**Original Research Article**

**Weather-Driven Population Trends of *Helicoverpa armigera* (Hubner) in Chickpea Ecosystems**

**ABSTRACT**

Chickpea (*Cicer arietinum* L.) is a vital pulse crop widely cultivated in South Asia and the Mediterranean region. However, its production is severely impacted by the gram pod borer, *Helicoverpa armigera* (Hübner), a major pest causing substantial yield losses. The study investigates the seasonal incidence and population dynamics of *H. armigera* in chickpea fields during the Rabi seasons of 2022–23 and 2023–24 was conducted at the College of Agriculture, Sumerpur (Pali), India, with a focus on the influence of meteorological factors. The pest was first observed in the 46th Standard Meteorological Week (SMW) in both years, with peak infestations recorded in the 49th & 50th SMW and 8th SMW (February), coinciding with the flowering and podding stages of the crop. Regression analysis indicated that maximum temperature had a significant positive effect on larval population in 2022–23 (p = 0.003), while minimum temperature exerted a significant negative influence (p = 0.01). In 2023–24, relative humidity emerged as a significant factor (p = 0.01), whereas temperature effects were non-significant. Correlation analysis further suggested that fluctuations in temperature and humidity played a crucial role in pest dynamics. To model the population growth of *H. armigera*, Exponential and Gompertz regression models were evaluated using Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). The Exponential model demonstrated a superior fit across both years, with lower AIC and BIC values compared to the Gompertz model, suggesting its efficacy in predicting larval population trends. These findings underscore the necessity of integrating predictive models into pest management strategies to enable early detection and control.

***Key words:*** *Chickpea, Helicoverpa armigera, pest dynamics, seasonal incidence, climate factors, Gompertz model*

**1. INTRODUCTION**

Chickpea (*Cicer arietinum* L.), commonly known as Bengal gram, is a vital pulse crop cultivated extensively across South Asia, the Middle East, and the Mediterranean region. As a member of the Fabaceae family, chickpea is believed to have originated in Southwestern Asia (Singh *et al*. 1998). It holds significant global importance as the third most cultivated pulse crop after beans and peas (FAO 2022). India leads in chickpea production and consumption, contributing over 70% to the global supply (Nair *et al.* 2021). Chickpea serves as a rich source of plant-based protein (18–25%), carbohydrates (52–65%), dietary fiber, essential amino acids, minerals (such as calcium, phosphorus, and iron), and vitamins (Jukanti *et al*. 2012, Farooq *et al.* 2023). Additionally, the crop enhances soil fertility through its symbiotic association with *Rhizobium* bacteria, which aids in biological nitrogen fixation (Rubio-Tesoro *et al.* 2020).

Despite its nutritional and agronomic significance, chickpea production is constrained by various biotic and abiotic stress factors, with insect pest infestations being one of the most prominent challenges (Sharma 2014). Among the 150 insect pest species reported to attack chickpea, approximately 25 cause substantial economic damage in India alone (Bindra 1968, Ahmed *et al.* 2020). The gram pod borer, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae), is considered the most devastating pest due to its widespread occurrence and highly destructive feeding behaviour. This pest infests chickpea and other economically important crops such as cotton, pigeon pea, and tomato (Sharma 2005, Kaur *et al.* 2022). *H. armigera* damages chickpea from the seedling stage through pod development, causing pod losses ranging from 50 to 60 per cent, and in severe infestations, yield losses can exceed 80 per cent in untreated fields (Rao *et al.* 2021, Reddy *et al.* 2023). The insect’s polyphagous nature, high reproductive potential, facultative diapause, and increasing resistance to conventional insecticides make its management particularly challenging (Tay *et al.* 2013, Yang *et al.* 2020). Understanding the seasonal abundance and population dynamics of *H. armigera* in relation to climatic variables is essential for the development of effective pest management strategies (Rehman *et al.* 2022). Research has indicated that the population fluctuations of *H. armigera* are strongly influenced by environmental factors such as temperature, relative humidity, and rainfall (Shinde *et al.* 2013, Pandey *et al.* 2019). Generally, elevated temperatures and lower relative humidity have been associated with increased pest activity (Kumar *et al.* 2015, Malik *et al.* 2021). However, variations in infestation trends across different agro-climatic regions necessitate localized studies to accurately predict peak infestation periods and implement timely control measures (Choudhary *et al*. 2020). In this context, the present study aims to examine the seasonal incidence of *H. armigera* on chickpea and its correlation with key abiotic factors. The findings of this study will contribute valuable insights for optimizing integrated pest management (IPM) strategies to mitigate yield losses in chickpea cultivation, ensuring sustainable production and food security.

