Importance of *Spodoptera frugiperda* among Lepidoptera larvae in maize crops in Yamoussoukro (Côte d'Ivoire)

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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 plots of the farm of the National Institut Polytechnic Houphouët-Boigny in Yamoussoukro. This study aims to monitor the dynamics, determine the importance (frequency and abundance) and assess the damage of Lepidopteran pests of maize. The maize variety EV8728 SR was sown in a completely randomized block pattern with four replicates on 05 September 2020. Insects were collected by direct observation and capture of larvae on the plants. A total of five species grouped into three families, all belonging to the Lepidoptera order, were counted on the plot. *Spodoptera frugiperda* was the most frequent (C = 20.9%) and highly abundant (Ar = 65.79%) species. 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%). Then, three Lepidoptera species (*E. saccharina*, *O. nubilalis* and *H. zea*) were were minor pests (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 of 2.4±0.42 t/ha to 2.61±0.71 t/ha. Populations of *S. frugiperda* larvae and their damage appear to be more important than those of other Lepidoptera. Knowledge of 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.

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

INTRODUCTION

Maize (*Zea mays* L. Poaceae) is one of the most important food crops for both food security and agricultural income of rural populations in West Africa (**Midega *et al*., 2018**). It's also the most important staple food crop grown predominantly by smallholder farmers in sub-Saharan Africa (**Abate et al., 2017**). In this zone, maize occupies more than 36 million hectares of land each year. In Côte d'Ivoire, maize is mainly produced in the Sudanian and Sudano-Guinean zones by smallholder farmers (**Cairns et al., 2013**). This crop is in fact the fifth most important food crop in Côte d'Ivoire by tonnage after cassava, plantain, yam and rice (**FAO, 2022**). National maize production was estimated from 600 000 to 700 000 tonnes per year. However, according to FAO production estimates, and compared to the situation in neighbouring countries, the Ivorian maize sector appears to be rather slowly growing (**RONGEAD, 2014**). Despite large production areas and the importance of maize, the average grain yield is less than 1.8 ton/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 major (**Kfir et al., 2002**). More recently, however, an invasive insect *Spodoptera frugiperda* (Smith) (Lepidoptera : Noctuidae) also known as the fall armyworm, is becoming a major pest causing substantial yield losses on maize in the region (**Goergen et al., 2016 ; Kumela et al., 2018**). This pests 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 also 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 lead to yield losses of 15 to 73% when 55 to 100% of the plants were infested by *Spodoptera frugiperda* (**Hruska & Gould, 1997**). Furthermore, according to **IITA (2016),** *Spodoptera frugiperda* larvae appear to be more damaging on maize in West and Central Africa than most other larvae species. In Côte d'Ivoire, several Lepidoptera larvae have been reported on maize (**Nandjui *et al*., 2018 ; Moyal & Tran, 2023**). Therefore, it's necessary to assess the importance of each Lepidoptera larvae on maize in Côte d'Ivoire. This study aimed to monitor the larval population dynamics, to determine the importance and to assess damage severity of each pests on maize. So, plots were set up and observations were made on plants under natural conditions.

MATERIAL AND METHODS

Experimental design

Twenty (20) elementary plots were set up. The elementary plots covered 81 m^2 (9m x 9m) and were separeted to 2 m apart. Pots were spaced 0.75 m between rows and 0.5 m on the row, giving 13 rows and 19 pots per row. So, we had 247 pots per elementary plot, such as a density of 26 667 per hectare. The sowing of the variety EV8728 SR was carried out on

September 2020 at two seeds per pot. Subsequently, weeding were done manually during the differents stages of plant developpement (emergence, growth, flowering, fructification and maturation).

Data collected

Thirty (30) plants per elementary plot on the central rows, to avoid border effects were observed. Four data were collected : the plants infestation, the damage, the damage severity and the yield. Then, insects were sent to the laboratory for identification. After identification, the occurrence (C) and relative abundance (Ar) of the insects were determined. The occurrence is the ratio of the number of records where the species is found (Pi) to 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%).

The relative abundance expresses the ratio between the number of individuals of a species (Ni) considered and the total number of individuals of all species combined (N) (**Adja et al., 2014)**.

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

They definied five relative abundance classes ; very abundant species (Ar ≥ 50%) ; medium abundant species (10% ≤ Ar <50%) ; moderate abundant species (5% ≤ Ar < 10%) ; little species (1% ≤ Ar < 5%) ; Very little species (Ar < 1%).

