

# Seasonal Dynamics of Stem Borer Composition, Diversity, and Damage on Maize (*Zea mays* L.) in Ghana: Insights from Historical Field Records

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## Abstract

Maize stem borers are among the most destructive insect pests affecting maize production in sub-Saharan Africa. Understanding their seasonal dynamics is essential for effective pest management strategies. This study evaluated seasonal differences in infestation levels, species composition, diversity, and damage indicators of stem borers infesting maize during the major and minor cropping seasons in Ghana. The study utilized historical data derived from field experiments conducted in 2009 at the Teaching and Research Farm of the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana. Weekly observations of stem borer infestation were recorded over five weeks during the major season and four weeks during the minor season. Three stem borer species were identified: *Busseola fusca*, *Eldana saccharina*, and *Sesamia calamistis*. Mean larval abundance was comparable between seasons, with values of 2.47 larvae per plant during the major season and 2.49 larvae per plant during the minor season. Independent sample t-tests indicated no statistically significant differences in seasonal infestation levels ( $p > 0.05$ ). Harvest assessments indicated slightly higher plant damage during the minor season. Species diversity, as measured by Shannon indices, was similar between the major and minor seasons (1.00 and 1.02, respectively). These findings provide valuable baseline information on maize stem borer communities in Ghana prior to the invasion of fall armyworm (*Spodoptera frugiperda*). The study highlights the importance of continuous monitoring and integrated pest management strategies for sustainable maize production.

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## Keywords

Maize, Stem Borers, Seasonal Infestation, Species Diversity, *Busseola fusca*, *Eldana saccharina*, *Sesamia calamistis*

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## 1. Introduction

Maize (*Zea mays* L.) is one of the most important staple crops in sub-Saharan Africa, providing food, income, and employment for millions of households [1]. However, maize production is constrained by several insect pests, among which stem borers are considered one of the most destructive groups affecting cereal crops [2].

Stem borers damage maize plants by tunneling into stems and feeding on internal tissues, disrupting nutrient transport and causing symptoms such as leaf damage, dead hearts, and exit holes [3]. Severe infestations can significantly reduce maize yields and lead to substantial economic losses for farmers [4].

Several species of stem borers are associated with maize production in Africa. Among the most economically important are *Busseola fusca* Fuller (Lepidoptera: Noctuidae), *Sesamia calamistis* (Lepidoptera: Noctuidae), and *Eldana saccharina* (Lepidoptera: Pyralidae), which are widely distributed across the continent and cause significant crop damage [2] [5].

Seasonal variations in climatic factors such as rainfall, temperature, and humidity strongly influence stem borer population dynamics and infestation levels [6]. Understanding seasonal patterns of infestation is therefore essential for developing effective pest management strategies.

Furthermore, historical information on maize pest complexes prior to the invasion of fall armyworm (*Spodoptera frugiperda*) is increasingly valuable. Since its detection in Africa in 2016, fall armyworm has become a major pest affecting maize production across the continent [7] [8]. Baseline data on earlier pest communities, therefore, provide important insights into long-term shifts in pest dynamics and ecological interactions within maize agroecosystems.

The objective of this study was to evaluate seasonal variation in stem borer infestation levels, species composition, diversity, and plant damage indicators on maize grown in Ghana during the 2009 major and minor cropping seasons.

## 2. Materials and Methods

### 2.1. Study Area

The study was conducted at the Teaching and Research Farm of the Department of Crop and Soil Sciences at Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi, Ghana. The region lies within the semi-deciduous forest agro-ecological zone and experiences a bimodal rainfall pattern that supports two maize cropping seasons annually.

The major season experiment was conducted from April to August 2009, while the minor season experiment was conducted from October 2009 to January 2010.

## 2.2. Experimental Design and Data Collection

The dataset used in this study was derived from a field experiment conducted in 2009 to evaluate the effects of salicylic acid application on maize stem borer infestation. The maize variety used was Obatampa, an improved open-pollinated variety widely cultivated in Ghana.

The original experiment was established using a split-plot design with four replications. The main plot factor consisted of two fertilizer regimes (fertilized and unfertilized), while the sub-plot factor comprised five salicylic acid treatments. Each main plot was divided into sub-plots, and treatments were randomly assigned within each replication.

The treatments included four concentrations of salicylic acid (0.5, 1.0, 2.0, and 4.0 g·L<sup>-1</sup>) and a control (water only). All treatments were applied at a spray volume of 100 L·ha<sup>-1</sup> using a knapsack sprayer. Applications commenced at 10 days after sowing (DAS) and were repeated at 10-day intervals until 60 DAS.