**2. MATERIALS AND METHODS**

The study on the seasonal abundance of *Helicoverpa armigera* in chickpea (*Cicer arietinum* L.) was conducted during the Rabi seasons of 2022–2023 and 2023–2024 at the research farm of College of Agriculture, Sumerpur (Pali), India. The chickpea variety CSJ-515 was sown on last week of October in four plots. Each experimental plot measured 4.0 × 2.4 m², maintaining a row-to-row spacing of 30 cm and a plant-to-plant spacing of 10 cm. Standard agronomic practices were followed for crop management, and no insecticides were applied to allow for natural pest infestation. To monitor the seasonal abundance of *H. armigera*, five plants per plot were randomly selected and tagged. Weekly observations of the larval population were recorded from the first appearance of larvae until crop harvest. The larvae were visually counted in situ during early morning hours when pest activity was highest. Weather parameters, including weekly maximum and minimum temperatures (°C) and relative humidity (%), were obtained from the meteorological observatory at KVK, Pali. The collected data were statistically analysed using R software. The larval population data were subjected to simple correlation analysis to determine the relationship between *H. armigera* infestation and key abiotic factors. Regression analysis was also performed to assess the impact of environmental variables on pest dynamics. The significance of correlations was tested at p < 0.05 and p < 0.01 levels. Additionally, time-series analysis and regression modelling were applied to predict pest outbreaks based on historical trends and meteorological variables. The generalized linear model (GLM) and stepwise multiple regression were used to identify the most influential abiotic factors affecting larval population fluctuations.

**3. RESULTS AND DISCUSSION**

**3.1 Seasonal incidence of *H. armigera* in Chickpea (2022-23)**

The seasonal incidence of *H. armigera* in chickpea during 2022-23 (Table 1 & Fig. 1) revealed that the pest first appeared on the tender leaves of chickpea plants in the 46th Standard Meteorological Week (SMW) with a mean larval population of 0.50 per plant. The early instars of *H. armigera* larvae were observed feeding on the succulent leaves of the plant. The population increased gradually, reaching an initial peak (1.45 larvae per plant) in the 49th SMW (first week of December), when the maximum and minimum temperatures were 27.9°C and 8.1°C, respectively, with a relative humidity of 42.0 per cent. A temporary decline in population was observed from the 50th SMW onward, but the pest reappeared in the 4th SMW (last week of January) at 0.60 larvae per plant.

The pest population gradually increased after 4th SMW (last week of January), when the crop was at the 50 per cent flowering stage, and its population gradually increased until the podding stage, persisting up to harvest. A subsequent peak infestation was recorded in the 8th SMW (last week of February), reaching 1.50 larvae per plant when the maximum and minimum temperatures were 35.4°C and 15.2°C, respectively, with a relative humidity of 18.1 per cent. This peak population, comprising both early and late larval instars, was observed damaging buds, flowers, and leaves. Thereafter, a declining trend in larval population was recorded, and by the 12th SMW (second week of March), pest activity ceased as the seeds became hard and unsuitable for larval feeding.

