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Seasonal incidence and bio-ecology of fall armyworm on maize in tropical lowlands

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Abstract
Since its first detection in India in 2018, the fall armyworm (*Spodoptera frugiperda* J.E. Smith) has established itself as a persistent threat to maize cultivation across the country, but its seasonal population dynamics in the humid subtropical lowlands of northeast India have not been characterized. This research recorded the monthly incidence, life table parameters, and natural enemy activity of fall armyworm on maize at the Instructional-cum-Research Farm of Assam Agricultural University, Jorhat, during the kharif seasons of 2022 and 2023. Larval populations peaked in August at 22.6 per 10 plants, coinciding with maximum temperature (28.8 °C) and relative humidity (91.3%). Egg mass density peaked one month earlier in July at 8.4 per 10 plants. The total developmental period from egg to adult averaged 41.0 ± 3.8 days under field conditions. Larval parasitism by Cotesia marginiventris and Chelonus insularis reached 16.8% at peak season. Fecundity averaged 846 eggs per female. Multiple regression showed that temperature and relative humidity together explained 78.4% of the variation in larval population. These baseline bio-ecological data provide the foundation for developing locally calibrated forecasting models and IPM schedules for fall armyworm in northeastern India.

Keywords: Fall armyworm, *Spodoptera frugiperda*, seasonal incidence, maize, bio-ecology, invasive pest, life table, natural enemies, population dynamics, northeast India

Introduction
When fall armyworm was first spotted in Karnataka in May 2018, entomologists across India quickly realized they were dealing with an invasive pest unlike anything local maize growers had faced before. Native to the tropical Americas, *S. frugiperda* has a combination of traits that makes it exceptionally difficult to manage: high fecundity, strong migratory flight capacity, polyphagous feeding habits spanning over 350 plant species, and pre-existing resistance to several insecticide classes [1, 2]. Within two years of its arrival, the pest had spread to every maize-growing state in India [3].

Northeast India grows about 0.9 million hectares of maize, much of it under rainfed conditions during the kharif season [4]. The warm, humid climate of the Brahmaputra valley is highly conducive to rapid fall armyworm multiplication, but systematic data on its seasonal abundance patterns and bio-ecology under these specific conditions are lacking. Understanding when populations build up, how long each life stage lasts under local temperatures, and which natural enemies are active is essential for timing management interventions effectively [5]. This research documented the seasonal incidence and constructed life tables for fall armyworm on maize in the Jorhat district of Assam over two consecutive kharif seasons.

Seasonal Variations and Weather Correlations
Weekly meteorological data were obtained from the Agrometeorological Observatory located 200 m from the experimental field. During the 2022 kharif season, mean weekly temperatures ranged from 24.1 °C (late October) to 31.2°C (July third week). Total rainfall was 1,284 mm between June and November. In 2023, temperatures were 0.8 °C higher on average and rainfall was 11% lower at 1,142 mm. Correlation analysis between fortnightly weather parameters and pest incidence showed that maximum temperature ($r = 0.82^{**}$), minimum temperature ($r = 0.74^{**}$), and morning relative humidity ($r = 0.71^{**}$) were all positively correlated with larval population. Rainfall showed a weak negative correlation (r =

−0.34) likely because heavy downpours physically dislodge early-instar larvae from whorls [6].

Material and Methods

Material

The research was conducted at the Instructional-cum-Research Farm of Assam Agricultural University, Jorhat, Assam (26.76° N, 94.22° E, elevation 86 m), during kharif 2022 and 2023. Maize hybrid NK-6240 was sown in the first week of June each year at 60 × 20 cm spacing in plots of 10 m × 8 m. A recommended dose of 120:60:40 kg $N:P_2O_5:K_2O$ per hectare was applied. No insecticide was used in the observation plots to allow natural pest buildup. Four replicate plots were maintained in a randomized block design [7].

Methods: Seasonal incidence was recorded at fortnightly intervals from June through November. On each date, 10 randomly selected plants per plot were examined for egg masses, larvae (by instar), pupae (by soil excavation around plant base), and adult moths (using pheromone traps at one per plot). Larval counts were made by carefully unrolling the leaf whorl. Natural parasitism was assessed by collecting 50 larvae per plot at each sampling and rearing them in the laboratory; emerged parasitoids were identified to species [8]. For life table construction, 200 freshly laid egg masses were collected from the field and individual cohorts were followed through each developmental stage under ambient conditions in field cages (1.5 m × 1.5 m × 2 m). Duration of each stage, survival rate, and adult fecundity were recorded [9]. Data were analyzed using correlation and multiple regression against meteorological variables in SPSS version 26.

Results

Table 1: Monthly incidence of fall armyworm on maize and associated weather parameters (pooled, 2022-2023)

Month	Larval Pop./10 plants	Egg Mass /10 plants	Parasitism (%)	Temp. (°C)	RH (%)
June	12.8	4.2	8.4	28.6	84.2
July	18.4	6.8	12.6	29.4	88.7
August	22.6	8.4	16.8	28.8	91.3
September	16.3	5.6	14.2	27.4	86.8
October	9.4	3.1	10.8	24.6	78.4
November	5.8	1.8	6.2	20.2	72.6
SEm(±)	1.42	0.48	1.14	-	-
CD (P=0.05)	4.26	1.44	3.42	-	-

Larval populations built up from 12.8 per 10 plants in June to a peak of 22.6 in August, then declined through the post-monsoon months (Table 1). Egg mass density preceded larval peaks by approximately one month. Natural parasitism was highest in August at 16.8%, driven mainly by Cotesia marginiventris.

