to normal distribution patterns. GLMs, as a category of statistical frameworks, furnish an abstract yet simplified representation of empirical data. They are designated as GLMs due to their generalization of traditional linear models that rely on normal distributions. In addition to encompassing the linear regression component, GLMs incorporate a specialized exponential family that transforms the mean through a "link function," thereby establishing a connection between the regression component and the mean of one of these distributions (Mugenyi *et al.,* 2021; Iamba, 2022). However, the response of pest populations to weather is often delayed, as climatic conditions influence earlier life stages such as oviposition, egg hatch and early larval development. Consequently, the use of lagged weather variables provides a more biologically meaningful understanding of pest weather relationships than same-week associations. GLMs, particularly those based on Poisson error distribution, are widely used for analysing insect count data due to their ability to handle non-normal, discrete response variables (Iamba, 2022; Kavallieratos *et al.,* 2024). Incorporation of lagged weather parameters within a Poisson GLM framework allows robust quantification of delayed meteorological effects on pest population dynamics (Yogeesh *et al.,* 2023).

Despite several studies examining the influence of weather on *H. armigera*, the season-specific combined effect of one and two-week lagged meteorological variables on *H. armigera* larval population has not been systematically evaluated. Therefore, the present study was undertaken to document the seasonal dynamics of *H. armigera* larval population during the rabi seasons of 2023-24 and 2024-25 and quantify the influence of contemporaneous and lagged meteorological variables on larval abundance using Poisson generalized linear models.

MATERIALS AND METHODS

The present investigation was conducted during the rabi seasons of 2023-24 and 2024-25 at the N.E.B. Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India. The study area falls under tarai region of Uttarakhand characterized by cool winters and gradual increase in temperature towards late rabi season.

Larval population monitoring

Larval population of *H. armigera* was recorded on a weekly basis throughout the rabi season following standard entomological procedures. Observations were taken from 10 randomly selected plants and larval density was expressed as number of larvae per plant. Weekly mean larval density was computed for further analysis.

Meteorological data collection

Weekly meteorological data corresponding to the observation period were obtained from the nearby meteorological observatory. The weather variables considered in the study included mean temperature (°C), mean relative humidity (%), total rainfall (mm) and sunshine hours (h per day). Weather data were summarized on a Standard Meteorological Week (SMW) basis to align with larval population observations.

Descriptive analysis

Seasonal trends in larval population and weather variables were examined using graphical representation given in Figure 1 and Figure 2. The weekly meteorological parameters along with corresponding larval density for each season and line graphs were constructed to visualize seasonal dynamics are presented in Table 1 and Table 2.

Statistical analysis

The relationship between *H. armigera* larval population and weather variables was analysed using Generalized Linear Models (GLMs) with Poisson error distribution and log link function, as larval count data were discrete and non-normally distributed (Iamba, 2022).

Initially, same-week Poisson GLMs were fitted using contemporaneous weather variables. The general form of the model is (Hinde, 1982):

$$\log(\mu) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \dots\dots\dots.. + \beta_p X_p$$

where μ is the response variable, β_0 and β are numeric coefficients, β_0 being the intercept, X is the predictor/

explanatory variable, β_p is the i-th coefficient and X_p is the i-th predictor variable.
To account for delayed biological responses, lagged Poisson GLMs were subsequently fitted by incorporating one and two-week lagged weather variables with the equation:

$$\log(\mu) = \beta_0 + \beta_1 X_{t-1} + \beta_2 X_{t-2} + \cdots \ldots\ldots$$

Model adequacy was assessed using the dispersion statistic (ratio of deviance to residual degrees of freedom). Models with dispersion values close to unity were considered appropriate. Regression coefficients, standard errors, z-values and p-values were used to assess the significance of individual weather variables. All statistical analyses were performed using Python (pandas, matplotlib.pyplot, statsmodels.api and statsmodels.formula.api library).

RESULTS AND DISCUSSION

The results of the present study describe the seasonal dynamics of *H. armigera* larval population in relation to weekly meteorological variables during the rabi seasons of 2023-24 and 2024-25 and quantify the influence of weather parameters using Poisson generalized linear models (GLM). Weekly variations in temperature, relative humidity, rainfall, sunshine hours, and larval density are presented descriptively, followed by graphical illustration of seasonal trends and statistical evaluation of lagged weather effects on larval abundance.

