POPULATION DYNAMICS OF THE FALL ARMYWORM, *SPODOPTERA FRUGIPERDA* J. E. SMITH (LEPIDOPTERA: NOCTUIDAE) ON EARLY AND LATE SEASON MAIZE

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ABSTARCT

Maize (Zea mays L.), an important staple food crop in Nigeria is recently threatened by an invasive pest species; the fall armyworm (FAW), Spodoptera frugiperda (J. E. Smith) in different parts of the country. Investigating the population dynamics of this pest will be useful for quantifying and forecasting future trends and provide a proper framework for control. A field experiment was conducted to investigate the dynamics of Spodoptera frugiperda on maize during the 2019 maize cropping season in Benin City, Edo State, Nigeria. Weekly data on number of larvae and number of plants with live larvae or fresh frass were collected on 20 maize plants randomly selected at five locations following a 'W' pattern in the bulk plot. Meteorological data were obtained from National Centre for Energy and Environment, University of Benin, Benin City. These data were analysed using Analysis of Variance (ANOVA), t-test and Pearson's correlation analysis. Results revealed that in the early and late cropping season there was a significant difference (p<0.05) in the larval abundance, larval instar distribution and percentage infestation in the different sampling weeks (SW). Weather parameters varied in both seasons. Larval abundance had a significant negative correlation with rainfall and humidity and a significant positive correlation with temperature in the early season, however, in the late season; larval abundance had a non-significant correlation with rainfall and humidity but a significant negative correlation with temperature. FAW population and larval instar distribution were influence by the crop phenological stage and prevailing weather.

Keywords: Fall armyworm, Population dynamics, Crop phenology, Weather, Cropping season

INTRODUCTION

Fall armyworm (FAW, *Spodoptera frugiperda* J. E. Smith 1797, Lepidoptera: Noctuidae) is a moth whose larva has great destruction tendencies and one of the major problems for agricultural crop production, especially maize under warm and humid conditions (Day *et al.,* 2017). Maize (*Zea mays* L. Poales: Poaceae) is Africa's most staple food crop (Ado *et al.,* 2010) and one of the most important cultivated crop in Nigeria (Odeyemi *et al.,* 2020). The prevalence of maize and other crops on which this highly polyphagous pest feeds associated with agro-ecological conditions suitable for FAW in most part of sub-Saharan Africa makes it a serious (and most certainly perennial) threat to food security in the region (Day *et al.,* 2017). The fall armyworm has four life stages which are egg, larva, pupa and adult. The pest poses greater damages to plant at the larva stage (Day *et al.,* 2017). While fall armyworm can damage maize plants in nearly all stages of development, it will concentrate on later plantings that have not yet silked. Population dynamics is the part of ecology that deals with the variation in time and space of population size and density for one or more species (Begon *et al.,* 1986). Insect population varies with response to changes in ecological conditions (Schowalter, 2011). Many ecological factors such as competition, natural enemies, resources (Ylioja *et al.,* 1999) and climatic factors like rainfall and temperature affect the distribution and abundance of pest species (Cammell and Knight, 1992). These environmental factors, as well as crop phenology and cropping season may contribute to the dynamics of a pest in a given locale. Quantitative descriptions of the changes in a species population number over time in a given locale is useful for quantifying and forecasting future trends; such data would show when control effort is justified and the expected population sometime in the future for necessary intervention. Therefore, the objectives of this study were to investigate the population dynamics of *S. frugiperda* larvae, distribution of its larval instar stages and the influence of weather parameters on its dynamics on maize in Benin City, Edo State, Nigeria.

MATERIALS AND METHODS

Study Area: The field experiment was conducted during the early maize cropping season (April – July, 2019) and late maize cropping season (August – November, 2019) at the Teaching and Research Farm of Crop Science, Faculty of Agriculture, University of Benin, Ugbowo Campus, Benin City, Edo State, located at 6°24.105'N, 5°37.508'E at an elevation of 94 m above sea level. This location is in the rainforest zone of Nigeria (Ewansiha and Osaigbovo, 2016).

Land Preparation, Planting and Agronomic Practices: A plot size of 200 m^2 was manually cleared and ploughed. Maize seeds were sown at a depth of 2 – 3 cm in the plot at the rate of 3 seeds per stand with a spacing of 75 × 25 cm and were thinned to one seed per stand two weeks later. Poultry manure was applied two weeks before and after planting and six weeks after planting at the rate of 40.5 kg/hectare. Weeding was done when necessary.

