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Varietal Tolerance of Maize (*Zea mays* L.) Crops to *Spodoptera frugiperda* (Lepidoptera: Noctuidae) Infestation in Northern Benin (West Africa)

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Abstract

This study aims to evaluate in a real environment, the susceptibility of frequently cultivated varieties (SYNEE 2000, TZE, local) to infestation by the *Spodoptera frugiperda* caterpillar. For this, 12 experimental plots were installed in the Atacora department at the rate of 3 plots in Cobly, 3 plots in Matéri-Centre, 3 plots in Matéri-Porga and 3 plots in Tanguiéta. Observations (symptoms and damage) and collections (larvae counting) were carried out on 30 plants per plot, at a rate of one plant per pocket. At flowering-fruiting, the presence or absence of the pest was also checked on each ear, and finally the yield per hectare was determined for each of the varieties selected. Of the three varieties, SYNEE 2000 is the most cultivated with a high cultivation frequency (75 to 100%) in the study area. It is noted that *S. frugiperda* caterpillars cause significant damage to vegetative and fruiting organs. The damage recorded on the leaves is of high incidence. For local varieties, the yield varied from 0.82 to 1.76 t/ha, or an average of 1.31 ± 0.26

t/ha. For the SYNEE 2000 variety, the yield varied from 1.4 to 2.8 t/ha, or an average of 2 ± 0.36 t/ha. For the TZE variety, the yield varied from 1.5 to 2.4 t/ha, or an average of 2.02 ± 0.27 t/ha. Considering all the damage and yields, the SYNEE 2000 variety is the most profitable and the most tolerant, on the other hand the TZE is the least tolerant and the most attacked by *S. frugiperda.*

Keywords: *Zea mays, S. frugiperda,* tolerance, yield, Benin.

Introduction

Maize, the world's leading cereal crop, is one of the thirteen sectors selected in the Strategic Plan for the Recovery of the Agricultural Sector in Benin (PSRSA) by the Ministry of Agriculture, Livestock and Fisheries (MAEP) to be promoted to ensure food security and economic growth in Benin (MAEP, 2011). The dominant position of maize in Africa in general and in West Africa in particular has been favored by its adaptability to agro-ecological conditions and by its strategic roles as both a cash crop and a high-consumption product. In Benin and in most West African countries, maize constitutes the basis of the diet of rural populations. It is used for human and animal consumption and serves as a raw material in certain industries (brewing, soap making and oil making) (Boone *et al*., 2008; Adégbola *et al.*, 2011). Corn is the main cereal used in the diet of populations (ONS, 2010). It is the most energetic cereal (Charcoss and Gallais, 2009), due to its nutritional benefits (rich in starch, presence of proteins, minerals) and the most economical from a production point of view (crop simple to produce, harvest and store) (Nuss and Tanumihardjo, 2011).

In Benin, maize (Zea *mays* L.) is the main cereal grown by producers, and even maize production has spread to cotton-growing areas in the northern regions. The production volume crossed the 800,000-ton mark in 2004 and 1 million tons in 2009. Maize production in Benin has recorded significant growth over the last forty years. It increased from 230,000 tons in the early 1970s to more than 1,345,820 tons in 2013. The same is true for yield, which increased from an average of 600 kg/ha in 1970 to 1.4 t/ha in 2009 (Semassa *et al*., 2016). About fifteen maize varieties with different agronomic characteristics are cultivated in Benin. The maize grain yield showed that the most productive variety is TZPB SR-W which produces 4 T/Ha in a rural environment, and the least productive varieties are SYNEE 2000 and TZEE-W with 2.5 to 3 T/Ha in a rural environment (MAEP, 2016; Dato, 2010; Semassa *et al*., 2016).

Despite the importance and potential of this sector, maize cultivation faces significant agronomic constraints such as declining soil fertility, diseases and pests that reduce production (FARE, 2004). Indeed, pests are a significant constraint in maintaining and improving maize productivity, but their control is still based on chemical control (Madjebi Collela, 2018) with its harmful effects on the environment. These include the stem-boring insects *Eldana saccharina* Walker and *Sesamia calamistis* Hampson. To these has recently been added *Spodoptera frugiperda* JE Smith, a voracious and polyphagous species even more devastating than the former (Goergen *et al*., 2016; Schmidt-Durán *et al*., 2015; Murúa *et al*., 2009). This fall armyworm can cause significant yield losses of up to 21-53% (FAO, 2018; Prasanna *et al*., 2018). In Benin, the most recent case is the invasion of maize fields which caused a lot of damage despite chemical control (Dassou *et al*., 2021).