**Table 1 : Seasonal incidence of *H. armigera* (Hub.) larvae in chickpea crop during 2022-23.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SMW** | **Mean Larval Population per Plants** | **Maximum Temperature (°C)** | **Minimum Temperature (°C)** | **Relative Humidity (%)** |
| 46 | **0.50** | 31.6 | 12.3 | 32.6 |
| 47 | **1.00** | 30.4 | 9.3 | 28.1 |
| 48 | **1.30** | 30.7 | 7.4 | 29.9 |
| 49 | **1.45** | 27.9 | 8.1 | 42.0 |
| 50 | **1.30** | 28.9 | 10.9 | 31.7 |
| 51 | **0.65** | 27.9 | 7.6 | 33.7 |
| 52 | **0.55** | 24.6 | 7.1 | 37.6 |
| 1 | **0.50** | 24.1 | 6.6 | 25.0 |
| 2 | **0.30** | 26.0 | 10.0 | 33.4 |
| 3 | **0.50** | 23.4 | 6.3 | 22.3 |
| 4 | **0.60** | 22.4 | 7.8 | 37.4 |
| 5 | **0.75** | 24.7 | 11.9 | 45.2 |
| 6 | **0.80** | 30.0 | 12.4 | 21.1 |
| 7 | **0.90** | 32.2 | 11.1 | 12.9 |
| 8 | **1.50** | 35.4 | 15.2 | 18.1 |
| 9 | **1.05** | 35.2 | 18.1 | 19.7 |
| 10 | **0.95** | 34.1 | 18.5 | 26.0 |
| 11 | **0.65** | 34.7 | 18.5 | 27.3 |
| 12 | **0.30** | 31.6 | 19.7 | 29.1 |
| **Correlation coefficient with Mean Larval Population (r)** | 0.428 | 0.035 | -0.130 |

Correlation analysis indicated that the infestation exhibited a positive but non-significant correlation with maximum temperature (r = 0.428), minimum temperature (r = 0.035), and a negative correlation with relative humidity (r = -0.130). The regression analysis (Table 3) indicated that the intercept was -1.89 (SE = 0.91, p = 0.05), which was statistically non-significant. Maximum temperature had a significant positive effect on the mean larval population, with a coefficient of 0.10 (SE = 0.03, p = 0.003), suggesting that a one-unit increase in maximum temperature leads to a 0.10 unit increase in larval population. Conversely, minimum temperature exhibited a significant negative effect, with a coefficient of -0.06 (SE = 0.02, p = 0.01), indicating that higher minimum temperatures reduce the larval population. Relative humidity had a positive but non-significant effect on larval population, with a coefficient of 0.01 (SE = 0.01, p = 0.25), suggesting that changes in relative humidity may have a limited impact. These findings align with Patel *et al.* (2021) and Yadav *et al*. (2020), who reported a significant role of minimum temperature in influencing *H. armigera* larval survival, with a peak infestation coinciding with pod formation. Similarly, Singh *et al*. (2022) and Reddy *et al.* (2021) documented that *H. armigera* population buildup is positively correlated with minimum temperature and negatively with relative humidity, which supports the observed trends in the present study.

**3.2 Seasonal incidence of *H. armigera* in Chickpea (2023-24)**

For the 2023-24 season (Table 2 & Fig. 2), *H. armigera* first appeared in the 46th SMW, with a mean larval population of 0.60 per plant. The population gradually increased, peaking at 1.50 larvae per plant in the 49th SMW, when the maximum and minimum temperatures were 25.7°C and 13.8°C, respectively, with a relative humidity of 44.7 per cent. Unlike the previous year, the pest incidence remained relatively stable during the early weeks of infestation.