In addition, 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. Six index ranging from 0 to 5 were selected based on the scoring scale proposed by **Sally-Sy (2013)** and adapted (Table 1). The percentage of plants or cobs attacked per treatment were then calculated according to the damage indices.

Table 1. Damage severity index (Sally-Sy., 2013) adapted

Index	**Severity damage**	**Observation**
0	No visible damage	No visible attack

1	From 1 to 10% of damage	Isolated attacks
2	From 10 to 25% of damage	Moderate attacks
3	From 25 to 50% of damage	Medium attacks
4	From 50 to 75% of damage	Heavy attacks
5	More than 5% of damage	Plants destroyed

Therefore, a damage intensification index was calculated to determine the species whose damage is detrimental to the crop. This calculation was 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 low level attacks, 25% for plants with moderate level attacks, 50% for those with medium level attacks, 75% for severe level attacks and 100% for destroyed plants. The damage intensification index (I) was evaluated.

Damage intensification index

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

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 attacks ; N5: number of plants showing very severe attacks.

The values of the damage intensity index were grouped into five classes established by Aléne 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 : $50\% < I_4 \leq 75\%$; Highly damage : $75\% < I_5 \leq 100\%$. Based on this classification of the damage, the following categorisation of insect pests has been proposed as minor pests are those with low intensity of damage (I_1) ; important pests are those with moderate to medium intensity damage (I_2 and I_3) ; major pests are those with high or very high intensity of damage (I_4 and I_5). Yield was assessed by the weigh of the dried grains on 30 plots, using an electronic scale with a capacity of 2 kg.

Data Analysis

The data were analysed using Microsoft Excel 2010 and STATISTICA 10.1 for Windows. The STATISTICA 10.1 software was used to perform the analysis of variance. In the case of a significant difference (α=0.05), the Duncan's test was used to identify the different homogeneous groups. For plant damage, the percentage of plants attacked is determined according to the damage indices for each treatment.

RESULTS AND DISCUSSION

Results

Specie inventories, occurrence and abundance

Five species of Lepidoptera larvae belonging three families were collected from the maize plants. The most diverse family is 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* (Figure 1d) Crambidae and *Eldana saccharina* (Figure 1e) Pyralidae. All these insects were maize plants pests. Considering the occurrence and relative abundance, *S. frugiperda* was frequent specie (C = 22.9%) and very abundant (Ar = 64.39%). Then, *S. calamistis* was accessory (C = 5.5%) and medium abundant (Ar=15.46%). The other Lepidoptera species were sparses (C < 5%). Then, *E. saccharina* was medium abundant (Ar=10.31%) while and *O. nubilalis* (Ar=5.15%) was moderate abundant and *H. zea* was little abundant (Ar=4.69%) (Table 2).

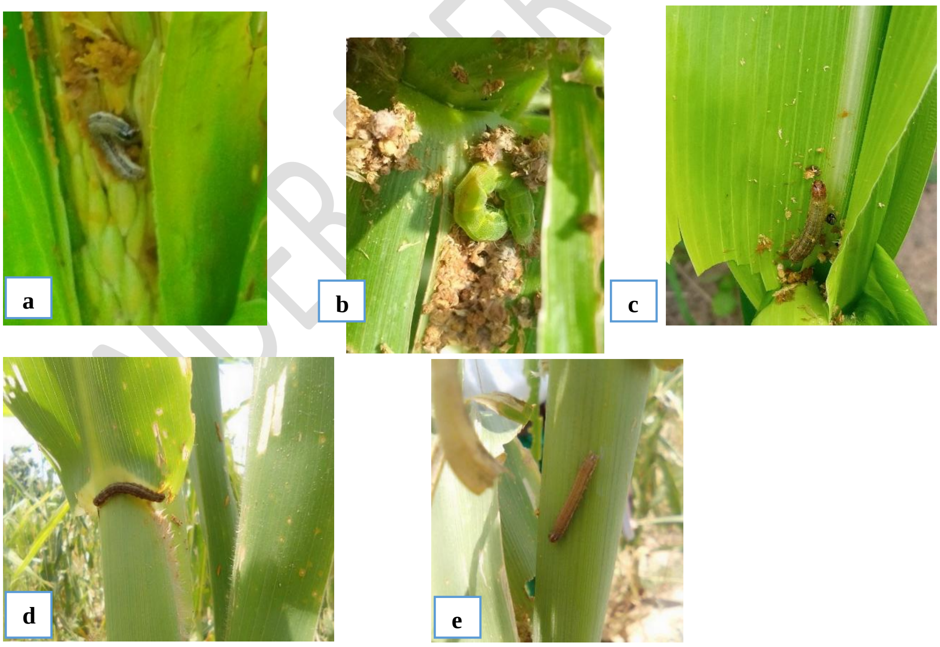

Figure 1. Main Lepidoptera larvae collected on maize plant

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, occurence and abundance of Lepidoptera larvae collected on maize plants