The fall armyworm or American corn borer is native to tropical and subtropical regions of the Americas and was first reported in 2016 in Africa (FAO *et al*., 2017; FAO, 2016; Goergen *et al*., 2016; IITA, 2016) and causes significant damage to maize crops. First detected in Benin in August 2016, the Beninese press put forward the figure of 30,000 to 40,000 ha of maize destroyed in the regions of northern Benin. According to FAO (2018), the armyworm threatens the food security of more than 300 million people in Africa, mainly

small farmers. Faced with these situations, recognizing the damage caused by this pest and finding effective control methods are a priority to ensure development and food security. For this, experiments deserve to be conducted in order to identify varieties tolerant to attacks by *Spodoptera frugiperda.* In addition, in view of the disadvantages of chemical control, varietal resistance or tolerance appears to be an increasingly favored component in sustainable pest management (Adango *et al*., 2021; Chiriboga Morales *et al*., 2021). However, very little documentation exists to date on the differential behavior of maize varieties with regard to their susceptibility to *S. frugiperda.* It is therefore important to evaluate in a real environment, the susceptibility of frequently cultivated varieties to caterpillar infestation in order to propose them for further studies for their integration into integrated pest management methods. This is what justifies the present study entitled: "Varietal tolerance of maize (*Zea mays* L.) crops to *Spodoptera frugiperda* (Lepidoptera: Noctuidae) infestation in northern Benin (West Africa)". The general objective of this study is to contribute to the preservation of the diversity of varieties or cultivars in the fight against *Spodoptera frugiperda* in the north of Benin. The specific objectives are: (i) compare the leaf characteristics of the different varieties studied; (ii) assess the extent of damage caused by *Spodoptera frugiperda* on cultivated maize and the varietal tolerance of maize in northern Benin; and (iii) compare corn yields obtained according to varieties.

Materials and Methods

Study area

This study was conducted in the Atacora department located in the northwest of Benin (Figure 1), characterized by a unimodal rainfall regime with two seasons, including a rainy season from May to October and a dry season from November to April (Akoègninou *et al*., 2006). Average annual rainfall varies between 900 and 1100 mm of water per year. The average temperature fluctuates around 27°C. The highest temperatures are recorded between March and April, with a maximum of 37°C, while the minimum is 15°C and is observed between December and January. The soils are of tropical ferruginous type. The vegetation is composed mainly of wooded savannah, wooded savannah and shrub savannah, gallery forest and relict patches of dense dry forest and open forest (Akoégninou *et al*., 2006). The Atacora range, with an average altitude of 700 metres, whose summit is located at Boukoumbé (835 m), represents the water tower of Benin, from which flow the great rivers of Benin and Togo (Ouémé, Mono, Mékrou, Pendjari and Oti, Kérou or Kouamongou, etc.).