Table 2: Life table parameters of fall armyworm under field conditions in Jorhat, Assam

Life Stage	Duration (days)	Survival (%)	Fecundity (eggs/female)	Key Observation
Egg	3.4 ± 0.6	87.2	-	Laid in masses of 150-200
Larva (L1-L3)	8.6 ± 1.2	72.4	-	Feed on leaf whorl
Larva (L4-L6)	9.8 ± 1.4	64.8	-	Bore into ear; cannibalistic
Pre-pupa	1.6 ± 0.4	92.1	-	Cease feeding, shrink
Pupa	9.2 ± 1.8	88.6	-	In soil at 3-5 cm depth
Adult	8.4 ± 2.1	-	846 ± 124	Nocturnal; strong fliers

The total developmental period from egg to adult averaged 41.0 ± 3.8 days (Table 2). Larval survival was the lowest among all stages at 64.8% for late instars, primarily due to cannibalism and parasitism. Adult females laid an average of 846 eggs over their 8.4-day lifespan.

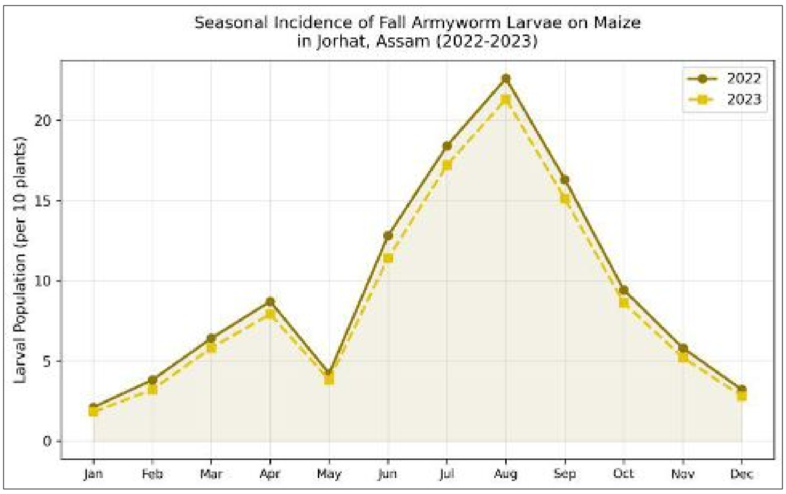

Fig 1: Seasonal incidence of fall armyworm larvae on maize in Jorhat, Assam, during kharif 2022 and 2023

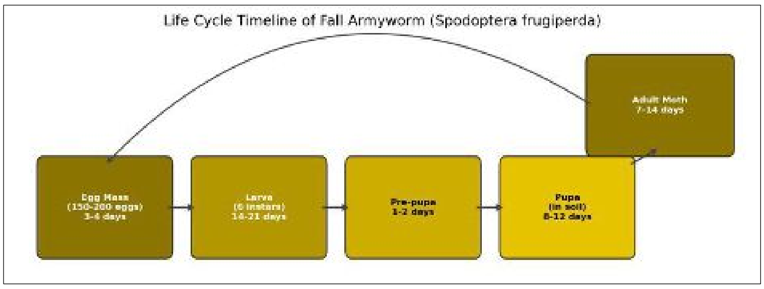

Fig 2: Life cycle timeline of fall armyworm showing duration and key characteristics of each developmental stage under field conditions

Comprehensive Interpretation

Multiple regression of larval population on temperature and relative humidity gave $R^2 = 0.784$ ($p < 0.001$), with the fitted model: $Y = -42.6 + 1.84(\text{Temp}) + 0.21(\text{RH})$. This indicates that about 78% of population variation can be predicted from these two weather variables, providing a basis for early warning systems.

Discussion

The August population peak aligns with reports from other tropical regions of India and Africa and corresponds to the whorl-stage of the kharif maize crop, which is the most vulnerable growth phase for fall armyworm attack [1, 3]. The one-month lag between egg mass and larval peaks reflects the 3-4 day incubation period plus the time needed for early instars to reach a detectable size within the whorl. The natural parasitism rate of 16.8% is lower than the 25-35% reported from the Americas where co-evolved parasitoid complexes exist, but it is encouraging as a sign that local parasitoids are adapting to this new host [5].

The 41-day generation time under Jorhat conditions means that 3-4 overlapping generations can complete within a single kharif season, which explains the rapid population buildup observed. Management interventions, particularly targeted application of Bt-based products or spinosad, should be timed to coincide with early larval instars in the whorl stage, approximately 7-10 days after peak egg-laying activity detected by pheromone traps [8].

Conclusion

Fall armyworm on maize in northeastern India follows a unimodal seasonal pattern peaking in August, driven by temperature and humidity. The 41-day generation time permits 3-4 generations per kharif season. Natural parasitism reaches 16.8% at peak season, mainly from Cotesia marginiventris. These baseline bio-ecological data support the development of forecasting models using easily accessible weather variables and can guide the timing of IPM interventions for maize growers in the region.

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