The highest peak infestation of 1.65 larvae per plant occurred in the 8th SMW (third week of February), when the maximum and minimum temperatures were 29.9°C and 17.1°C, respectively, with a relative humidity of 33.9 per cent. The population then declined, and by the 12th SMW, the pest disappeared completely. Correlation analysis showed that maximum temperature had a non-significant negative correlation (r = -0.014), whereas relative humidity (r = 0.525) and minimum temperature (0.176) had a non-significant positive correlation. The regression analysis (Table 3) revealed that the intercept was -0.66 (SE = 1.29, p = 0.62), indicating a statistically non-significant effect. Minimum temperature exhibited a non-significant positive relationship with the mean larval population, with a coefficient of 0.05 (SE = 0.04, p = 0.021), suggesting that a one-unit increase in minimum temperature results in a 0.05-unit rise in larval population. In contrast, maximum temperature had a negative but non-significant effect, with a coefficient of -0.01 (SE = 0.05, p = 0.81), implying that higher maximum temperatures may reduce larval population. Relative humidity showed a significant positive effect, with a coefficient of 0.03 (SE = 0.01, p = 0.01), indicating that increased relative humidity contributes to a rise in larval population. These results are in agreement with Kumar *et al*. (2021), Malik *et al*. (2023), and Pandey *et al.* (2022), who found that *H. armigera* infestation in chickpea varied with seasonal temperature fluctuations, with increased pest activity observed in warmer and drier conditions.

The results of this study on the seasonal incidence of *H. armigera* in chickpea during 2022-23 and 2023-24 demonstrate a clear influence of meteorological factors on pest dynamics. The appearance of *H. armigera* in the 46th SMW, with peaks in the 49-50th SMW (December) and 8th SMW (February), is consistent with previous research. These findings closely align with those of Patel *et al.* (2021) and Yadav *et al.* (2020), who reported peak infestation in chickpea fields in February, coinciding with pod formation. Further, Kumar *et al*. (2021) and Malik *et al*. (2023) emphasized that *H. armigera* incidence increases significantly when minimum temperatures range between 13°C and 17°C, matching the conditions recorded during the peak infestation weeks in this study. Moreover, Sharma *et al.* (2022) and Verma *et al*. (2023) provided evidence that fluctuating temperatures contribute to the emergence of multiple infestation peaks, particularly in warmer and drier conditions. The presence of two distinct infestation peaks in both cropping seasons aligns with the observations of Mehta *et al.* (2022) and Kumar *et al.* (2023), who reported a bimodal pattern of *H. armigera* incidence under variable temperature and humidity conditions.

**Table 2 : Seasonal incidence of *H. armigera* (Hub.) larvae in chickpea crop during 2023-24**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SMW** | **Mean Larval Population per Plants** | **Maximum Temperature (°C)** | **Minimum Temperature (°C)** | **Relative Humidity (%)** |
| 46 | **0.60** | 30.0 | 13.9 | 32.7 |
| 47 | **1.10** | 30.2 | 12.9 | 46.9 |
| 48 | **1.40** | 27.2 | 16.0 | 50.1 |
| 49 | **1.50** | 25.7 | 13.8 | 44.7 |
| 50 | **1.60** | 27.2 | 10.5 | 49.1 |
| 51 | **0.70** | 27.2 | 10.7 | 45.1 |
| 52 | **0.65** | 27.6 | 13.3 | 38.6 |
| 1 | **0.55** | 23.1 | 9.1 | 41.4 |
| 2 | **0.25** | 24.2 | 8.9 | 33.7 |
| 3 | **0.45** | 25.9 | 10.1 | 31.4 |
| 4 | **0.65** | 26.3 | 10.7 | 32.0 |
| 5 | **0.90** | 27.7 | 17.3 | 48.0 |
| 6 | **0.95** | 25.6 | 14.5 | 36.1 |
| 7 | **1.00** | 28.2 | 14.1 | 31.1 |
| 8 | **1.65** | 29.9 | 17.1 | 33.9 |
| 9 | **1.15** | 29.0 | 17.6 | 39.9 |
| 10 | **1.00** | 29.2 | 15.7 | 28.4 |
| 11 | **0.60** | 32.7 | 18.7 | 23.7 |
| 12 | **0.40** | 35.8 | 22.0 | 23.7 |
| **Correlation coefficient with Mean Larval Population (r)** | -0.014 | 0.176 | 0.525 |

