Damage caused by Lepidopteran pests on maize fields in Yamoussoukro, Central Côte d'Ivoire

ABSTRACT

Various larvae of Lepidoptera cause severe damage to maize crops. The dynamics of these maize larvae pests have been studied during all stages of plant development. The trial was carried out on the Institut National Polytechnique Houphouët-Boigny farm plots in Yamoussoukro (central Cote d'Ivoire). The study aims were to monitor the dynamics, determine the importance (frequency and abundance), and assess the damage of Lepidopteran pests on the maize variety EV8728 SR using a randomized complete block design with four replicates. The variety was sown on 05 September 2020. Insects were characterized with keys following on-site observation and capture of larvae on the plants. Five Lepidopteran species, grouped into three families, were counted on the plots. *Spodoptera frugiperda* was the most frequent (Occurrence C = 20.9%) and highly abundant (Relative Abundance Ar = 65.79%). The other Lepidoptera species were rare (C < 5%). However, *Sesamia calamistis* was very abundant (Ar=15.22%), while *Eldana saccharina* (Ar = 9.44%) and *Ostrinia nubilalis* (Ar = 5.25%) were abundant. *Helicoverpa zea* is scarcely abundant (Ar=4.3%). Furthermore, three Lepidoptera species (*E. saccharina*, *O. nubilalis*, and *H. zea*) were as minor pests (Damage Index I < 10%), while *S. calamistis* was important pest (I < 25%) and *S. frugiperda* was major pest (I< 75%). The populations of the insects fluctuated during crop development. The mean dried grain yield varied from 2.4±0.42 to 2.61±0.71 t/ha. Populations of *S. frugiperda* larvae and their damage appeared more important than those of other Lepidoptera. Knowledge of maize lepidopteran larvae is essential for effectively and efficiently controlling these pests and improving the quality and quantity of maize production.

Keywords : *Spodoptera fruigiperda*, Lepidoptera, pests, maize, Côte d'Ivoire

INTRODUCTION

Maize (*Zea mays* L. Poaceae) is one of West Africa's most important food crops in terms of both food security and agricultural income for rural populations (Midega et al., 2018). It is also the main staple food crop grown mainly by sub-Saharan African smallholders, occupying over 36 million hectares of land yearly (Abate et al., 2017). In Côte d'Ivoire, smallholder farmers mainly produce maize in the Sudanian and Sudano-Guinean zones (Cairns et al., 2013). In terms of tonnage, this crop is the fifth most important Ivorian food crop, after cassava, plantain, yams, and rice (FAO, 2022). National maize production was estimated from 600 000 to 700 000 tonnes annually.

However, based on FAO production estimates and compared with the state of play in neighboring countries, the Ivorian maize sector appears to be growing relatively slowly (RONGEAD, 2014). Despite vast production areas and the importance of maize, the average grain yield is less than 1.8 tons/ha (Abate et al., 2017). This may be due to several abiotic and biotic constraints. Among the biotic factors, the damage caused by cereal stem borers is significant (Kfir et al., 2002).

Nevertheless, an invasive insect, *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae), also known as the fall armyworm, is becoming a significant pest causing substantial yield losses on maize in the region (Goergen et al., 2016; Kumela et al., 2018). This pest attack maize and can cause significant damage up to total yield loss (De Almeida et al., 2002). The larvae can feed on many cultivated grasses (Georgen et al., 2016), such as millet, sorghum, rice, and sugarcane. It attacks all above-ground parts of plants, including stems, leaves, flowers, and ears (De Almeida et al., 2002). Thus, infestations during the development stage of maize yield losses of 15 to 73%, when up to 55 to 100% of the plants are infested by *S. frugiperda* (Hruska & Gould, 1997). Furthermore, *S. frugiperda* larvae appear more damaging on West and Central African maize than most other larvae species (IITA (2016).

In Côte d'Ivoire, several Lepidoptera larvae have been reported on maize (Nandjui et al., 2018; Moyal & Tran, 2023). Therefore, assessing the importance of each Lepidoptera larvae on maize in Côte d'Ivoire is necessary. This study aimed to monitor the larval population dynamics, determine the importance, and assess the damage severity of each Lepidopteran pest on maize.