Weekly variation in weather parameters and H. armigera larval density during rabi 2023–24

Weekly meteorological variables and *H. armigera* larval density per plant recorded during the rabi season of 2023-24 are presented in Table 1. Mean weekly temperature during the study period ranged from 9.100 to 29.300 °C, while relative humidity varied between 36.300% to 90.700%. Rainfall was largely absent during most weeks, except for sporadic events, with a pronounced rainfall peak of 60.800 mm during the 9th Standard Meteorological Week (SMW). Sunshine hours increased progressively from early winter weeks, ranging from 0.200 to 10.300 h per day.

Larval population remained nil or very low during early SMW (48th to 2nd SMW), coinciding with lower temperatures, higher relative humidity and limited sunshine hours. Initial larval incidence was observed from the 3rd to 5th SMWs, followed by a gradual increase in abundance with improving thermal and solar conditions. A sharp rise in larval density was recorded from the 10th SMW onwards, corresponding to increasing temperature and sunshine duration.
Peak larval density was observed during the 12th to 16th SMWs, with maximum infestation reaching 8.500 larvae per plant in the 16th SMW. This period was characterized by moderate to high temperatures (20.700-27.900 °C), lower relative humidity (37.900-63.700%), negligible rainfall and extended sunshine hours (7.900-9.600 h). Thereafter, larval population declined rapidly during the 17th-19th SMWs, despite continued high temperatures, suggesting progression of crop phenology presented in Figure 1.

The observed seasonal increase in larval population during mid-season weeks corresponds well with the significant positive effects of lagged temperature and sunshine hours identified through Poisson GLM analysis presented in Table 3.

Weekly variation in weather parameters and H. armigera larval density during rabi 2024–25

Weekly meteorological parameters and *H. armigera* larval density per plant recorded during the rabi season of 2024-25 are presented in Table 2. Mean weekly temperature during the season ranged from 13.050 to 29.250 °C, while relative humidity varied between 33.500 and 82.850%. Rainfall occurred intermittently, with notable precipitation events during the 15th (45.800 mm) and 18th (45.600 mm) SMW. Sunshine hours showed an overall increasing trend from early to mid-season, ranging from 2.700 to 10.200 h per day.
Larval population remained absent or negligible during the early SMWs (48th to 2nd SMWs), corresponding with relatively lower temperatures, higher relative humidity and reduced sunshine duration. Initial larval appearance was observed from the 3rd to 4th SMWs, followed by a gradual increase

Table 1: Weekly meteorological variables and *H. armigera* larval density (per plant) during *rabi* season 2023-24

2023-24	Mean Temperature (°C)	Mean Relative Humidity (%)	Rainfall (mm)	Sun-Shine Hrs	*H. armigera* larvae per plant
48th SMW	19.600	67.150	0.000	4.400	0.000
49th SMW	18.700	63.900	1.000	7.800	0.000
50th SMW	14.400	70.300	0.000	6.500	0.000
51st SMW	14.500	66.800	0.000	6.500	0.000
52nd SMW	15.200	76.200	0.000	5.500	0.300
1st SMW	12.700	82.200	0.000	2.200	0.000
2nd SMW	10.900	86.600	0.000	0.200	0.000
3rd SMW	10.100	90.700	0.000	1.200	0.700
4th SMW	9.100	86.700	0.000	1.400	0.600
5th SMW	13.900	75.000	10.000	3.800	0.600
6th SMW	13.900	72.800	1.600	5.800	0.600
7th SMW	16.700	65.100	0.000	7.400	0.500
8th SMW	17.100	59.000	2.600	7.300	1.100
9th SMW	17.300	70.700	60.800	5.300	0.600
10th SMW	16.900	68.500	0.000	9.200	1.700
11th SMW	20.200	59.900	0.000	9.500	2.300
12th SMW	20.700	63.700	0.000	7.900	8.300
13th SMW	25.100	58.800	0.000	8.600	8.100
14th SMW	23.900	43.900	0.000	9.300	7.900
15th SMW	25.900	40.300	0.000	8.300	8.000
16th SMW	27.900	37.900	0.000	9.000	8.500
17th SMW	28.300	37.800	0.000	10.300	2.900
18th SMW	27.800	36.300	0.000	9.600	1.300
19th SMW	29.300	51.000	0.800	7.300	0.400

Table 2: Weekly meteorological variables and *H. armigera* larval density (per plant) during *rabi* season 2024-25