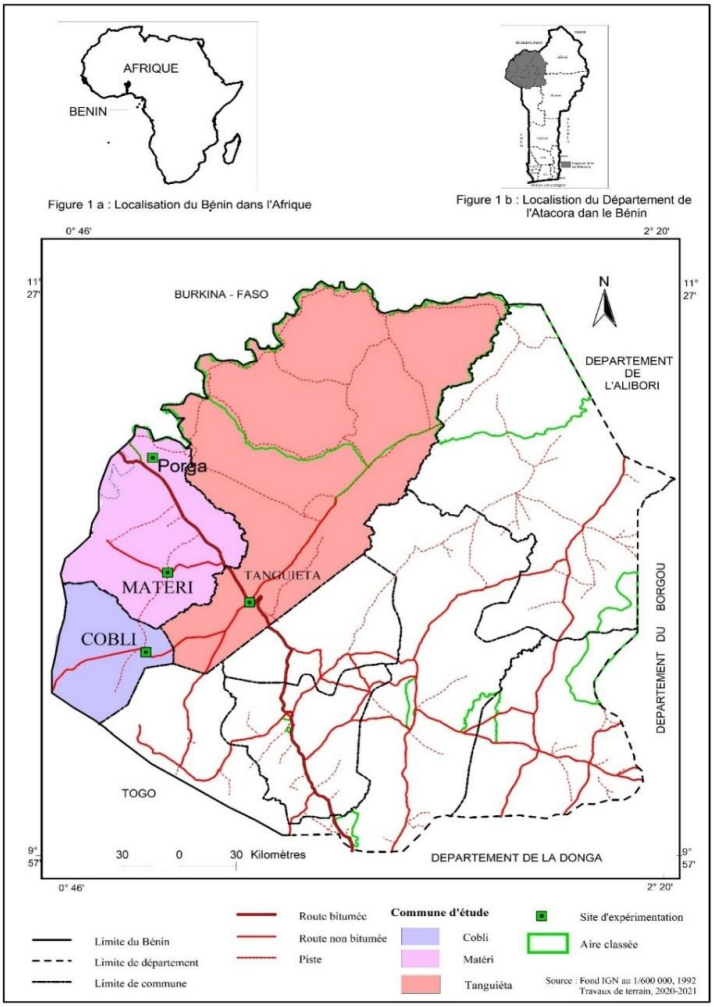

Figure 1: Location of Benin, the Atacora department and the surveyed sites

Data collection

In the context of this study, four sites were selected based on the differential climate trend: Cobly, Matéri-Centre, Matéri-Porga and Tanguiéta. In total, 12 experimental plots were selected: tree plots in Cobly, tree plots in Matéri-Centre, tree plots in Matéri-Porga and tree plots in Tanguiéta. The technical itineraries adopted were those used by the majority of producers in the tree municipalities concerned. For the 12 plots, plowing was carried out at the beginning of the rainy season and manual sowing was carried out one week after plowing (end of May) at a depth of 3 to 5 cm. Before the actual sowing, it was essential to check the germination power of the seeds. The spacings used are: 0.80 m between rows and 0.40 m between plants. Maintenance operations are limited to weeding and rational fertilization. No phytosanitary treatment was applied.

Data analysis

S. frugiperda infestation was determined on three varieties commonly grown in these municipalities. These are: SYNEE 2000, TZE and the local variety. For this purpose, observations (symptoms and damage) and surveys (larvae counting) were carried out on 30 plants per plot, at a rate of one plant per pocket. These observations were made every 7 days after sowing until the ears matured. To assess the extent of pest damage to maize plants, leaf damage was

observed and assessed using scores or indices from 0 to 3, where: 0 = zero damage; 1 = 10% to 25% damage; 2 = 25% to 50% damage; and 3 = 50% to 75% damage. At each visit, the number of maize plants with leaves freshly consumed by *S. frugiperda* was determined. At flowering-fruiting, the presence or absence of the pest was also checked on each ear. The amount of corn harvested per plot was obtained by despathing, drying, shelling and weighing 1000 grains with an electronic scale to determine the grain yield per plot; and then, this yield was reported per hectare.

The extent of damage caused by *Spodoptera frugiperda* on the maize crop and its yield was assessed for each of the varieties selected. A comparison was then made to determine the variety most tolerant to this pest. The percentage or rate of infestation of maize plants was determined by calculating the ratio between the number of plants infested or harboring the pest. The incidence of damage was assessed by variety and the percentages of damaged leaves, bored stems, destroyed inflorescences and attacked ears were determined. The average of the recorded values was therefore determined for each variety and for each observation phase. Tests of equality of means and proportions were carried out to compare the average values two by two. Analyses of variance (ANOVA) were carried out taking into account the variables: varieties, plots, observation phases, yields, municipalities. The yield for each variety was a function of the number of plants/ha, number of ears per plant and number of grains per ear.

Results

Comparison of leaf characteristics according to varieties

Across the study area, the number of maize leaves varied significantly from one variety to another ($p<0.01$; $p<0.05$). For local varieties, the number of leaves varied from 5 to 23 leaves, or an average of 12.06 ± 3.45 leaves. For the SYNEE 2000 variety, the number of leaves varied from 6 to 18 leaves, or an average of 11.37 ± 2.21 leaves. For the TZE variety, the number of leaves varied from 8 to 14 leaves, or an average of 11.05 ± 1.53 leaves (Table 1). The average number of leaves for local varieties is statistically higher than the average number of leaves for the improved varieties SYNEE 2000 and TZE ($p < 0.05$). However, the latter have numbers that are statistically similar ($p > 0.05$).