Families	Species	Occurrence	Relative abundance
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**

Evolution of population of Lepidoptera larvae in maize plots

S. frugiperda larvae were present at the emergence of maize plants with a mean of 4.3±1.66 individuals on 30 plants per elementary plot. The larval population of this insect fluctuated from the growth to the maturation (Figure 2). The populations were high during all the maize plant 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). Those species were absent at the maturation. However, the populations of *H. zea* and *O. nubilalis* were absent during the emergence and growth (Figure 2). The larvae of those insects 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) (Figure 2). Furthermore, there were significant differences ($p<0.05$) between insect larval populations. In addition, *S. frugiperda* larvae were significantly higher than the other species larvae at all the maize plant development (Table 3).

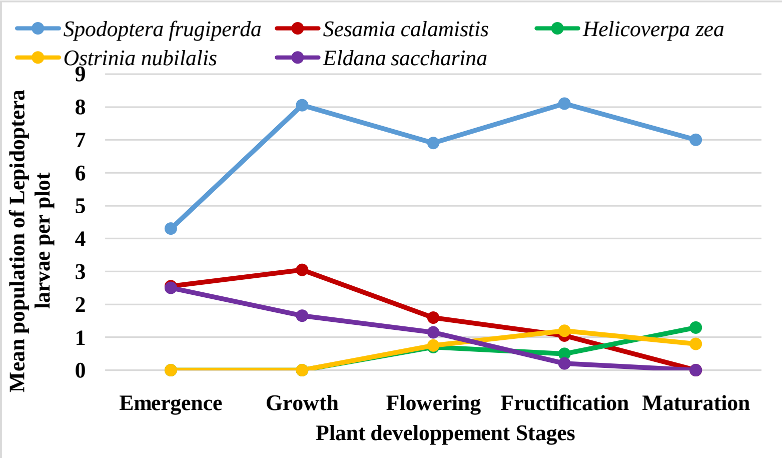

Figure 2. Evolution of the population of Lepidoptera larvae according to maize plant development

Table 3. Mean populations of Lepidoptera larvae per plot according to 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 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 a
Helicoverpa zea	0±0 a	0±0 a	0.7±0.86 a	0.5±0.69 ab	1.3±0.84 b
Ostrinia nubilalis	0±0a	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

5.1.3. Assessment of damage and severity caused by Lepidoptera larvae

During emergence, 78.83% of the plants were healthy (index 0) while 21.17% were attacked (index 1 to 5) on all the plots (Figures 3a and 3b). These attacks were caused by *S. frugiperda* which presented medium damage (I=32.76), *S. calamistis* (I=12.5) and *E. saccharina* (I=10.9) which presented moderate damage. During the growth, 67.5% of the plants were healthy (index 0) while 32.5% were attacked (index 1 to 5) on all the plots (Figures 3 c and 3d). These attacks were caused by *S. frugiperda* which presented high damage (I=61.96), *S. calamistis* with moderate damage (I=14.25) and *E. saccharina* minor damage (I=6.45). During flowering, 63% of the plants were healthy (index 0), while 37% were attacked (index 1 to 5) on all the plots (Figure 3e). These attacks were caused by *S. frugiperda* 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 fructification, 64.67% of the plants were healthy (index 0), while 35.33% were attacked (index 1 to 5) on all the plots (Figure 3f and 3g). These attacks were caused by *S. frugiperda* 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 (index 0) while 33.83% were attacked (index 1 to 5) on all the plots (Figure 3h). These attacks were caused by *S. frugiperda* 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. Damage intensification index of Lepidoptera larvae according to maize plant development