**Table 3: Regression analysis of environmental factors influencing larval population (2022–23 and 2023–24)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Estimate** | **Std. Error** | **p- value** |
| **2022-23** | **2023-24** | **2022-23** | **2023-24** | **2022-23** | **2023-24** |
| **Intercept**  | -1.89181 | -0.65900 | 0.91325 | 1.29459 | 0.05597 | 0.6181 |
| **Max. Temp.** | 0.10727 | -0.01268 | 0.03090 | 0.05116 | 0.00342 \*\* | 0.8076 |
| **Mini. Temp.** | -0.06782 | 0.05267 | 0.02553 | 0.03982 | 0.01797 \* | 0.2058 |
| **R.H.** | 0.01213 | 0.03141 | 0.01036 | 0.01123 | 0.25983 | 0.0136 \* |

Significant codes: ‘\*\*’ 0.01 ‘\*’ 0.05

**3.3 Model performance and implications for *H. armigera* larval population dynamics**

The Exponential and Gompertz regression models (Table 4) were evaluated to analyse the population dynamics of the larval population in relation to SMW across two study years. The Exponential model consistently demonstrated a better fit compared to the Gompertz model, as indicated by lower Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values. In 2022–23, the Exponential model had an AIC of 20.59 and a BIC of 23.42, whereas the Gompertz model exhibited higher values (AIC = 22.46, BIC = 26.25). A similar trend was observed in 2023–24, where the Exponential model maintained a lower AIC (25.06) and BIC (27.89) compared to the Gompertz model (AIC = 26.93, BIC = 30.71).

**Table 4 Exponential and Gompertz model for larval population**

|  |  |  |
| --- | --- | --- |
| **Evaluation criteria** | **Exponential Model** | **Gompertz Model** |
| **2022-23** | **2023-24** | **2022-23** | **2023-24** |
| **AIC** | 20.59057 | 25.06389 | 22.46800 | 26.93241 |
| **BIC** | 23.42389 | 27.89721 | 26.24576 | 30.71016 |

These findings suggest that the Exponential model more accurately captures the relationship between larval population and SMW across both study periods (Fig. 3 & 4). The observed variations in population dynamics between years may be attributed to fluctuations in temperature and relative humidity, which play a crucial role in larval survival and development. The superiority of the Exponential model in predicting population trends aligns with the findings of Singh *et al.* (2023), Sharma *et al.* (2022), and Patel *et al.* (2023), who demonstrated the effectiveness of population growth models in forecasting pest infestations under varying climatic conditions.

This study highlights the importance of integrating predictive models with pest management strategies to enhance early warning systems and optimize control measures. Consistent with the recommendations of Sharma *et al.* (2023), Kumar *et al.* (2023), and Mehta *et al.* (2022), the results emphasize the need to incorporate climatic variables such as temperature and humidity into pest forecasting models, particularly in chickpea agroecosystems.

**Fig. 3 Comparison of Exponential and Gompertz models for larval population dynamics across SMW during 2022-23**

**Fig. 4 Comparison of Exponential and Gompertz models for larval population dynamics across SMW during 2023-24**

**4. CONCLUSION**

This study examines the seasonal incidence and population dynamics of *H. armigera* in chickpea over two cropping seasons (2022–23 and 2023–24), emphasizing the role of meteorological factors. The pest exhibited a bimodal infestation pattern, peaking in December (49th –50th SMW) and February (8th SMW), coinciding with key crop growth stages. Regression analysis identified minimum temperature as a significant factor influencing larval population, while relative humidity and maximum temperature showed variable effects. Comparative modelling demonstrated that the Exponential model provided a better fit than the Gompertz model, accurately reflecting larval population trends. These findings highlight the importance of integrating weather-based forecasting into pest management strategies. Incorporating predictive models into IPM programs can enhance early warning systems and optimize control measures. Future research should refine predictive models by incorporating additional climatic and ecological variables to improve forecasting accuracy.

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