Table 1: Distribution of the number of leaves according to the varieties

Experimental sites	Corn varieties	Mean number of leaves per plant ± Standard error	Minimum number of leaves per plant	Maximum number of leaves per plant
Tanguieta	SYNEE 2000	11.10 ± 1.38	8	13
	TZE	11.05 ± 1.53	8	14
Cobly	LOCAL	12.09 ± 3.42	6	21
	SYNEE 2000	13.23 ± 1.53	10	17
Matéri-Centre	LOCAL	14.13 ± 3.35	7	23
	SYNEE 2000	10.99 ± 2.26	7	18
Matéri-Porga	LOCAL	9.94 ± 2.03	5	14
	SYNEE 2000	10.16 ± 1.93	6	14
Study area	LOCAL	12.06 ± 3.45 [a]	5	23
	SYNEE 2000	11.37 ± 2.21 [b]	6	18
	TZE	11.05 ± 1.53 [b]	8	14

For the study area, mean values followed by different superscript letters are significantly different ($p < 0.05$) from one site to another and those with the same letters are similar ($p > 0.05$).

Estimation of damage by *Spodoptera frugiperda* on maize crops and varietal tolerance

The number of leaves damaged by *S. frugiperda* varied significantly from one variety to another ($p<0.01$; $p<0.05$). For local varieties, the number of damaged leaves ranged from 0 to 18 leaves, with an average of 3.13 ± 3.47 leaves. For the SYNEE 2000 variety, the number of damaged leaves ranged from 0 to 8 leaves, with an average of 1.97 ± 2.10 leaves. For the TZE variety, the number of damaged leaves ranged from 0 to 6 leaves, with an average of 2.76 ± 2.06 leaves (Table 2). The average number of damaged leaves for the SYNEE 2000 variety was statistically lower than the average number of damaged leaves for the TZE and local varieties ($p<0.05$). However, the latter have numbers that are statistically similar ($p > 0.05$). In addition, the percentage of attacked leaves is 26% for local varieties, 25% for TZE and 18% for SYNEE 2000. We deduce that the foliage of the improved variety SYNEE 2000 is much more tolerant to *S. frugiperda* caterpillars.

Table 2: Distribution of the number of ravaged leaves according to the varieties

Experimental sites	Corn varieties	Mean number of damaged leaves per plant ± Standard error	Minimum number of leaves damaged per plant	Maximum number of leaves damaged per plant
Tanguieta	SYNEE 2000	2.77 ± 2.06	0	6
	TZE	2.76 ± 2.06	0	6
Cobly	LOCAL	2.37 ± 3.10	0	16
	SYNEE 2000	1.68 ± 1.99	0	8
Matéri-Centre	LOCAL	5.31 ± 3.90	0	18
	SYNEE 2000	2.53 ± 2.41	0	8
Matéri-Porga	LOCAL	1.71 ± 2.03	0	8
	SYNEE 2000	0.97 ± 1.30	0	5
Study area	LOCAL	3.13 ± 3.47 [a]	0	18
	SYNEE 2000	1.97 ± 2.10 [b]	0	8
	TZE	2.76 ± 2.06 [a]	0	6

For the study area, mean values followed by different superscript letters are significantly different ($p < 0.05$) from one site to another and those with the same letters are similar ($p > 0.05$).

Regarding damage or ravages caused by *S. frugiperda* caterpillars, lesions, perforation (presence of holes on the leaves, galleries in the stems and fruits), cutting and consumption (presence of shredded material and droppings) were observed (Figure 2).

Figure 2: Photos of some damage caused by *S. frugiperda* caterpillars

Table 3 shows the extent of this damage to the aerial organs of maize varieties. The number of *S. frugiperda* observed per plant varied from 0 to 6 caterpillars in local varieties and 0 to 5 caterpillars in improved varieties. The damage observed on the ears and inflorescences is of a large magnitude on the TZE variety, respectively 52% and 68% of the plants. On the other hand, the magnitude is less (less than 30%) and similar on the other SYNEE 2000 and local varieties. Similarly, the damage observed on the stems and leaves is of a large magnitude on the TZE variety, respectively 71% and 72% of the plants. On the other hand, the magnitude is average (less than 60%) and similar on the other SYNEE 2000 and local varieties. *S. frugiperda* caterpillars cause significant damage to the vegetative and fruiting organs of the TZE variety. On the other hand, the SYNEE 2000 and local varieties are the most tolerant. Overall, the damage recorded on the leaves is of high incidence.