Sampling Methods and Data Collection: Weekly sampling began in April 2019 in the early season and August 2019 in the late season when the plant showed 2 leaf collar (V2-V3) between 7.00 and 11.00 hours and continued until the beginning of the reproductive stage (R1). Following methodologies by Prasanna *et al.* (2018), number of plants showing fresh damaged leaves/infested with live larvae or fresh frass and number of FAW larvae were recorded on 20 maize plants from each of 20 sq. m area randomly selected at five locations following a 'W' pattern in the entire bulk plot. The number of FAW infested plants was used to calculate the percentage infestation as follows: % of FAW Infested plants = Number of Infested plants/Total number of plants × 100.

Meteorological data of rainfall, maximum and minimum temperature and relative humidity were collected from National Centre for Energy and Environment, University of Benin, Benin City.

Data Analysis: Weekly data on number of larvae, larval instar distribution and percentage infestation were transformed using square root transformation after which they were subjected to Analysis of Variance (ANOVA). Significant means were separated using Duncan Multiple Range test. Mean differences of percentage infestation, larval abundance and weather parameters between seasons were analysed using t-test. Pearson's correlation analysis was used to determine the correlation between FAW larval abundance and weather parameters. All tests were done using SPSS version 16.0 software.

RESULTS AND DISCUSSION

Fall Armyworm Larval Abundance and Infestation: There was significant difference ($p<0.05$) in the larval abundance and percentage infestation (Table 1) in the different

Table 1: *Spodoptera frugiperda* larval abundance and percentage infestation across the sampling weeks in the early and late season maize

Sampling week	Number of larvae		Percentage infestation (%)	
	Early season	Late season	Early season	Late season
1	0.40 ± 0.25^{e}	0.15 ± 0.16^{b}	1.48 ± 0.63^{d}	0.39 ± 0.40^{ab}
2	27.24 ± 0.39^{a***}	0.15 ± 0.16^{b}	59.82 ± 0.24^{a***}	0.39 ± 0.40^{ab}
3	15.92 ± 0.58^{b***}	0.05 ± 0.00^{b}	76.34 ± 0.82^{a***}	0.05 ± 0.00^{b}
4	13.40 ± 0.64^{b**}	0.50 ± 0.20^{ab}	70.20 ± 0.98^{a***}	4.11 ± 0.49^{ab}
5	8.22 ± 0.24^{bc***}	0.72 ± 0.29^{ab}	60.17 ± 0.47^{a***}	3.55 ± 0.79^{ab}
6	3.28 ± 0.30^{cd}	0.86 ± 0.31^{ab}	74.88 ± 0.20^{a***}	4.28 ± 0.83^{ab}
7	1.60 ± 0.51^{de}	1.73 ± 0.36^{a}	25.33 ± 0.66^{b*}	6.84 ± 0.74^{a}
8	2.62 ± 0.51^{d}	0.39 ± 0.25^{ab}	16.28 ± 1.20^{c}	3.97 ± 0.72^{ab}
9	0.39 ± 0.25^{e}	0.15 ± 0.16^{b}	4.28 ± 0.83^{cd}	1.15 ± 0.85^{ab}
10	0.05 ± 0.00^{e}	0.05 ± 0.00^{b}	0.39 ± 0.40^{d}	0.05 ± 0.00^{b}

*[abcde] Means in the same column with different letter superscript are significantly different ($p<0.05$); *Means in the same row for early and late seasons with asterisk (*) are significantly different (* = $p<0.05$, ** = $p<0.01$ and *** = $p<0.001$)*

sampling weeks (SW) which corresponded to different stages of maize growth in the early and late season. Larval abundance was highest in the 2nd (27.24 ± 0.39 larvae) and 7th (1.73 ± 0.36 larvae) SW of the early and late season respectively. Lowest larval abundance was recorded in the1st (0.40 ± 0.25 larvae), 9th (0.39 ± 0.25 larvae) and 10th (0.05 larvae ± 0.00) SW in the early season and 1st (0.15 ± 0.16 larvae), 2nd (0.15 ±0.16 larvae), 3rd (0.05 ± 0.00 larvae), 9th (0.15 larvae) and 10th (0.05 ± 0.00) SW of the late season. Percentage infestation was highest in sampling weeks 2, 5, 4, 6 and 3 with a mean percentage infestation of 59.82 ± 0.24, 60.17 ± 0.47, 70.20 ±0.98, 74.88 ± 0.20 and 76.34 ± 0.82% and lowest in sampling weeks 10(0.39 ± 0.40%) and 1(1.48 ± 0.63%) in the early season, while in the late season, percentage infestation was highest in the 7th (6.84 ± 0.74%) SW and lowest in the 3rd (0.05 ± 0.00%) and 10th (0.05 ± 0.00%) SW.