In total, the experiment consisted of 40 plots (2 fertilizer regimes × 5 treatments × 4 replications), with each sub-plot serving as an experimental unit. Standard agronomic practices for maize production in the region were followed, and no chemical pest control measures were applied, allowing natural stem borer infestation to occur.

Stem borer infestation was monitored through weekly sampling during crop development. Sampling commenced at 3 weeks after sowing (WAS) in both seasons and continued at weekly intervals; the major season included one additional observation at 7 WAS due to a longer crop duration. Observations were conducted for five consecutive sampling periods during the major cropping season and four sampling periods during the minor season.

Within each sub-plot, maize plants were randomly selected for destructive sampling. At each sampling period, four plants were uprooted per plot and dissected to determine the presence of stem borer larvae, identify species composition, and assess the infestation responsible for dead heart symptoms. The number of larvae per plant and the number of egg masses observed were recorded.

Larvae collected during sampling were identified to the species level using morphological characteristics based on the identification keys developed by [5]. The species identified included *B. fusca*, *E. saccharina*, and *S. calamistis*.

At harvest, ten randomly selected plants per plot were uprooted and dissected to identify stem borer species present within the maize stalks. The number of exit holes per plant was recorded, along with other indicators of damage, including leaf feeding and the incidence of dead heart symptoms. The total number of larvae recovered per plant was also recorded to estimate overall infestation levels.

### 2.3. Data Aggregation and Analysis

In the present study, treatment effects were not evaluated directly. Instead, the dataset was reorganized to assess seasonal variation in stem borer infestation patterns.

To achieve this, data from all treatment combinations (five salicylic acid levels and two fertilizer regimes) and all replications were pooled within each season. For each sampling period, observations obtained at the plot level (based on four plants per plot) were first averaged to generate a mean value per plot. These plot-level means were then averaged across the four replications within each treatment. Subsequently, values were averaged across all treatments and fertilizer regimes to obtain a single composite mean per sampling period for each season.

Similarly, harvest data (based on ten plants per plot) were first averaged at the plot level, then across replications, and finally pooled across all treatments to generate overall seasonal means for plant damage indicators and total larval counts.

Data were square-root transformed using  $\sqrt{x + 0.5}$  to stabilize variance prior to analysis. Weekly mean values were calculated for infestation parameters. Seasonal comparisons of infestation levels were conducted using independent sample t-tests to determine whether significant differences existed between the major and minor seasons.

Pearson correlation analysis was performed to evaluate the relationships between stem borer infestation levels and plant damage indicators, including exit holes and dead heart symptoms.

The following ecological diversity indices were used to assess species diversity in the maize stem borer community.

1) Shannon-Wiener Diversity Index ( $H'$ )

Formula:

$$H' = -\sum (p_i \ln p_i)$$

where:

$p_i$  = proportion of individuals belonging to the  $i$ -th species

$\ln$  = natural logarithm

$\Sigma$  = summation across all species in the community

2) Simpson Diversity Index ( $D$ )

Formula:

$$D = 1 - \sum (p_i^2)$$

where:

$p_i$  = proportion of individuals belonging to the  $i$ -th species

$\Sigma$  = summation across all species in the community

3) Species Proportion Calculation

Formula:

$$p_i = n_i / N$$

where:

$n_i$  = number of individuals of species  $i$

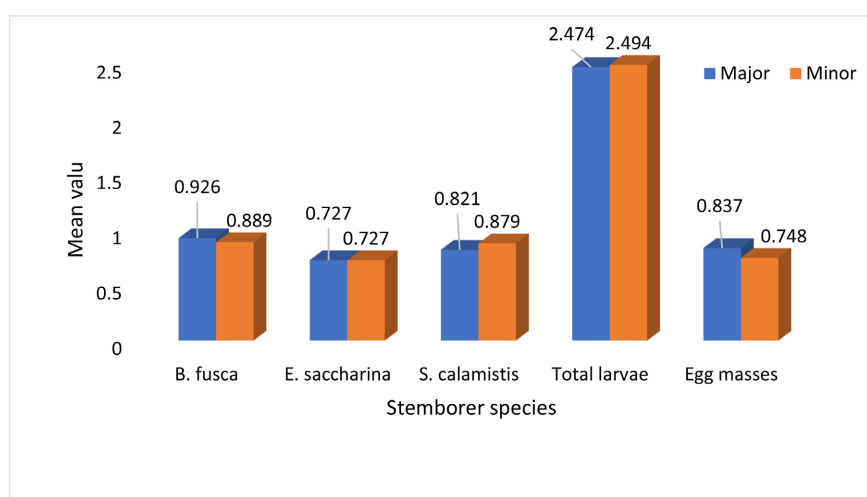
$N$  = total number of individuals of all species

These indices are commonly used in ecological studies to quantify species diversity and evenness within biological communities. Statistical significance was determined at  $p < 0.05$ .