Table 3: Extent of damage observed on corn plants

Extent of damage		**LOCAL**	**SYNEE 2000**	**TZE**
Number of *S. frugiperda* per plant	**Min. to max.**	0 to 6	0 to 5	0 to 5
	Avg.	1 ± 1	1 ± 1	2 ± 2
Percentage of plants with ears destroyed by *S. frugiperda*		6%	19%	52%
Percentage of plants with inflorescences destroyed by *S. frugiperda*		15%	23%	68%
Percentage of plants with stems damaged by *S. frugiperda*		17%	26%	71%
Percentage of plants with destroyed leaves		58%	52%	72%

Figure 3 shows the relationship between the number of caterpillars recorded per plant and the damage indices recorded on the leaves for all growth stages. For each variety, the linear regression analysis reveals a significantly positive relationship between the pest population and the extent of damage on the leaves, with a high coefficient of determination. Furthermore, it is clear from this figure that the incidence of damage increases as the number of caterpillars increases, regardless of the growth stage and the variety.

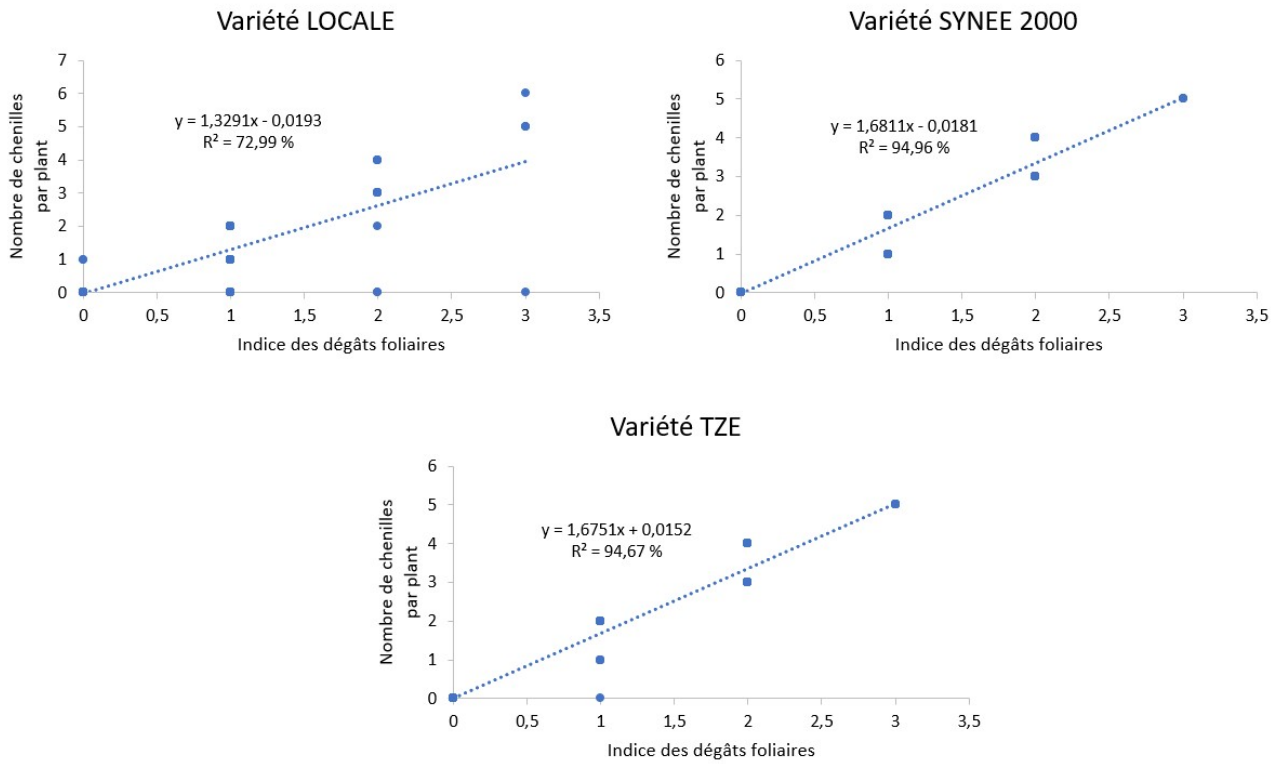

Figure 3: Relationship between the number of caterpillars recorded per plant and leaf damage indices