It was observed from this study that *S. frugiperda* larvae builds up from the early whorl stage to the late whorl stage and begins to decrease in the tasseling and silking stage as the larvae prefers to feed within the whorl in the vegetative stages of the maize plant (Capinera, 2008). Caniço *et al.* (2020) in their study found that at the plant level, the infestation by FAW was age-dependent because younger stages of maize had more infestation than older stages. In a 4-year study, Murúa *et al.* (2006) reported age-dependent response in *S. frugiperda* infestation in the first and second year with the VE-V3 stages being the most preferred stages with higher larval numbers recorded, while for the other years, larval populations were consistent throughout the vegetative plant phase.

Distribution of *Spodoptera frugiperda* Larval Stages: In the early season (Table 2), small larvae (L1-L3) were significantly higher with a mean abundance of 24.81 ± 0.46 larvae in week 2 (in V2-V4 plant stages) where about one to eight larvae were observed per plant, medium larvae (L4-L5) were significantly higher in weeks 2, 5, 4 and 3 (corresponding to V2-V12 plant stages) with mean abundance of 1.23 ± 0.23, 1.66 ± 0.31, 3.42 ± 0.68 and 4.01 ± 0.60 larvae respectively and about one to two larvae/plant were found while large larvae (L6) were significantly higher in weeks 4 and 5 (in V6-V12 plant stages) with mean abundance of 2.96 ± 0.41 and 5.09 ±0.30 larvae respectively, but only one larvae/plant was found. The distribution of the different larval instars across the weeks (corresponding to maize growth stages) were however similar in the late season (Table 3). This finding was similar to findings of Beserra *et al.* (2002) where the distribution of FAW larvae and eggs varied according to the phenological stage of maize. In their study, first and second instars were predominant during the early plant stages (V1-V3), with about one to six larvae per plant, while only one larva was observed per plant during V4 and V6 plant stages.

Table 2: Number of small, medium and large *Spodoptera frugiperda* larvae across the sampling weeks in the early and late season maize

Sampling week	Number of small larvae		Number of medium larvae		Number of large larvae	
	Early	Late	Early	Late	Early	Late
1	0.39 ± 0.25[c]	0.15 ± 0.16[a]	0.05 ± 0.00[c]	0.05 ± 0.-00[a]	0.05 ± 0.00[e]	0.05 ± 0.00[a]
2	24.81 ± 0.46[a***]	0.15 ± 0.16[a]	1.23 ± 0.23[abc**]	0.05 ± 0.00[a]	0.50 ± 0.30[cde]	0.05 ± 0.00[a]
3	9.38 ± 0.34[b***]	0.05 ± 0.00[a]	4.01 ± 0.60[a*]	0.05 ± 0.00[a]	1.87 ± 0.21[bc**]	0.05 ± 0.00[a]
4	4.93 ± 0.57[b*]	0.50 ± 0.19[a]	3.42 ± 0.68[ab*]	0.05 ± 0.00[a]	2.96 ± 0.41[ab**]	0.05 ± 0.00[a]
5	0.72 ± 0.29[c]	0.30 ± 0.19[a]	1.66 ± 0.31[abc]	0.22 ± 0.24[a]	5.09 ± 0.30[a***]	0.15 ± 0.16[a]
6	0.62 ± 0.24[c]	0.50 ± 0.19[a]	0.69 ± 0.37[bc]	0.15 ± 0.16[a]	1.49 ± 0.20[bcd*]	0.15 ± 0.16[a]
7	0.83 ± 0.45[c]	0.83 ± 0.45[a]	0.05 ± 0.00[c]	0.05 ± 0.00[a]	0.59 ± 0.34[cde]	0.39 ± 0.25[a]
8	0.99 ± 0.41[c]	0.05 ± 0.00a	0.69 ± 0.37[c]	0.05 ± 0.00[a]	0.75 ± 0.16[cde]	0.39 ± 0.25[a]
9	0.05 ± 0.00[c]	0.05 ± 0.0[a]	0.15 ± 0.16[c]	0.15 ± 0.16[a]	0.22 ± 0.24[de]	0.05 ± 0.00[a]
10	0.05 ± 0.00[c]	0.05 ± 0.00[a]	0.05 ± 0.00[c]	0.05 ± 0.00[a]	0.05 ± 0.00[e]	0.05 ± 0.00[a]