MATERIAL AND METHODS

Experimental design

The experiment was conducted on a Randomized Complete Block Design with four replications. All the plots were treated alike. Twenty (20) elementary plots were set up. The elementary plots covered 81 m^2 (9m x 9m), each 2 m apart from the next plot. Within a plot, pots are spaced 0.75 m between rows and 0.5 m on each row, resulting in 13 rows and 19 pots per row. So, we had 247 pots per elementary plot. The maize variety EV8728 SR sowing was performed on September 2020 with two seeds per pot. Subsequently, weeding was applied manually during the maize's development phases (Emergence, Growth, Flowering, fruiting, and ripening).

Data collection

Thirty (30) plants per elementary plot were observed in the central rows to avoid border effects. Lepidopteran insect pests were identified according to the keys of Bosque-Perez (1995) and Ayana (2019), along with their occurrence (C), relative abundance (Ar), and damage to maize plants were assessed. Occurrence is the ratio between the number of records in which a given species is identified (Pi) and the total number of records (P) (Adja et al., 2014).

$$\boldsymbol{C}\,(\%) = \boldsymbol{Pi} * \mathbf{100}/\boldsymbol{P}$$

The authors defined five occurrence classes: ubiquitous species (C = 100%); constant species (50% ≤ C < 100%); frequent species (20% ≤ C < 50%); accessory species (5% ≤ C < 20%); sparse species (C < 5%). Relative abundance expresses the ratio between the number of individuals of a given species (Ni) and the total number of individuals of all lepidopteran species (N) (Adja et al., 2014).

$$\boldsymbol{Ar} = \boldsymbol{Ni} * \mathbf{100}/\boldsymbol{N}$$

Five relative abundance classes were defined: very abundant species (Ar ≥ 50%); medium abundant species (10% ≤ Ar <50%); moderate abundant species (5% ≤ Ar < 10%); little abundant species (1% ≤ Ar < 5%); and very little abundant species (Ar < 1%).

In addition, the damage was assessed by visually estimating the plant health status (unattacked and attacked plants) and the degree of damage caused by insect pests on stems, leaves, flowers, and cobs of plants by assigning an index code. Six codes ranging from 0 to 5 were selected (Table 1), adapted from the scoring scale proposed by Sally-Sy (2013). The percentage of plants or cobs attacked per plot. was then calculated according to the damage index.

Table 1. Damage code and scoring adapted from Sally-Sy (2013)

Codes	Damage scoring	Estimated health status
0	No visible damage	No visible attack
1	From 1 to 9% of damage	Isolated attacks
2	From 10 to 24% of damage	Moderate attacks

3	From 25 to 49% of damage	Medium attacks
4	From 50 to 74% of damage	Heavy attacks
5	More than 75% of damage	Plants destroyed

Consequently, a damage intensity index has been calculated to determine the species whose damage is detrimental to the crop. This calculation is inspired by the method of Alene et al. (2006). Depending on the level of attack, percentages were attributed. They were estimated at 10% for plants with isolated attacks, 25% for plants with moderate-level attacks, 50% for those with medium-level attacks, 75% for heavy attacks and 100% for destroyed plants. The damage intensification index (I) was evaluated (Ouali N'goran et al., 2021).

Damage intensification index

$$\boldsymbol{I} = \frac{((N \times 10\%) + (N2 \times 25\%) + (N3 \times 50\%) + (N4 \times 75\%) + (N5 \times 100\%))}{(N0 + N1 + N2 + N3 + N4 + N5)}$$

I: damage intensification index per plot; N0: number of healthy plants; N1: number of plants with low-level of attack; N2: number of plants with moderate-level of attack; N3: number of plants showing medium-level of attack; N4: number of plants showing severe-level attacks; N5: number of destroyed plants.