Comparison of corn yields obtained according to varieties

Maize yields varied significantly among varieties ($p<0.01$; $p<0.05$). For local varieties, yield ranged from 0.82 to 1.76 t/ha, or an average of 1.31 ± 0.26 t/ha. For the SYNEE 2000 variety, yield ranged from 1.4 to 2.8 t/ha, or an average of 2 ± 0.36 t/ha. For the TZE variety, yield ranged from 1.5 to 2.4 t/ha, or an average of 2.02 ± 0.27 t/ha (Figure 4). The mean comparison test reveals that the average yields of local varieties are statistically lower than the yields of the improved varieties SYNEE 2000 and TZE ($p < 0.05$). The SYNEE 2000 variety has the highest yields.

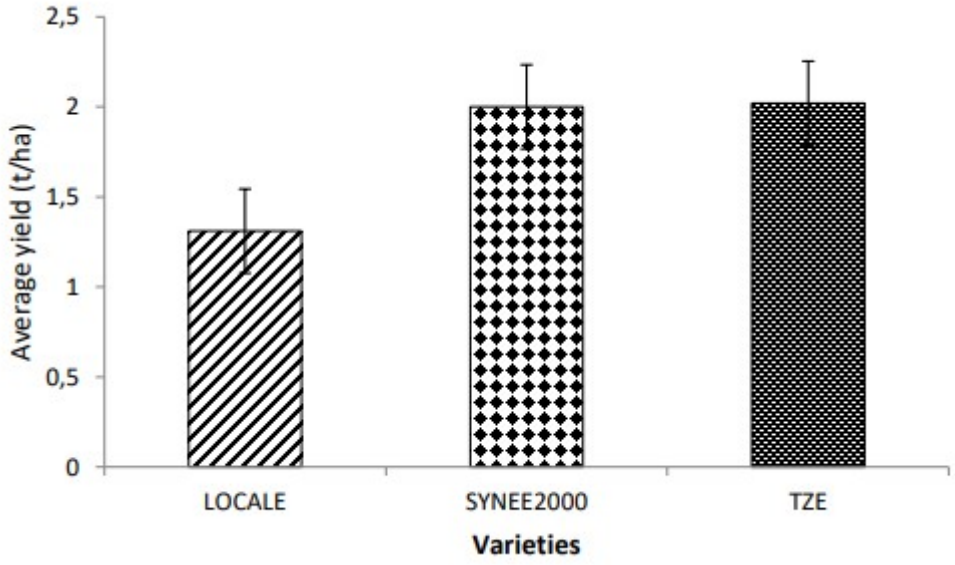

Figure 4: Distribution of average yields according to varieties

Discussion

This study investigated the performance of maize varieties in the face of *S. frugiperda* attack under natural conditions. These were the local varieties, SYNEE 2000 and TZE. The latter two are improved varieties and considering their sowing-to-maturity cycle, SYNEE 2000 (80 days) is earlier than TZE (90 days) (MAEP, 2016). The study identified maize varieties resistant and/or tolerant to *S. frugiperda attacks,* in the search for better yields despite the damage observed. The results of the study show that none of these three varieties is completely resistant to *S. frugiperda*; however, the degree of susceptibility to the pest varies from one variety to another. Depending on the different stages of development, the population dynamics of the pest and the extent of damage revealed that the TZE variety was the most attacked by *S. frugiperda* while SYNEE 2000 and locale were the most tolerant with low and statistically similar infestation rates. Similar results were obtained in the Sudanian zone by Mbaidiro *et al*. (2021) which reveal the susceptibility and vulnerability of TZE varieties to *S. frugiperda.* In addition, early varieties would be less attacked because they would have already passed through their stage of vulnerability before the outbreak of said pest. This could justify the tolerance of SYNEE 2000. Furthermore, this difference in susceptibility could also be explained by the morphological characteristics of the varieties tested. However, the average numbers of *S. frugiperda* caterpillars recorded in *Zea mays* during our study are significantly lower than the average numbers recorded by Mbaidiro *et al*. (2021) in Chad. These differences could be explained by the sampling technique adopted, climatic changes from one region to another or the resistance of varieties from one region to another.