*[abcde]Means in the same column with different letter superscript are significantly different (p<0.05); *Means in the same row for early and late seasons with asterisk (*) are significantly different (* = p<0.05, ** = p<0.01 and *** = p<0.001)*

Table 3: Weekly weather parameters recorded during the early and late cropping season of 2019

Standard Meteorological Week	Duration	Mean Temperature (˚C)	Mean Relative Humidity (%)	Total Rainfall (mm)
15	April 7 – 13	26.62 ± 0.11[be]	80.79 ± 0.22[f]	43.29
16	April 14 – 20	27.03 ± 0.07[a]	78.94 ± 0.49[g]	14.85
17	April 21 – 27	27.26 ± 0.19[a]	81.10 ± 0.16[ef]	18.97
18	April 28 – May 4	26.90 ± 0.09[ab]	82.78 ± 0.40[d]	38.18
19	May 5 – 11	27.26 ± 0.12[a]	82.08 ± 0.31[de]	14.31
20	May 12 – 18	27.26 ± 0.14[c]	84.70 ± 0.56[c]	57.97
21	May 19 – 25	25.87 ± 0.08[d]	86.65 ± 0.52[b]	52.40
22	May 26 – June 1	25.21 ± 0.18[e]	91.28 ± 0.38[a]	39.79
23	June 2 – 8	24.95 ± 0.17[e]	92.31 ± 0.37[a]	52.93
24	June 9 – 15	24.96 ± 0.09[e]	91.58 ± 0.25[a]	30.69
36	Sept 1 – 7	24.38 ± 0.09[cd]	92.26 ± 0.36[a]	56.40
37	Sept 8 – 4	24.22 ± 0.16[d]	91.55 ± 0.24[ab]	92.79
38	Sept 15 – 21	24.97 ± 0.22[b]	90.87 ± 0.29[b]	82.22
39	Sept 22 – 28	24.79 ± 0.10[bc]	91.18 ± 0.32[b]	77.70
40	Sept 29 – Oct 5	24.20 ± 0.06[d]	92.30 ± 0.25[a]	112.30
41	Oct 6 – 12	24.19 ± 0.15[d]	91.35 ± 0.38[ab]	103.94
42	Oct 13 – 19	24.47 ± 0.15[cd]	89.46 ± 0.33[c]	59.49
43	Oct 20 – 26	24.60 ± 0.19[bcd]	88.82 ± 0.26[c]	70.11
44	Oct 27 – Nov 2	24.53 ± 0.24[bcd]	85.76 ± 0.54[d]	32.81
45	Nov 3 – 9	25.84 ± 0.10[a]	84.59 ± 0.27[e]	13.96

[abcde]Means in the same column with different letter superscript are significantly different (p<0.05)

Rajisha *et al.* (2022) also observed that first and second larval instars were more in the early plant stages (V2-V3) with about two to three larvae/plant, while late larval stages were more frequently observed in late whorl stages (V11-V12) in the 2019 cropping season. Durocher-Granger *et al.* (2021) in their study also revealed that FAW larvae and egg distribution varied according to the phonological stage of the crop.

Weather Parameters during the Early and Late Cropping Seasons: Data for weather parameters are presented in Table 3. There was significant difference (p<0.05) in the weekly average temperature, mean relative humidity and total rainfall during the period of sampling in the early and late cropping season. Lower temperatures were observed in the late cropping season than in the early cropping season.

However, higher relative humidity and rainfall were recorded in the late cropping season than in the early cropping season. Similarly, Nivetha *et al.* (2022) recorded lower temperatures and higher relative humidity and rainfall during the 2019 cropping season (rainy season) than summer 2020 cropping season. Also, differences in the monthly temperature and rainfall were recorded between seasons by Caniço *et al.* (2020).

Relationship between *Spodoptera frugipera* Larval Abundance with Weather Parameters: In the early season (Table 4), larval abundance had a significant negative correlation with rainfall and humidity and a significant positive correlation with temperature.