Five classes of damage intensity index values have been assigned by Alene et al. (2006): low damage $I_1 \leq 10\%$, moderate damage $10\% < I_2 \leq 25\%$, medium damage $25\% < I_3 \leq 50\%$, important damage $50\% < I_4 \leq 75\%$ and high damage $75\% < I_5 \leq 100\%$. Based on this damage ranking, the following categorization of our studied lepidopteran pests has been proposed: Minor pests are those with low damage intensity (I1); important pests are those with moderate to medium damage intensity (I2 and I3); major pests are those with high or very high damage intensity (I4 and I5).

The yield was assessed by weighing the dry grains on 30 plants per elementary plot, using a 2 kg capacity electronic scale.

Data Analysis

The data were analyzed using and STATISTICA 10.1 for Windows. The STATISTICA 10.1 software was used to compute a one-way analysis of variance. In the case of a significant difference (α=0.05), Duncan's test was used to separate insect populations at each stage of the crop's development. The percentage of plants attacked for plant damage was determined according to the damage index.

RESULTS AND DISCUSSION

Results

Species inventory, occurrence, and abundance

Five species of Lepidoptera larvae belonging to three families were collected from the maize plants. The most membered family was the Noctuidae, with three species *Spodoptera frugiperda* (Figure 1a), *Helicoverpa zea* (Figure 1b), and *Sesamia calamistis* (Figure 1c). The other two insects were *Ostrinia nubilalis* Crambidae (Figure 1d) and *Eldana saccharina* Pyralidae (Figure 1e). All these insects are maize plant pests.

Regarding occurrence and relative Abundance, *S. frugiperda* was a frequent (C = 22.9%) and very abundant (Ar = 64.39%) species. Next, *S. calamistis* is an accessory species (C = 5.5%) and moderately abundant (Ar = 15.46%). Other Lepidoptera species were sparse (C < 5%). However, *E. saccharina* was medium abundant (Ar = 10.31%) species, *O. nubilalis* (Ar = 5.15%) was a moderately abundant species, and *H. zea* was a little abundant (Ar = 4.69%) species (Table 2).