2024-25	Mean Temperature (°C)	Mean Relative Humidity (%)	Rainfall (mm)	Sun-Shine Hrs	*H. armigera* larvae per Plant
48th SMW	17.600	67.000	0.000	7.100	0.000
49th SMW	17.300	65.650	0.400	7.500	0.000
50th SMW	13.550	66.250	0.000	7.100	0.000
51st SMW	15.000	64.550	0.000	7.500	0.000
52nd SMW	15.700	75.400	5.600	4.000	0.200
1st SMW	13.500	82.850	0.000	2.700	0.000
2nd SMW	13.050	74.600	2.800	4.400	0.000
3rd SMW	14.800	80.500	1.400	4.800	0.500
4th SMW	13.900	77.350	0.000	4.600	0.600
5th SMW	15.700	67.550	0.000	8.000	0.300
6th SMW	15.150	71.650	0.000	7.900	0.600
7th SMW	15.700	66.100	0.000	8.400	0.400
8th SMW	17.550	67.700	2.000	7.700	0.900
9th SMW	18.600	73.950	14.000	5.200	1.300
10th SMW	18.500	64.750	0.000	9.100	1.100
11th SMW	22.400	57.800	6.400	8.700	4.000
12th SMW	21.150	57.400	0.000	10.200	7.800
13th SMW	22.700	50.150	0.000	9.800	6.800
14th SMW	25.050	42.450	0.000	10.200	5.800
15th SMW	26.200	55.500	45.800	8.900	7.100
16th SMW	27.850	56.050	19.400	9.300	8.200
17th SMW	28.550	33.500	0.000	9.100	2.000
18th SMW	27.850	54.550	45.600	6.600	1.700
19th SMW	29.250	49.600	0.000	8.900	0.700

in abundance with rising temperature and sunshine hours. A pronounced increase in larval density was evident from the 9th SMW onwards, coinciding with improved thermal conditions and increased solar radiation.

Peak larval density was recorded during the 12th to 16th SMWs, with maximum infestation reaching 8.200 larvae per plant during the 16th SMW. This peak period was characterized by moderate to high temperatures (21.150-27.850 °C), lower to moderate relative humidity (42.450-57.400%) and extended sunshine duration (8.900-10.200 h per day). Despite the occurrence of substantial rainfall during the 15th and 18th SMWs, larval population remained high during mid-season, indicating that favourable sunshine and temperature conditions likely offset the suppressive effects of rainfall. Following the peak, larval density declined sharply during the 17th-19th SMWs, even under high temperature conditions, suggesting progression of crop maturity. This was consistent with the significant effects of sunshine hours at same-week and one-week lag identified through Poisson GLM analysis given in Table 3.

Overall, the temporal pattern indicated that *H. armigera* larval incidence was closely associated with favourable thermal and solar conditions, while periods of lower temperature and high humidity during early winter weeks were unfavourable for larval build-up.

