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Insights into the population dynamics of *Helicoverpa armigera*: A three-year study using light traps and weather correlations

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Abstract

The study focused on monitoring the population dynamics of *Helicoverpa armigera* (Hubner), a significant agricultural pest, over a span of three years (2021-2023) using light traps. These traps, illuminated with white light, operated from 6:00 PM to 6:00 AM during the months of January to June. The research consistently revealed that the peak moth captures occurred during the 14th week of April in all three years. Furthermore, an intriguing relationship was established between the moth population in the light traps and the larval population of *H. armigera* in tomato fields. The study found a positive correlation, suggesting that an increase in moths captured in the light traps corresponded to higher larval counts in the tomato fields. The observed connection was partially attributed to prevailing weather conditions. Specifically, temperatures during the second half of February to the second half of April were found to favor the maximum buildup of both moth and larval populations. These findings underscore the significance of weather patterns in understanding and managing the population dynamics of *H. armigera*, which can be crucial for pest control and crop protection strategies.

Keywords: Fruit borer, *Helicoverpa armigera*, insect pest, light trap.

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Introduction

Helicoverpa armigera (Hubner, 1805), a member of the Lepidoptera family Noctuidae, is a notorious agricultural pest with a broad range of host plants, earning it the reputation of being highly polyphagous. This pest's status as a significant threat to various crops, including the economically important tomato (*Lycopersicon esculentum* Mill.), is primarily attributed to several key factors that define its impact on agricultural ecosystems. One of the primary drivers of its pest status is its remarkable mobility. *H. armigera* exhibits the capacity to disperse over large distances, making it a formidable adversary for farmers and agricultural systems. This capacity for long-distance migration enables the pest to colonize new regions and exploit a wide array of host plants, a trait that contributes significantly to its adaptability and pest status.

Helicoverpa armigera (Hubner, 1805), known as the fruit borer, is an agricultural pest with a strong affinity for a wide range of host plants. Its notoriety as a primary menace to crops, including the vital tomato (*Lycopersicon esculentum* Mill.), can be attributed to several key characteristics, such as its remarkable mobility, capacity to feed on numerous plant species (polyphagy), a prolific reproductive rate, and the ability to enter diapause. In the Asian region, the fruit borer inflicts extensive damage on tomato crops. For instance, historical reports indicate substantial losses, with Srinivasan (1959) noting that this pest damaged 40 to 50% of fruits in Tamil Nadu, while Singh and Singh (1975) reported losses of approximately 30% in Punjab. In western Uttar Pradesh, it has emerged as a particularly severe threat to tomatoes, causing 36.2 to 39.1% fruit damage (Kumar and Ramkishore, 2005). This pest's impact is not limited to the fruit alone; it utilizes all parts of the plant as sources of sustenance, shelter, and breeding sites. In addition to physical damage caused by feeding, insects like *H. armigera* can also contribute to reduced plant growth or even plant death. Moreover, they can vector diseases, including viruses and mycoplasma, further compounding their threat to crops. One of the challenges in managing *H. armigera* is its development of resistance to various insecticides, making traditional control methods less effective. Given the significant fruit losses attributed to this pest, there is an evident need to develop more suitable pest management strategies. With this objective in mind, a study was conducted to investigate the population dynamics of *H. armigera* over three consecutive years (2021, 2022, and 2023) using light traps. The study aimed to establish a relationship between moth captures in the light trap and the larval population in the field. The light trap proved to be an efficient tool for monitoring population trends, with the ultimate goal of developing predictive methods for managing this persistent agricultural pest.

Polyphagy is another key feature of *H. armigera*. This pest is not limited to a single crop or plant species; rather, it exhibits a remarkable ability to infest and damage a wide range of host plants, encompassing various crops of economic importance. Its diverse diet includes cotton, maize, soybeans, and, notably, the tomato, making it a threat to the global agricultural industry. The high reproductive rate of *H. armigera* is yet another factor that accentuates its impact. This pest can reproduce rapidly, with female moths laying a substantial number of eggs, which quickly develop into voracious larvae. This reproductive capacity can lead to swift population growth, exacerbating the challenges faced by farmers attempting to manage its presence.