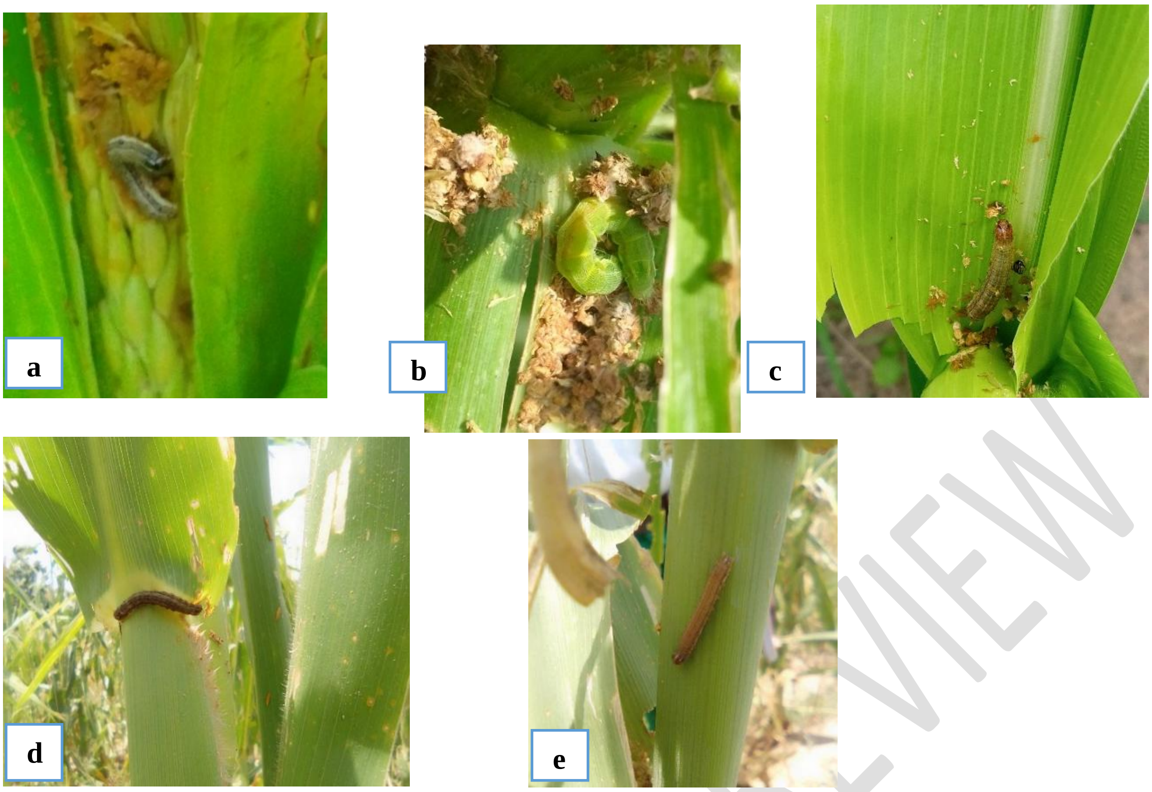

Figure 1. Main Lepidoptera larvae collected on maize plant

Larva of *Spodoptera fruigiperda* (a), Larva of *Helicoverpa zea* (b), Larva of *Sesamia calamitis* (c), Larva of *Ostrinia nubilalis* (d) and Larva of *Eldana saccharina* (e)

Table 2. Inventory, occurrence, and abundance of Lepidoptera larvae collected on maize plants

Families	Species	Occurrence (C)	Relative abundance (Ar)
Noctuidae	*Spodoptera frugiperda*	22.9	64.39
	Sesamia calamistis	5.5	15.46
	Helicoverpa zea	1.67	4.69
Crambidae	*Ostrinia nubilalis*	1.83	5.15
Pyralidae	*Eldana saccharina*	3.67	10.31
03	**05**		**100**

Populations of Lepidoptera larvae and maize development stages

S. frugiperda larvae were present at maize plant emergence, averaging 4.3±1.66 individuals on 30 plants per elementary plot. The larval population of this insect fluctuated from Growth to ripening (Figure 2). Populations were high throughout maize development (3.9±1.43 to 8.1±2.63). *S. calamistis* and *E. saccharina* larval populations decreased from the emergence (2.5±1.32 and 2.55±1.14) to the Fructification (0.2±0.4 and 2.5±1.32) stages. Those species were absent at the maturation (ripening stage). However, *H. zea* and *O. nubilalis* populations were absent during Emergence and Growth (Figure 2). Their larvae appeared during flowering (0.7±0.86 and 0.75±0.78) and increased until maturation (0.8±0.76 and 1.3±0.84), as shown in Figure 2. Moreover, there were significant differences ($p<0.05$) between insect larval populations for a given physiological or phenological stage. Specifically, *S. frugiperda* larvae were significantly more numerous than larvae of other species at all stages of maize development (Table 3).

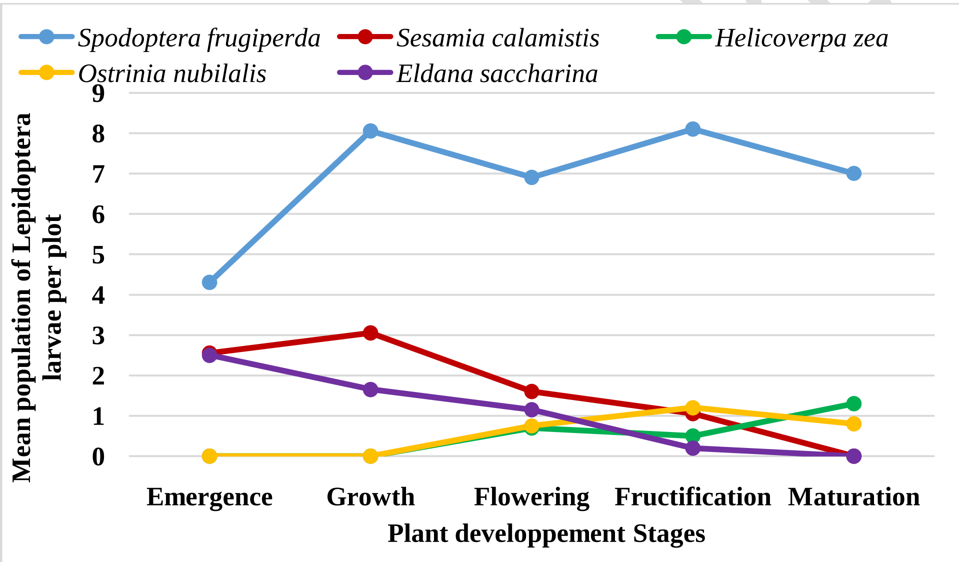

Figure 2. Dynamics of Lepidoptera larvae populations during maize plant development