Lagged Poisson GLM analysis of weather effects

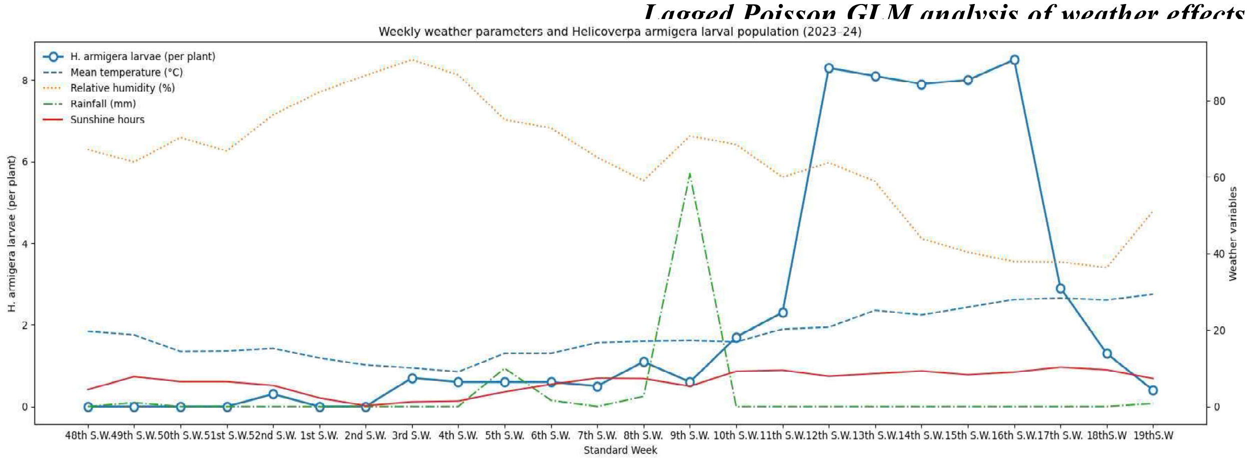

Fig. 1: Seasonal dynamics of *H. armigera* larval population (per plant) in relation to weekly weather parameters during *rabi* 2023–24.

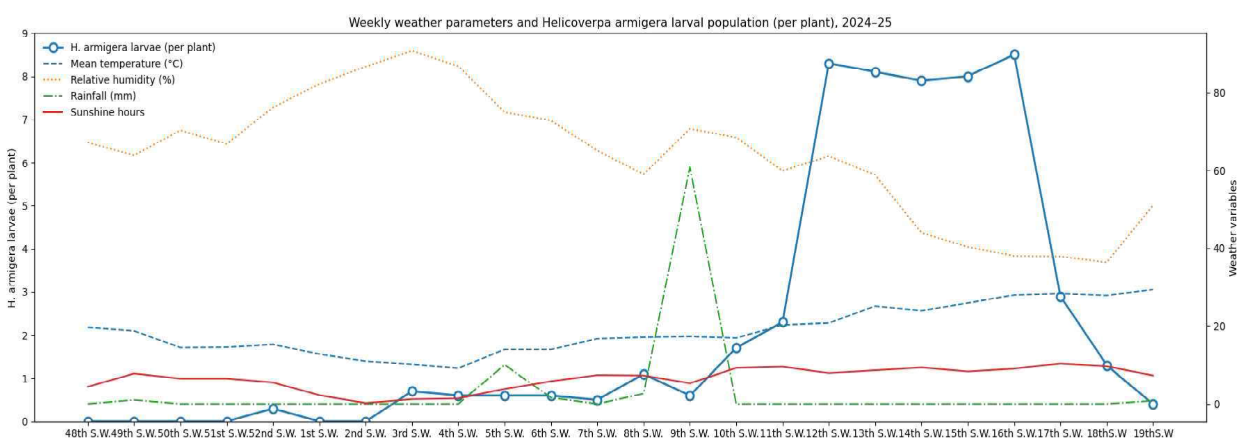

Fig. 2: Seasonal dynamics of *H. armigera* larval population (per plant) in relation to weekly weather parameters during rabi 2024–25

Table 3: Lagged Poisson GLM estimates for weather effects on *H. armigera* larval population

Season	Predictor	B estimate	Std err	z	P>|z|
2023-24	Temp_lag1	0.263	0.078	3.390	0.001
	Temp_lag2	-0.160	0.083	-1.923	0.054
	RH_lag1	0.029	0.029	0.994	0.320
	Rain_lag1	0.003	0.015	0.172	0.863
	Sun_lag1	0.247	0.123	2.014	0.044
2024-25	Temp_lag1	0.207	0.125	1.658	0.097
	Temp_lag2	-0.236	0.111	-2.139	0.032
	RH_lag1	0.011	0.033	0.316	0.752
	Rain_lag1	0.026	0.015	1.712	0.087
	Sun_lag1	0.797	0.208	3.840	0.001

on H. armigera larval population

To quantify the influence of antecedent weather variables on larval population dynamics, Poisson GLM analyses were performed using both same-week and lagged meteorological parameters. Lagged Poisson generalized linear model analysis revealed distinct seasonal patterns in the influence of antecedent weather variables on *H. armigera* larval population (Table 3). One and two-week lags were selected as they correspond to biologically relevant stages of oviposition, egg hatch and early larval development in *H. armigera*. During the 2023-24 season, mean temperature at one-week lag exerted a highly significant positive effect on larval abundance ($\beta = 0.263, p = 0.001$), indicating that a 1 °C increase in temperature during the preceding week resulted in an approximate 30% increase in expected larval density per plant. Sunshine hours at one-week lag also showed a significant positive association with larval abundance ($\beta = 0.247, p = 0.044$). Temperature at two-week lag exhibited a negative effect, which was marginally significant ($p = 0.054$), suggesting that delayed thermal conditions may exert a suppressive influence on larval population dynamics. Relative humidity and rainfall at one-week lag did not significantly affect larval abundance during this season ($p > 0.05$). Compared to same-week models, lagged models provided clearer and more biologically meaningful insights into the influence of antecedent weather conditions on larval abundance. Some models exhibited moderate overdispersion, which is common in ecological count data. However, coefficient estimates and inference were stable, and Poisson GLM was retained for interpretability. The results should therefore be interpreted in terms of relative effects rather than exact prediction.