### 3. Results

#### 3.1. Seasonal Abundance of Stem Borer Species

Mean larval abundance was similar between the two seasons, with values of 2.47 larvae per plant during the major season and 2.49 larvae per plant during the minor season. *B. fusca* recorded the highest abundance during the major season, while *S. calamistis* showed slightly higher abundance during the minor season. *E. saccharina* exhibited similar abundance levels in both seasons, and egg masses were somewhat higher during the major season (Figure 1).

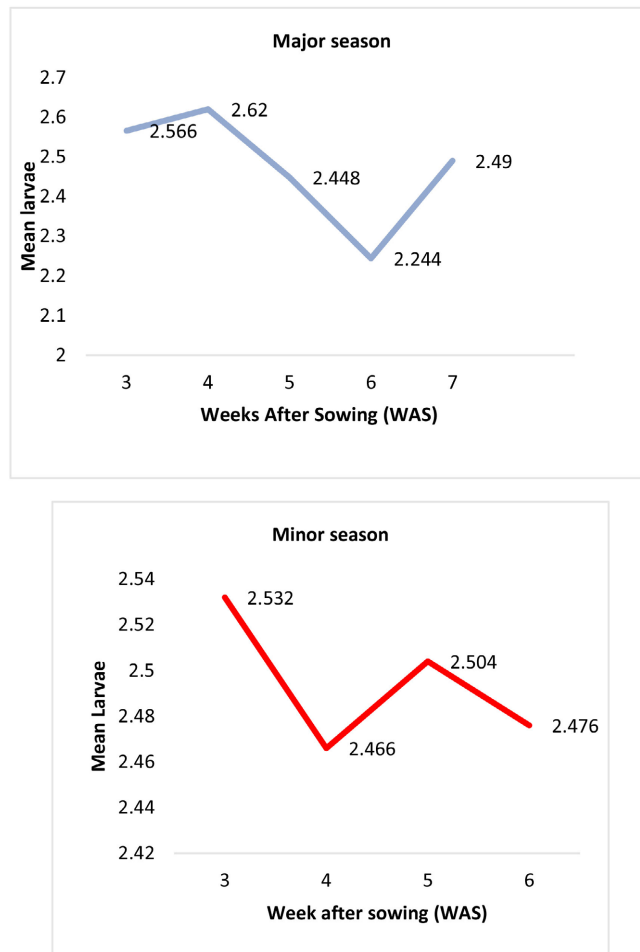


**Figure 1.** Mean abundance of stem borer species and egg masses during the major and minor cropping seasons.

#### 3.2. Weekly Infestation Patterns

Based on the study, the major season infestation levels increased rapidly during the early vegetative stage, reaching a peak at the mid-vegetative stage (second sampling period), followed by a gradual stabilization toward the later growth stages. In contrast, the minor season exhibited relatively stable infestation levels across comparable growth stages, with no pronounced peak observed. Although the overall mean larval abundance was similar between seasons (approximately 2.5 larvae per plant), the temporal pattern differed markedly. The major season showed a distinct mid-stage infestation peak, whereas the minor season maintained a more uniform infestation pressure throughout the crop development period (Figure 2).

Sampling commenced at 3 WAS in both seasons and continued at weekly intervals; the major season included one additional observation at 7 WAS due to a longer crop duration.



**Figure 2.** Weekly stem borer infestation trends in maize during the major and minor cropping seasons. Infestation levels are expressed as the mean number of larvae per plant and presented by crop age (weeks after sowing, WAS). Sampling was conducted at weekly intervals from 3 to 7 WAS in the major season and from 3 to 6 WAS in the minor season, reflecting differences in crop duration.

### 3.3. Harvest Damage Indicators

Descriptive presentation of the harvest indicators shows higher levels of plant damage during the minor season compared with the major season. The mean number of exit holes increased from 2.37 in the major season to 2.92 in the minor season, while the incidence of dead heart symptoms was also higher in the minor season (Table 1).