	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

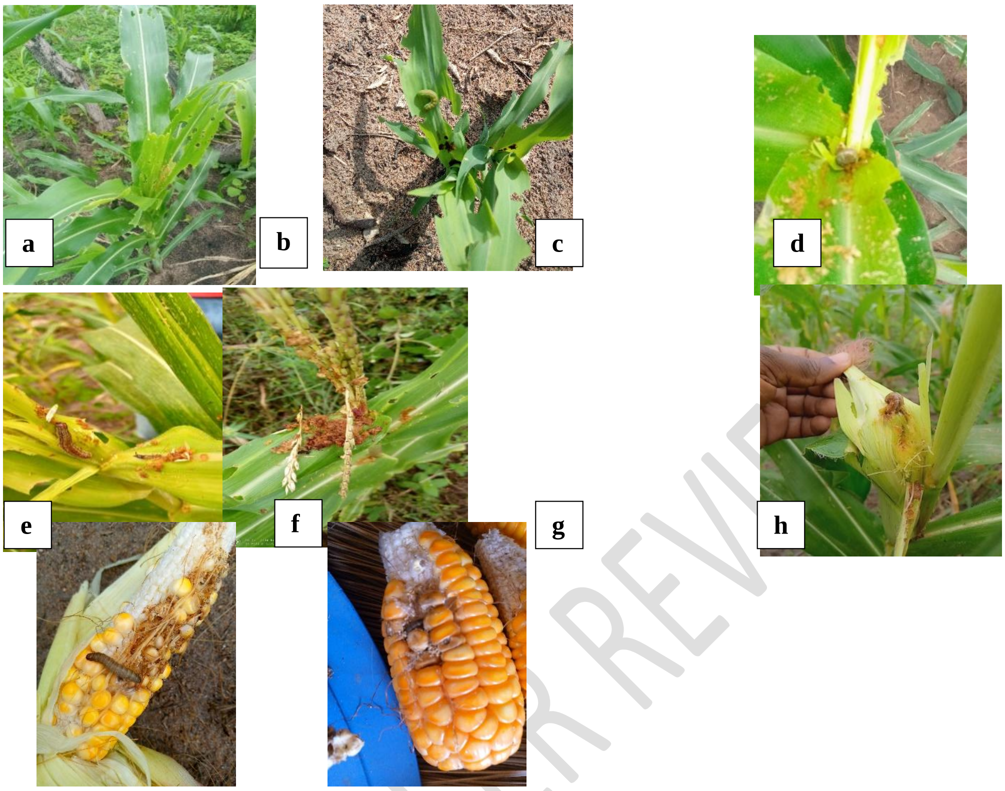

Figure 3. Damage observed on maize at different stages of development

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

5.1.4. Yield assessment

The yield of dried grains varies between 2.4±0.42 t/ha and 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 (centre of 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. In fact, outbreaks of *S. frugiperda* were first observed in southwest Nigerian maize fields in January 2016 (**IITA, 2016**), and shortly thereafter 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, fall armyworm can have up to eight generations per year in maize fields in tropical areas (**Busato et al., 2005**). It did not enter into diapause. Seasonal migration is a major factor in the life history of fall armyworm and it is considered one of the most mobile noctuid crop pests (**Nagoshi & Meagher, 2008**). The fall armyworm is a highly polyphagous destructive migratory pest (**De Almeida et al., 2002 ; Georgen *et al*., 2016**) which have been an established in all the countries of west africa and in the whole Africa continent (**CABI, 2023 ; Kalyebi et al., 2023**). The moths generally disperse about 500 km before oviposition, which is sufficient to move from seasonally and colonise various agroecologycal areas (**Senay et al., 2022**). Starkly, over half (52.5%) of the African maize area deemed suitable for fall armyworm is also at risk from a further nine pests, while over a third (38.1%) of the area is susceptible to an additional 10 pests (**Saney et al., 2022**). Three Lepidoptera larvae were minor pests. They were sparses and medium abundant (*E. saccharina*) or moderate abundant (*O. nubilalis* and *H. zea*). *S. calamistis* was important pest. It was accessory and medium abundant. *S. frugiperda* was major pest. It 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**). This organization 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, obtened 1.64 to 2.34 t/ha. **Balla et al. (2019**) in India, estimated yield at 1.88 and 1.84 tons/ha, during 2018 and 2019 without accounting for fall armyworm damage. Further, yield losses due to fall armyworm was 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

This study aims to monitor the dynamics, determine the importance (frequency and abundance) and assess the damage of Lepidopteran pests of maize. It's revealed five species grouped into three families, were counted on the plot. This study showed that *Spodoptera frugiperda frugiperda* was the major pest on maize plant. It was the most frequent and highly abundant species. *Sesamia calamistis* was 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 of 2.4±0.42 t/ha to 2.61±0.71 t/ha. Populations of *S. frugiperda* larvae and their damage appear to be more important than those of other Lepidoptera. Knowledge of 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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