In contrast, during the 2024-25 season, mean temperature at two-week lag showed a significant negative effect on larval population ($\beta = -0.236, p = 0.032$), implying reduced larval abundance following elevated temperatures two weeks earlier. Sunshine hours at one-week lag emerged as the strongest predictor of larval population, exerting a highly significant positive influence ($\beta = 0.797, p < 0.001$), corresponding to more than a two-fold increase in larval abundance per plant with each additional hour of sunshine. Temperature and rainfall at one-week lag showed positive but statistically non-significant trends ($p < 0.10$), while relative humidity did not exhibit a significant association with larval population. The seasonal trends observed in Figure 1 and 2 are consistent with the Poisson GLM results, which identified temperature and sunshine hours particularly at short time lags as key drivers of *H. armigera* larval population.

Overall, the lagged Poisson GLM results demonstrate that *H. armigera* larval abundance is strongly influenced by antecedent thermal and solar conditions, with the relative importance and timing of these effects varying between seasons. For some same-week and lagged models, dispersion values exceeded unity, indicating moderate overdispersion. However, as coefficient estimates and inference remained stable, Poisson GLM was retained and full model diagnostics are provided in the Supplementary Material Appendix I to IV. The findings of this study are in agreement partially with the study of and Singh *et al.* (2024); Srivastav *et al.* (2025) and Demirel and Akgul (2025) who reported a positive correlation with temperature and sunshine hours (Chitralekha *et al.* (2024). While some studies (Dharavath *et al.,* 2021; Devi *et al.,* 2024; Alok *et al.,* 2022) showed positive correlation with the sunshine hours but negative correlation with the temperature.

CONCLUSION

The present study demonstrated clear seasonal patterns in *H. armigera* larval population during the rabi seasons of 2023-24 and 2024-25, with larval incidence remaining low during early weeks and attaining peak levels during mid-season. Descriptive analysis and graphical trends indicated that favourable thermal and solar conditions were closely associated with larval population build-up, while periods of lower temperature and higher relative humidity were unfavourable for larval establishment. The timing and magnitude of peak infestation varied between seasons, reflecting inter-annual variability in weather conditions.

Lagged Poisson generalized linear model analysis revealed that antecedent weather variables played a decisive role in regulating larval abundance, with temperature and sunshine hours emerging as key drivers. Temperature at one-week lag significantly influenced larval population during 2023-24, whereas sunshine hours at one-week lag and temperature at two-week lag exerted stronger effects during 2024-25. These findings underscore the importance of incorporating lagged weather effects in pest population studies and highlight the potential of weather-based models for improving the timing of *H. armigera* management interventions during the rabi season. The validation of lagged poisson generalised linear model requires further study across different agro-climatic zones and multiple seasons. Future work should also aim to integrate the models with economic threshold levels and IPM components for timely and targeted interventions against *H. armigera*.

REFERENCES

Agricultural Statistics at a Glance (2022). Agricultural Statistics at a Glance 2023. New Delhi, Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India.

Alok, N. K., Singh, S. K. and Chandra, U. (2022). Population dynamics of gram pod borer, *Helicoverpa armigera* (Hübner) in relation to abiotic factors on chickpea. *Journal of Experimental Zoology India*, 25(1): 553-556.

Balraj, G., R. Prasad, D. L. Devi and Sandeep, K. (2025). Influence of abiotic factors on the population dynamics of gram pod borer (*Helicoverpa armigera*) in chickpea. *Plant Archives,* 25(1): 2675-2678.

Chen, W., Sharma, H.C. and Muehlbauer, F. J. (2011). Chickpea and Lentil Crop Protection Compendium. American Phytopathological Society, St Paul, Minnesota, USA. 165 p.