Additionally, *H. armigera* is known to enter a state of diapause, allowing it to survive adverse environmental conditions, such as unfavorable weather or food scarcity. The diapause strategy enhances its ability to persist and return when conditions become more favorable for feeding and reproduction. Understanding the biology, behavior, and ecological adaptations of this highly polyphagous agricultural pest is crucial for developing effective pest management strategies. With its mobility, diverse diet, high reproductive rate, and survival mechanisms like diapause, *Helicoverpa armigera* poses a complex challenge to agriculture and underscores the importance of comprehensive research and integrated pest management approaches to mitigate its impact.*Helicoverpa armigera*, commonly known as the cotton bollworm or the corn earworm, is a highly polyphagous pest in the realm of agriculture. Its polyphagy refers to its ability to feed on and infest a wide variety of host plants, making it one of the most versatile and damaging agricultural pests worldwide. This pest poses a significant threat to numerous crops, impacting both food and cash crops.

Broad Range of Host Plants: *H. armigera* is known to attack and feed on a vast range of host plants from various plant families. Its host range includes crops like cotton, maize, tomato, soybean, sorghum, chickpeas, and various vegetables. This adaptability to different plant species contributes to its success as a pest. The adult moths of *H. armigera* are highly mobile and can fly long distances. This mobility allows them to move between fields and regions, further spreading the infestation to different crops.

H. armigera exhibits a prolific reproductive rate. A single female moth can lay a large number of eggs, and the development cycle from egg to adult is relatively short. This rapid reproduction can lead to explosive population growth under favorable conditions. Diapause is a state of dormancy that allows the pest to survive adverse environmental conditions, such as winter or dry periods. *H. armigera* has the ability to enter diapause, which enhances its survival and population persistence. *H. armigera* is found in various regions across the world, including Asia, Africa, Europe, and the Americas. It thrives in diverse climates and habitats, making it a cosmopolitan pest. The polyphagous nature of *H. armigera* poses substantial challenges to agriculture. It can cause significant economic losses by damaging crops, reducing yields, and affecting the quality of harvested produce. Additionally, managing this pest can be complex due to its adaptability and the development of resistance to chemical pesticides.

Effective pest management strategies for *H. armigera* often require a holistic approach that includes integrated pest management (IPM) practices. These strategies may involve the use of resistant crop varieties, biological control methods, cultural practices, and judicious pesticide application. Understanding the polyphagous behavior of this pest is essential for developing sustainable and effective methods to mitigate its impact on agriculture.

Materials and Methods

A light trap was positioned in the field, set at a height of one meter above the ground. It was in operation daily from 6:00 PM to 6:00 AM throughout the months of January to June in the years 2021, 2022, and 2023. The trap featured a funnel-shaped structure extending downwards, culminating in a catch box. The entire apparatus was supported by four iron legs. Within the trap, a 20-watt white light source was employed. The tally of moths captured was conducted every other day, and the data was then aggregated to determine the weekly count of trapped moths. Simultaneously, the incidence of larvae in the field was monitored on a weekly basis. This entailed observing 50 randomly selected tagged plants positioned at various locations within the field. The objective was to establish correlations between the number of moths captured and the larval population while considering the influence of weather-related factors. Multiple regression coefficients were computed to gain insights into the cumulative impact of weather conditions on the proliferation of both stages of this pest.