Table 4: Correlation between *Spodoptera frugiperda* larval abundance and weather parameters

Seasons	Correlation value
Early Season	
Larval abundance vs. Mean Temperature	0.680***
Larval abundance vs. Total Rainfall	-0.582***
Larval abundance vs. Relative humidity	-0.639***
Late Season	
Larval abundance vs. Mean Temperature	-0.293*
Larval abundance vs. Total Rainfall	0.233ns
Larval abundance vs. Relative humidity	0.179ns

**** Correlation is significant at the 0.001 level (2-tailed), * correlation is significant at the 0.05 level (2-tailed). ns: not significant at p<0.05*

However, in the late season; larval abundance had a non-significant correlation with rainfall and humidity but a significant negative correlation with temperature. The findings of this study is in consonance with the reports of Paul and Deole (2020) and Kumar *et al.* (2020) that FAW larvae exhibited a significant negative correlation with total rainfall and relative humidity. Similarly, Rajisha *et al.* (2022) in a 2018 study, observed a non-significant positive correlation of FAW trap catches with maximum and minimum temperature and a significant negative correlation with evening relative humidity and rainfall during Kharif cropping season which begins in June and end in October, while in contrast, there was no significant impact of weather on FAW trap catches during Rabi cropping season which begins in October and ends in April/May. Furthermore, Nboyine *et al.* (2020) reported a significant positive correlation between moth trap catches and rainfall.

Findings from this study suggest that changes in FAW population seem to be influenced by the prevailing weather conditions as FAW larval abundance (Figure 1) and percentage infestation (Figure 2) differed significantly in both seasons with a mean of 4.80 ± 0.26 larvae and 29.42 ± 0.49% in the early season (characterized by lower rainfall and relative humidity and higher temperature) and 0.36 ± 0.08 larvae and 1.79 ± 0.21% in the late season (with higher rainfall and relative humidity and lower temperature) respectively.

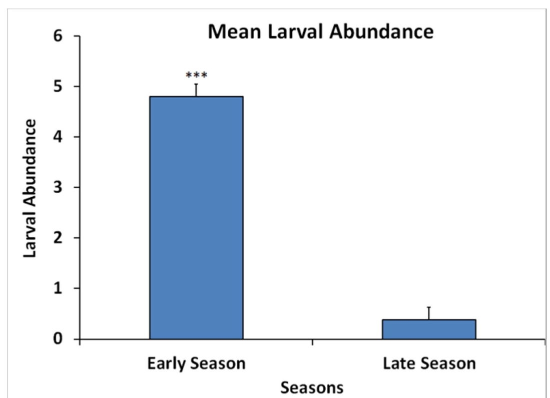

Figure 1: *Spodoptera frugiperda* larval abundance in the early and late season maize. ***Key:** ***Mean is significant at p<0.001*

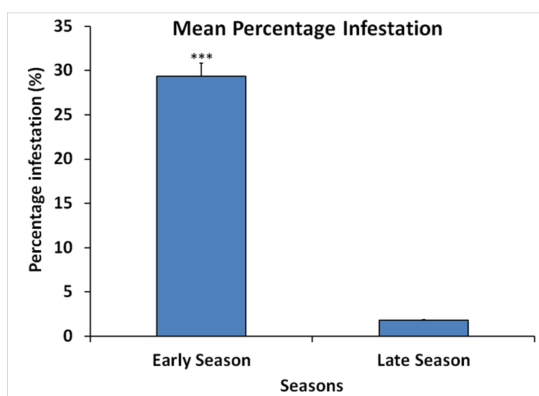

Figure 2: Percentage infestation of *Spodoptera frugiperda* in the early and late season maize. ***Key:** ***Mean is significant at p<0.001*

Similarly, Caniço *et al.* (2020) in their study in Mozambique, recorded higher population density of FAW in the dry season than in the rainy season. However, Nboyine et *al.* (2020) reported a contradicting scenario in Northern Ghana, where the rainy season positively influenced the population of FAW in maize fields. Some studies suggested that the population density of FAW was negatively influenced by rainfall; results from this study seem to follow this hypothesis as during the rainy season FAW larval population was relatively low as against that in the drier season (Early *et al.,* 2018; Garcia *et al.,* 2018). Temperature also plays a key role in the survival and development of FAW (Nboyine et *al.,* 2020). This is true in this study as a hotter drier weather condition led to an increase in FAW larva population

Conclusion: In this study, population of FAW larvae varied significantly with maize growth stages. FAW larvae, comprising mainly younger larval instars were more in younger maize plants than older plants, as fewer and mostly mature larval instars were found more in older plants. Larval abundance was influenced by weather conditions. There was a decrease in FAW larval population in the late season which was characterized by higher relative humidity and rainfall and lower temperature while the early season with comparatively lower relative humidity and rainfall and higher temperature recorded higher larval population. Efforts for control of FAW should therefore be considered during drier weather conditions and targeted at younger stages of maize when the younger larval instars which are easier to control are abundant.

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