Chitralekha, Prince, Verma, T. and Mehta, A. K. (2024). Effect of abiotic factors and date of sowing on population dynamics of *Helicoverpa armigera* (Hübner) on Chickpea. *International Journal of Agricultural Invention*, 9(1): 16-20.

Demirel, N. and Akgül, M. G. (2025). Seasonal Population Trends and Environmental Influences on *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) in Soybean Fields of the Eastern Mediterranean Region of Türkiye. *Turkish Journal of Agriculture-Food Science and Technology*, 13(8): 2244-2250.

Devi, R., Chandra, U., Kumar, P., Singh, S. K. and Rajak, R. K. (2024). Population Dynamics of *Helicoverpa armigera* in Chickpea, (*Cicer arietinum* L.). *Journal of Advances in Biology & Biotechnology*, 27(5): 389-396.

Dharavath, N., Kharbade, S. B., Shaikh, A. A., Sthool, V. A. and Hasabnis, S. N. (2021). Population dynamics and forewarning models for prediction of population of *Helicoverpa armigera* under different sowing window and pigeonpea varieties. *Environment and Ecology,* 39(4): 775-790.

FAO. (2022). FAOSTAT Statistical Database. Published by FAO, Rome, Italy. https://

www.fao.org/faostat/en/#data/QCL

Hinde J. (1982). Compound Poisson regression models. *"In GLIM 82: Proceedings of the International Conference on Generalised Linear Models. Springer-Verlag New York Inc."* 109-121.

Huang, J. (2021). Effects of climate change on different geographical populations of the cotton bollworm *Helicoverpa armigera* (Lepidoptera, Noctuidae). *Ecology and Evolution*, 11(24): 18357-18368.

Iamba, K. (2022). Data analysis of flea beetle (*Psylliodes chrysocephala* L.): Comparing three (3) distribution families of generalized linear model. *Journal of Entomology and Zoology Studies*, 10(1): 388-394.

Jaba J, Devrani A, Agnihotri M and Chakravarty S. (2017). Screening of Chickpea Cultivars against Pod Borer *Helicoverpa armigera (*Hübner) Under Un Protected Conditions. *Journal of Experimental Zoology, India,* 20(2): 835-843.

Kavallieratos, N. G., Skourti, A., Nika, E. P. and Malesios, C. (2024). Development of the edible Tenebrio molitor at different temperatures: a Poisson log-linear regression modeling approach. *Biologia*, 79(7): 2059-2069.

Mugenyi, A., Muhanguzi, D., Hendrickx, G., Nicolas, G., Waiswa, C., Torr, S., Welburn, S.C. and Atkinson, P.M. (2021). Spatial analysis of Gf fuscipes abundance in Uganda using Poisson and Zero-Inflated Poisson regression models. *PLoS Neglected Tropical Diseases*, 15(12): e0009820.

Singh, A. K., Yadav, D. K., Gourav, B. K., Vishwakarma, A. and Dwivedi, P. (2024). Population Dynamics of Gram Pod Borer *Helicoverpa armigera* (Hubner). *Indian Journal of Entomology*, (e24867).

Golla, S. K. (2017). Biochemical and molecular mechanisms of resistance to *Helicoverpa armigera* (Hubner) in wild relatives of chickpea. Doctor of Philosophy. Sri Venkateswara Agricultural College, Tirupati Acharya N.G. Ranga Agricultural University. Andhra Pradesh, 245p.

Srivastav, V. K., Tripathi, A. and Dwivedi, A. C. (2025). Spatial and Seasonal Variation in Population Dynamics of Gram Pod Borer, *Helicoverpa armigera* (Hübner) Infestations on Chickpea in Tropical Climatic Condition, India. *Journal of Advanced Zoology*, 46(2): 19-23.

Yogeesh, K. J., Singh, A., Ranjitha, K. and Raghuraman, M. (2023). Prediction model for population dynamics of brown plant hoppers (*Nilaparvata lugens*) based on generalized linear models (GLM'S). *International Journal of Statistics and Applied Mathematics,* SP-8(6): 1370-1372.