Light Trap for Catching Adult Moths

Moths trapped in the light trap

Infesting stages of *Helicoverpa armigera in* Tomato field

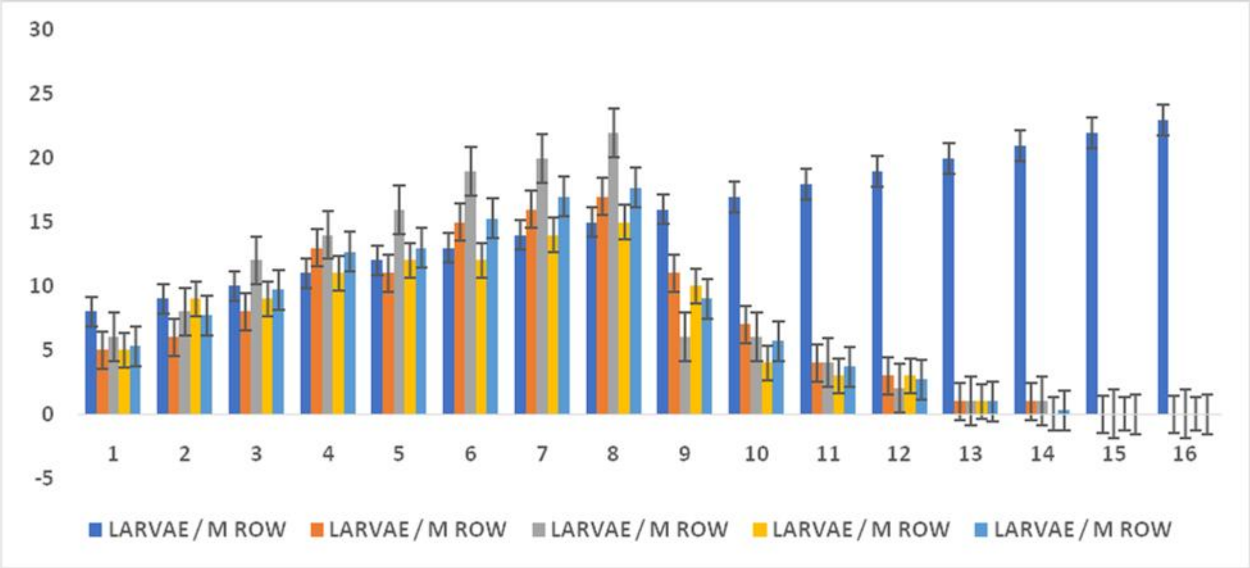
Results and Discussions

The analysis of the larval population during the study period (as presented in Table 1) revealed a consistent trend across the three years. Although the population buildup was similar in all years, it was notably higher in 2022 compared to 2021 and 2023.

Table: 1 Population build-up of *Helicoverpa armigera* (Hubner) larvae on tomatoes

	Larvae / M row			
Standard week	**2021**	**2022**	**2023**	**Average**
1	0	0	0	0.0
2	1	1	1	0.6
3	2	1	1	1.0
4	1	1	1	1.0
4	1	3	2	2.0
6	3	4	3	4.0
7	5	5	4	4.0.
8	5	6	5	5.3
9	6	8	9	7.7
10	8	12	9	9.7
11	13	14	11	12.7
12	11	16	12	13.0
13	15	19	12	15.3
14	16	20	14	17.0
15	17	22	15	17.7
16	11	6	10	9.0
17	7	6	4	5.7
18	4	4	3	3.7
19	3	2	3	2.7
20	1	1	1	1.0
21	1	1	0	0.3
22	0	0	0	0.0
23	0	0	0	0.0

Figure: 1 Population build-up of *Helicoverpa armigera* (Hubner) larvae on tomatoes