**Table 1.** Seasonal comparison of harvest damage indicators.

| Parameter    | Major Season | Minor Season |
|--------------|--------------|--------------|
| Exit Holes   | 2.37         | 2.92         |
| Leaf Damage  | 2.55         | 2.61         |
| Dead Heart   | 0.17         | 1.04         |
| Total Larvae | 5.59         | 6.30         |

### 3.4. Seasonal Comparison of Infestation Levels

Independent sample t-tests indicated that seasonal differences in larval populations were not statistically significant ( $p > 0.05$ ). However, total larval abundance at harvest was slightly higher during the minor season compared with the major season (**Table 2**).

**Table 2.** Independent sample t-test comparison of infestation parameters.

| Parameter            | p-Value |
|----------------------|---------|
| <i>B. fusca</i>      | 0.648   |
| <i>E. saccharina</i> | 0.989   |
| <i>S. calamistis</i> | 0.455   |
| Total Larvae         | 0.767   |
| Egg Masses           | 0.375   |

### 3.5. Relationship between Infestation and Damage Indicators

Correlation analysis showed strong positive relationships between larval infestation levels and plant damage indicators, as indicated in **Table 3**.

**Table 3.** Shows the correlation between infestation parameters and plant damage indicators.

| Parameter                 | p-value |
|---------------------------|---------|
| Dead Heart vs. Larvae     | 0.97    |
| Exit Holes vs. Larvae     | 0.91    |
| Exit Holes vs. Dead Heart | 0.94    |

### 3.6. Species Diversity

Species diversity indices indicated a relatively even distribution of stem borer species across both seasons. The Shannon diversity index ( $H'$ ) was 1.00 in the major season and 1.02 in the minor season, while the Simpson diversity index ( $D$ ) was 0.66 and 0.67, respectively (**Table 4**).

**Table 4.** Species proportions and diversity indices of maize stem borers during the major and minor seasons.

| Species                           | Major Seasonal Proportion ( $p_i$ ) | Minor Seasonal Proportion ( $p_i$ ) |
|-----------------------------------|-------------------------------------|-------------------------------------|
| <i>B. fusca</i>                   | 0.374                               | 0.356                               |
| <i>E. saccharina</i>              | 0.294                               | 0.291                               |
| <i>S. calamistis</i>              | 0.332                               | 0.353                               |
| Shannon Diversity Index ( $H'$ )  | 1.00                                | 1.02                                |
| Simpson's Diversity Index ( $D$ ) | 0.66                                | 0.67                                |
| Species Richness ( $S$ )          | 3                                   | 3                                   |

The proportional abundance of the three species *B. fusca*, *E. saccharina*, and *S. calamistis* was comparable across seasons, with no single species showing clear dominance.

#### 4. Discussion

The present study confirmed the presence of three major maize stem borer species in the study area: *B. fusca*, *S. calamistis*, and *E. saccharina*. These species have been widely reported as economically important pests of maize across sub-Saharan Africa [2] [5] [9] [10].

The proportional abundance of the three species was comparable across seasons, indicating no clear dominance by any single species. This is supported by the Shannon and Simpson diversity indices, which suggest a relatively even distribution despite low species richness. These findings contrast with previous reports of species dominance in similar agro-ecological systems, where *B. fusca* is often identified as the predominant maize stem borer [2].

Seasonal comparisons indicated slightly higher infestation and damage during the minor season, although the differences were not statistically significant. While environmental factors may contribute to such variation [6], they were not evaluated in this study. Furthermore, as the dataset is limited to a single site over one year, the results should be interpreted within the context of the study site. The strong correlations observed between larval infestation and damage indicators such as dead hearts and exit holes confirm that these symptoms are reliable indicators of stem borer activity in maize fields [3].

Importantly, this study provides valuable baseline information on maize pest dynamics prior to the invasion of fall armyworm (*Spodoptera frugiperda*) in Africa. Since its introduction in 2016, fall armyworm has altered pest complexes in maize systems, often co-occurring with indigenous stem borer species and influencing their population dynamics [11]-[13]. In this context, the relatively even distribution of stem borer species observed in this study may differ from current field conditions, highlighting the importance of historical datasets for understanding long-term changes in pest community structure.

#### 5. Conclusion

This study demonstrated that three major stem borer species infest maize crops in the study area, with similar representation across species. Infestation levels were broadly comparable between the major and minor cropping seasons, although slightly higher plant damage was observed during the minor season. The findings provide valuable baseline information on maize pest communities in Ghana prior to the invasion of fall armyworm and highlight the importance of continuous monitoring and integrated pest management strategies for sustainable maize production.

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### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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