Supplementary Material

Appendix I: POISSON GLM 2023-24

Generalized Linear Model Regression Results

Dep. Variable:	Larvae	No. Observations:	24.000
Model:	GLM	Df Residuals:	19.000
Model Family:	Poisson	Df Model:	4.000
Link Function:	Log	Scale:	1.000
Method:	IRLS	Log-Likelihood:	-46.474
Date:	Tue, 16 Nov 2025	Deviance:	48.775
Time:	16:04:06	Pearson chi2:	47.400
No. Iterations:	5.00	Pseudo R-squ. (CS):	0.820
Covariance Type:	Non-robust		

	coef	Std err	z	P>|z|	[0.025	0.975]
Intercept	-3.5369	2.925	-1.209	0.227	-9.27	2.196
Temp	0.0945	0.057	1.644	0.100	-0.018	0.207
RH	0.0082	0.025	0.332	0.740	-0.04	0.056
Rainfall	-0.0106	0.023	-0.452	0.651	-0.056	0.035
Sunshine	0.2482	0.12	2.061	0.039	0.012	0.484

Poisson dispersion statistic: 2.570

Appendix II: LAGGED POISSON GLM 2023-24

Generalized Linear Model Regression Results

Dep. Variable:	Larvae	No. Observations:	22.000
Model:	GLM	Df Residuals:	16.000
Model Family:	Poisson	Df Model:	5.000
Link Function:	Log	Scale:	1.000
Method:	IRLS	Log-Likelihood:	-43.651
Date:	Tue, 16 Nov 2025	Deviance:	43.131
Time:	16:04:13	Pearson chi2:	45.000
No. Iterations:	5.000	Pseudo R-squ. (CS):	0.8165
Covariance Type:	Non-robust		

	coef	Std err	z	P>|z|	[0.025	0.975]
Intercept	-4.930	3.269	-1.508	0.132	-11.338	1.478
Temp_lag1	0.263	0.078	3.390	0.001	0.111	0.415
Temp_lag2	-0.160	0.083	-1.923	0.054	-0.322	0.003
RH_lag1	0.029	0.029	0.994	0.320	-0.028	0.085
Rain_lag1	0.003	0.015	0.172	0.863	-0.026	0.031
Sun_lag1	0.247	0.123	2.014	0.044	0.007	0.487

Lagged Poisson dispersion statistic: 2.700

Appendix III: POISSON GLM 2024-25

Generalized Linear Model Regression Results

Dep. Variable:	Larvae	No. Observations:	24.000
Model:	GLM	Df Residuals:	19.000
Model Family:	Poisson	Df Model:	4.000
Link Function:	Log	Scale:	1.000
Method:	IRLS	Log-Likelihood:	-30.742
Date:	Tue, 16 Nov 2025	Deviance:	18.211
Time:	16:04:18	Pearson chi2:	22.100
No. Iterations:	6.000	Pseudo R-squ. (CS):	0.916
Covariance Type:	Non-robust		

	coef	Std err	z	P>|z|	[0.025	0.975]
Intercept	-9.451	3.481	-2.715	0.007	-16.274	-2.628
Temp	0.074	0.063	1.186	0.236	-0.048	0.197
RH	0.027	0.029	0.906	0.365	-0.031	0.084
Rainfall	0.022	0.011	1.984	0.047	0.000	0.044
Sunshine	0.802	0.177	4.538	0.001	0.456	1.149

Poisson dispersion statistic: 0.960

Appendix IV: LAGGED POISSON GLM 2024-25

Generalized Linear Model Regression Results

Dep. Variable:	Larvae	No. Observations:	22.000
Model:	GLM	Df Residuals:	16.000
Model Family:	Poisson	Df Model:	5.000
Link Function:	Log	Scale:	1.000
Method:	IRLS	Log-Likelihood:	-29.673
Date:	Tue, 16 Nov 2025	Deviance:	16.073
Time:	16:04:25	Pearson chi2:	16.600
No. Iterations:	6.000	Pseudo R-squ. (CS):	0.916
Covariance Type:	Non-robust		

	coef	Std err	z	P>|z|	[0.025	0.975]
intercept	-6.356	3.951	-1.609	0.108	-14.101	1.388
temp_lag1	0.207	0.125	1.658	0.097	-0.038	0.451
temp_lag2	-0.236	0.111	-2.139	0.032	-0.453	-0.020
RH_lag 1	0.011	0.033	0.316	0.752	-0.055	0.076
Rain_lag 1	0.026	0.015	1.712	0.087	-0.004	0.055
Sun_lag 1	0.797	0.208	3.840	0.000	0.390	1.204

Lagged Poisson dispersion statistic: 1.000

Received: December 17, 2025
Accepted: December 31, 2025