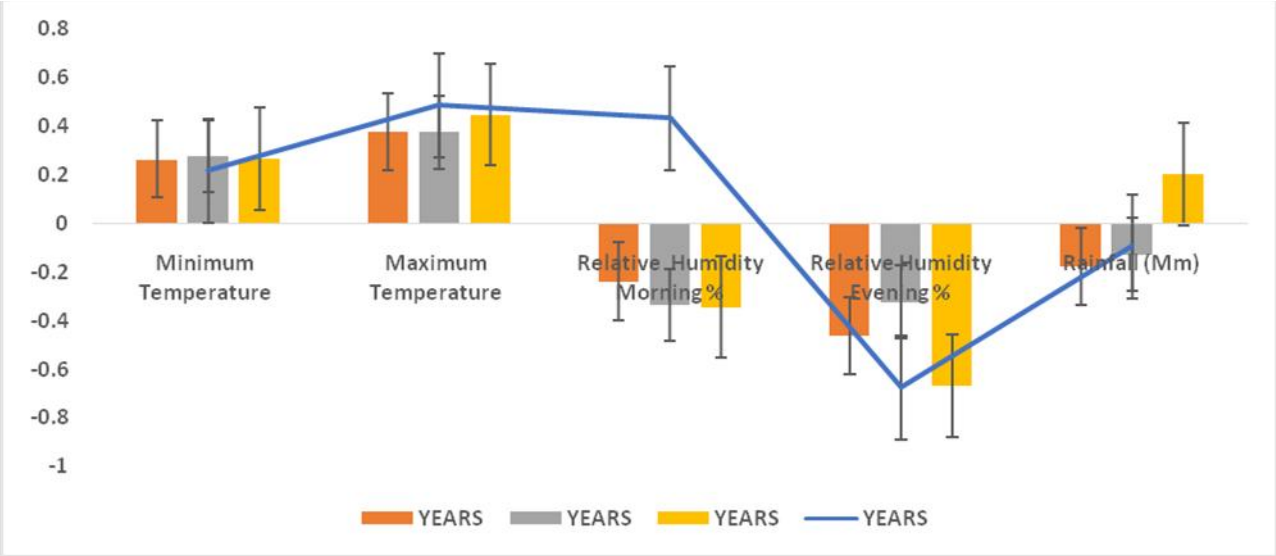


The larvae of *Helicoverpa armigera* were first observed on tomato crops during the 2nd standard week of January, with their numbers remaining relatively low up to the 8th week of February. During this period, the larval population ranged from 1 to 5 larvae per meter of row in 2021, 1 to 6 larvae per meter of row in 2022, and 1 to 5 larvae per meter of row in 2023. Subsequently, the larval population increased and reached its peak during the 15th standard week of April. At its peak, the numbers of larvae recorded were 17, 22, and 15 larvae per meter of row in 2021, 2022, and 2023, respectively. Following this peak, the larval population gradually declined, reaching just 1 larva per meter of row in the 21st standard week of May, leading to the eventual disappearance of the larvae from the tomato crops during the 22nd standard week of May.

Table: 2 Effect of weather factors

Weather Factors	Years			
	2021	2022	2023	Average
Minimum Temperature ^{0}C	0.215	0.264	0.277	0.267
Maximum Temperature ^{0}C	0.487	0.376	0.376	0.448
Relative Humidity Morning %	0.434	-0.238	-0.335	-0.345
Relative Humidity Evening %	-0.675	-0.464	-0.324	-0.668
Rainfall (Mm)	-0.096	-0.175	-0.127	0.203

Figure: 2 Effect of weather factors



The low number of larvae observed during January and February can be attributed to factors such as limited fruit availability during this period and the adverse impact of low temperatures on larval survival. Research by Vaishampayan and Veda (1980) supports the notion that pest activity is hampered below 8°C. On the other hand, Chaudhari et al. (1999) found that higher temperatures, which are typical during May, can also inhibit pest activity.

The rapid increase in larval numbers during April can be attributed to the combination of maximum fruiting and favorable weather conditions that promote swift larval development. This observation aligns with findings by Bhatnagar et al. (1998) and Srivastava et al. (2003), which reported increased pest activity in early April. Subsequently, the decline in larval population from the 16th standard week (April) onwards can be attributed to the crop progressing towards maturity and the adverse effects of rising temperatures on larval development.

Weather factors played a pivotal role in this pest's development, as evident from Table 2. The larvae appeared on the tomato crop during the 2nd standard week (January) and remained at low numbers until the 3rd standard week (February). A subsequent increase occurred over the next six standard weeks (from the 9th to the 15th standard week). Low rainfall (1.5 mm, 6.5 mm, and 9.9 mm) combined with an average maximum temperature of 34.8°C, 32.3°C, and 31.8°C, and minimum temperatures of 17.6°C, 17.2°C, and 18.8°C, as well as morning relative humidity at 71.8%, 80.4%, and 70.5%, and evening relative humidity at 30.0%, 27.8%, and 32.4% in 2021, 2022, and 2023 respectively, provided conducive conditions for larval development during this period. Conversely, the larval population started to decline from the 16th standard week (April) due to higher rainfall (177.1 mm, 20.0 mm, and 87.7 mm) and increased maximum temperatures (36.6°C, 42.1°C, and 36.2°C), along with reduced morning relative humidity (48.0%, 48.1%, and 58.5%) and evening relative humidity (29.1%, 24.2%, and 25.0%) prevailing from the 16th standard week (April) to the 22nd standard week (May) in 2021, 2022, and 2023, which created adverse conditions for larval development and led to a reduction in the larval population in subsequent weeks, ultimately resulting in the larvae disappearing from the tomato crop in the 22nd week (May).

Correlations were examined between larval population and weather factors prevalent during the study period in different years, revealing positive correlations for maximum temperature (r = 0.87, 0.376, and 0.376) and minimum temperature (r = 0.215, 0.265, and 0.277). However, the correlations were not statistically significant for minimum temperature. Morning relative humidity (r = -0.434, -0.238, and -0.335) and evening relative humidity (r = -0.675, -0.464, and -0.324) displayed negative correlations in 2021, 2022, and 2023, with the correlation being significant in 2021 and 2022 for evening relative humidity. Rainfall had no significant impact on the buildup of the larval population (r = -0.096, -0.175, and -0.127).