Table 3. Variability of Lepidoptera larvae populations during maize plant development

	Emergence	Growth	Flowering	Fructification	Maturation
Spodoptera frugiperda	4.30±1.66 [c]	8.05±1.94 [d]	6.9±4.01 [b]	8.1±2.63 [c]	7±2.15 [c]
Sesamia calamistis	2.55±1.14 [b]	3.05±1.8 [c]	1.6±1.63 [a]	1.05±1.03 [b]	0.0±0.0 [a]
Eldana saccharina	2.5±1.32 [b]	1.65±1.35 [b]	1.15±1.08 [a]	0.2±0.4 [a]	0.0±0.0 [a]

Helicoverpa zea	0.0±0.0 [a]	0.0±0.0 [a]	0.7±0.86 [a]	0.5±0.69 [ab]	1.3±0.84 [b]
Ostrinia nubilalis	0.0±0.0 [a]	0.0±0.0 [a]	0.75±0.78 [a]	1.2±1.51 [b]	0.8±0.76 [b]
F	115.613	207.747	32.717	167.922	503.884
P	0,0001	0,00001	0,0001	0,0001	0,0001

According to Duncan's test, means followed by the same letter in a column are not significantly different at the α = 5% level.

5.1.3. Damage severity assessment caused by lepidopteran larvae

During plant emergence, 78.83% of the plants were healthy (code 0), while 21.17% were attacked (code 1 to 5) on all plots (Figures 3a and 3b). These attacks were due to *S. frugiperda*, which caused medium damage (I=32.76), *S. calamistis* (I=12.5), and *E. saccharina* (I=10.9), which provoked moderate damage.

During the maize growth, 67.5% of the plants were healthy (code 0), while 32.5% were attacked (Codes 1 to 5) on all the plots (Figures 3 c and 3d). These attacks were provoked by *S. frugiperda*, which caused high damage (I=61.96), *S. calamistis* with moderate damage (I=14.25), and *E. saccharina* with minor damage (I=6.45).

During flowering, 63% of the plants were healthy (index 0), while 37% were attacked (code 1 to 5) on all the plots (Figure 3e). *S. frugiperda* caused these attacks with high damage (I=50.26), *S. calamistis* with moderate damage (I=10.6) and *E. saccharina* (I=4.9), *H. zea* (I=3.25) and *O. nubilalis* (I=3.1) with minor damage.

During maize fructification, 64.67% of the plants were healthy (code 0), while 35.33% were attacked (code 1 to 5) on all the plots (Figure 3f and 3g). *S. frugiperda* caused these attacks with high damage (I=62.01) and *S. calamistis* (I=2.25), *E. saccharina* (I=0.55), *H. zea* (I=2.95), and *O. nubilalis* (I=6.85) with minor damage.

During maturation, 66.17% of the plants were healthy (code 0), while 33.83% were attacked (index 1 to 5) on all the plots (Figure 3h). S. frugiperda caused these attacks with high damage (I=52.89), *S. calamistis* (I=4.85), *H. zea* (I=6.85), and *O. nubilalis* (I=4) with minor damage.