This study identified the damage caused by *S. frugiperda caterpillars* on maize. They corroborate those of Yoboue *et al*. (2022) who showed the impact of *Spodoptera Frugiperda attacks* on the production of 3 maize varieties in Ivory Coast. They also revealed that *S. frugiperda* caused significant damage to maize leaves. The results of our research also confirm those of Tchao *et al*. (2022), Dassou *et al*. (2021), Kumela *et al*. (2019) who showed that the severity of the damage is greater at the vegetative stages of the plant. Indeed, the noctuid *S. frugiperda* is a highly polyphagous insect and the most significant damage is observed on cereals in general and corn in particular. It is the larval stage that causes damage to crops. Young larvae feed deep in the whorls; the first two stages feed gregariously on the underside of young leaves. *S. frugiperda* caterpillars appear to be much more damaging to maize in West and Central Africa than most other African *Spodoptera* species (IITA, 2016). They attack all aerial parts of maize: stems, leaves, flowers, and ears (Figure 5). On young plants, the larvae feed inside the cornium of plants. Maize leaves are eaten, and the cornium (funnel) may be perforated and filled with brown larval excrement, with the edges of young leaves shredded. Young plants may be cut at the base by the larvae. Mature plants, on the other hand, are attacked on the reproductive organs (flowers and ears). The flowers are destroyed and the ears are attacked by the larvae which burrow between the grains (Munene, 2018; Maiga, 2017; Maiga *et al*., 2017; Madougou *et al*., 2017; Ali *et al*., 2016).

This study reveals that the yields obtained from local varieties are statistically lower than the yields obtained from the improved varieties TZE and SYNEE 2000. The latter is the most productive, i.e. 2.8 t/ha in traditional cultivation. This result is linked to the damage caused by *S. frugiperda* which is less on this variety (SYNEE 2000). In addition, it should be noted that the average yields obtained for SYNEE 2000 and TZE are close to the expected yields (2.5 to 3 t/ha) in a farming environment (MAEP, 2016). Our results are similar to those of Houngbo *et al*. (2020) who estimated a yield loss linked to *S. frugiperda attacks* at 49% of the total yield, causing enormous economic losses (Abro *et al*., 2021). Protection of maize crops against *Spodoptera Frugiperda* has been shown to be effective with insecticides such as PlantNeem and Viper 46 EC in Benin (Adeye *et al*., 2018). According to these authors, the insecticides Viper 46 EC at a dose of 1 l.ha $^{-1}$ and PlantNeem at a

dose of 4.5 l.ha $^{-1}$ had a positive impact on maize production following the reduction of the *S. frugiperda population* . Similarly, the decrease in the incidence of pests is illustrated by the low rates of perforated ears. In Togo, several control methods are based mainly on the use of chemical pesticides, namely Emacot (Emamectin benzoate 50 g/kg) and Thiodalm (Acetamipride 20 g/L + Bifenthrin 20 g/L). The biological alternatives used are neem seed powders and ash slurries. The production costs of one hectare of maize have increased considerably and have gone from 171,511 to 246,407 CFA francs due to the additional expenses related to pest management (Tchao *et al*., 2022). The majority of producers therefore use chemical control methods against *S. frugiperda* against a minority who adopt endogenous practices for managing the caterpillar (Tchao *et al*., 2022, Urge *et al*., 2020). This trend would be justified by the accessibility of chemical pesticides and their acquisition costs. Furthermore, there is a high rate of use of unregistered chemical pesticides to control *S. frugiperda* (Kumela *et al*., 2019).

Figure 5: Damage caused by *Spodoptera frugiperda* caterpillars on corn plants (left) and ears of corn (right) (CABI, 2017)

Conclusion

This study evaluated some maize varieties on infestation by the fall armyworm *S. frugiperda* in northern Benin, specifically in the Atacora department. The results showed that none of the tested varieties is totally resistant to *S. frugiperda*. However, the SYNEE 2000 variety, which was already the most widely grown in the area, gave the best yields and good tolerance to the attack of this pest. It could therefore be favored in the preventive control of *S. frugiperda* in Benin. Local varieties also showed good tolerance but with low yields. On the other hand, TZE is the least tolerant and the most attacked by *S. frugiperda.* Hypothesis 1, according to which improved varieties bear fewer leaves than local varieties, is verified. Hypothesis 2, according to which *S. frugiperda* caterpillars cause significant damage to the vegetative and fruiting organs of maize and local varieties are more tolerant, is partially verified. Hypothesis 3, according to which maize yields at the level of improved varieties are higher than at the level of local varieties, is verified.

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