This study indicates that the pest initiated activity during the 2nd standard week of January and continued until the 21st standard week of May. Throughout this period, the larval population ranged from 1 to 17 larvae per meter of row in 2021, 1 to 22 larvae in 2022, and 1 to 15 larvae per meter of row in 2023. Weather factors, including atmospheric temperature, relative humidity, and rainfall, played a critical role in influencing the pest's population. Specifically, maximum mean temperature of 32.9°C, minimum temperature of 17.9°C, morning humidity of 74.2%, evening humidity of 30.1%, and 6.0 mm of rainfall during the 10th standard week (February) to the 15th standard week (April) provided favorable conditions for larval development, resulting in peak larval populations of 17, 22, and 15 larvae per meter of row in 2021, 2022, and 2023, respectively. However, weather conditions above or below the optimal range were detrimental to larval development, as previously observed by Vaishampayan and Veda (1980). They reported that pest activity is slowed when temperatures fall below 8°C. Similarly, Chaudhari et al. (1999) found that average temperatures exceeding 37°C during the summer and intense rainfall during the monsoon months can inhibit insect growth and development. Mehto et al. (1985) also noted that the pest continued to build up at a minimum temperature of 15°C±3°C, supporting the findings of this study.

Conclusion

In summary, the study provided valuable insights into the population dynamics of *Helicoverpa armigera* (Hubner) and its relationship with weather factors. Over the course of three years (2021, 2022, and 2023), a consistent trend in larval population buildup was observed. While the overall patterns were similar, the year 2022 stood out with a notably higher larval population. The study revealed that the presence of *H. armigera* larvae in tomato crops typically began in the 2nd standard week of January, and their numbers remained relatively low until the 8th week of February. During this initial period, larval populations ranged from 1 to 5 larvae per meter of row in 2021, 1 to 6 larvae per meter of row in 2022, and 1 to 5 larvae per meter of row in 2023. Subsequently, the larval population increased steadily and reached its peak during the 15th standard week of April. At its peak, the recorded numbers of larvae were 17, 22, and 15 per meter of row in 2021, 2022, and 2023, respectively. Following this peak, the larval population gradually declined, ultimately dwindling to just 1 larva per meter of the row in the 21st standard week of May, at which point the larvae disappeared from the tomato crops in the 22nd standard week of May.

The lower larval numbers observed during January and February were attributed to factors such as limited fruit availability during this period and the negative impact of low temperatures on larval survival. Notably, the pest's activity is known to be hampered at temperatures below 8°C, as supported by research conducted by Vaishampayan and Veda (1980). Conversely, the study indicated that excessively high temperatures, which are typical in May, can also inhibit pest activity, aligning with findings by Chaudhari et al. (1999).

The substantial increase in larval numbers during April was attributed to a combination of factors, including increased fruiting and favorable weather conditions that facilitated rapid larval development. This observation is consistent with earlier research by Bhatnagar et al. (1998) and Srivastava et al. (2003), which reported heightened pest activity in early April. Subsequently, the decline in larval population from the 16th standard week (April) onward was linked to the crop maturing and the adverse effects of rising temperatures on larval development. Weather factors played a pivotal role in influencing the pest's development. During the early weeks of the year, low rainfall, along with average maximum and minimum temperatures, created conducive conditions for larval development. However, starting from the 16th standard week (April), increased rainfall and higher maximum temperatures, coupled with a decrease in humidity, created unfavorable conditions for larval development, leading to a reduction in their population in the following weeks.

The study established correlations between larval populations and various weather factors, revealing positive correlations with maximum and minimum temperatures. However, these correlations were not statistically significant for minimum temperature. Morning and evening relative humidity showed negative correlations, with some significant results for evening humidity in 2021 and 2022. Interestingly, rainfall did not appear to have a significant impact on larval population buildup.

In conclusion, this study provides critical insights into the population dynamics of *Helicoverpa armigera* and its sensitivity to weather conditions. These findings are valuable for understanding and managing this pest in agricultural settings, with implications for pest control and crop protection strategies.

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