Table 4. Changes in damage intensity index for Lepidoptera larvae at different stages of maize plant development

Lepidoptera larvae	Emergence	Growth	Flowering	Fructification	Maturation
Spodoptera frugiperda	32.76	61.96	50.26	62.01	52.86
Sesamia calamistis	12.5	14.25	10.6	2.25	4.85
Eldana saccharina	10.9	6.45	4.9	0.55	00
Helicoverpa zea	0	0	3.25	2.95	6.85
Ostrinia nubilalis	0	0	6.85	6.85	4

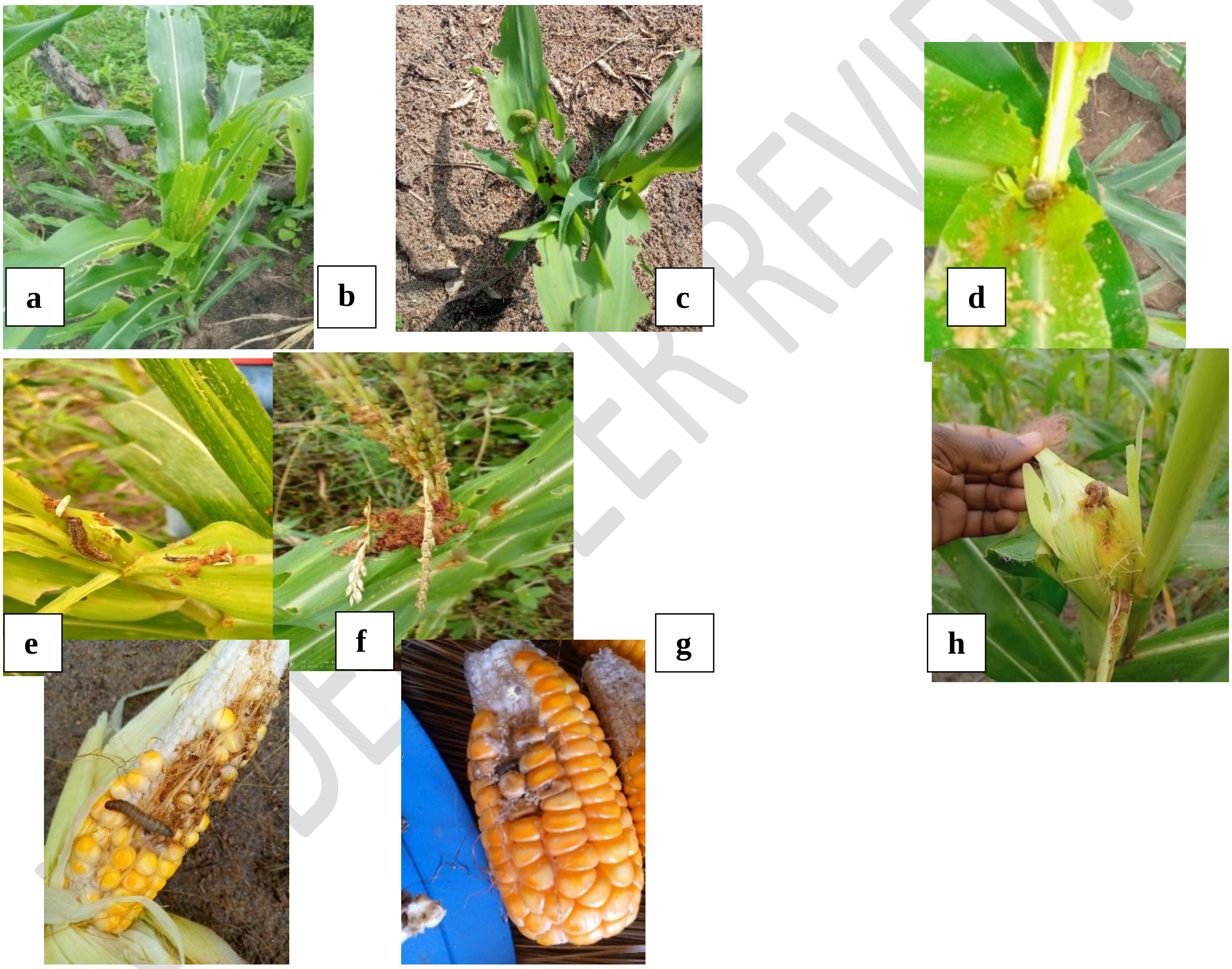

Figure 3. Lepidopteran larvae damage observed on different maize development stages

Damage at Emergence (a ; b), Growth (c ; d), Flowering (e), Fructification (f ; g), and Maturation (h)

5.1.4. Yield assessment

Dry grain yield ranged from 2.4±0.42 t/ha to 2.61±0.71 t/ha. The weight of 100 seeds varied between 32.67±3.05 and 34.67±0.57 g.

5.2. Discussion

This study carried out in Yamoussoukro (central Côte d'Ivoire) revealed five Lepidoptera larvae (*Spodoptera frugiperda*, *Sesamia calamistis*, *Eldana saccharina*, *Helicoverpa zea*, and *Ostrinia nubilalis*) on maize plants. Several Lepidoptera larvae have been reported on maize in Côte d'Ivoire (Bosque-Perez N. A., 1995; Nandjui et al., 2018; Moyal & Tran, 2023). Among the Lepidoptera insects encountered in this study, *S. frugiperda* is the most recent in Côte d'Ivoire. Outbreaks of *S. frugiperda* were first observed in southwest Nigerian maize fields in January 2016 (IITA, 2016) and shortly after that in Benin and Togo (Goergen et al., 2016) and later in Ghana since 2017 (Cock et al., 2017). Depending on the appearance of the migrating adults and climate, *S. frugiperda* can have up to eight generations per year in maize fields in tropical areas (Busato et al., 2005). Seasonal migration is a significant factor in the life history of fall armyworms, and it is considered one of the most mobile noctuid crop pests (Nagoshi & Meagher, 2008). *S. frugiperda* is a highly polyphagous destructive migratory pest (De Almeida et al., 2002; Georgen *et al.*, 2016) and has been established in the whole African continent (CABI, 2023; Kalyebi et al., 2023). The moths generally disperse about 500 km before oviposition, sufficient to colonize various agroecological areas (Senay et al., 2022). Over half (52.5%) of the African maize area is deemed suitable for *S. frugiperda* (Saney et al., 2022). Three of the Lepidoptera larvae encountered in this study were minor pests. They were sparses and medium abundant (*E. saccharina*) or moderate abundant (*O. nubilalis* and *H. zea*). Then, two of the Lepidoptera larvae encountered were important (*S. calamistis*) and major (*S. frugiperda*) pests. *S. calamistis* was accessory and medium abundant. *S. frugiperda* was frequent and very abundant. In Kenya, De Groote et al. (2020) reported that *S. frugiperda* is an important pest that arrived suddenly and spread very quickly, destroying about a third of the harvest and that farmers estimate the losses it causes at about one-third of their maize crop. Almost all of Africa's maize crop is at risk from the devastating fall armyworm pest (*Spodoptera frugiperda*) (CABI, 2023). The authors have highlighted how almost the entire African maize crop is grown in areas with climates that support seasonal infestations of the pest. Moreover, the yield of dried grains varies between 2.4±0.42 t/ha to 2.61±0.71 t/ha. Nandjui et al. (2018) in Côte d'Ivoire, recorded 1.64 to 2.34 t/ha. Balla et al. (2019) in India estimated yields at 1.88 and 1.84 tons/ha during 2018 and 2019, respectively, without accounting for fall armyworm damage. Further, yield losses due to fall armyworm were estimated at 33%. Then, yield loss varied between management strategies, with genetically modified and/or insecticide-treated crops typically retaining higher yields (Overton et al., 2021).

CONCLUSION

Our study aims to monitor the dynamics, determine the importance (frequency and abundance), and assess the damage of Lepidopteran pests of maize. Five species, grouped into three families, were recorded in this study. *Spodoptera frugiperda* was the major pest in maize plants. It was the most frequent and highly abundant species. *Sesamia calamistis* was an important pest, and the other Lepidopteran species (*Sesamia calamistis, Eldana saccharina,* and *Ostrinia nubilalis*) were minor pests. The populations of the insects fluctuated during crop development. The average dried grain yield varied from 2.4±0.42 t/ha to 2.61±0.71 t/ha. Populations of *S. frugiperda* larvae and their damage appear more important than those of other Lepidoptera. Knowledge about the larvae of Lepidoptera maize is the basis for considering an effective and efficient method of managing these pests in order to improve the quality and quantity of maize production.

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