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Evaluation of three biopesticides on the invasive pest *Spodoptera frugiperda* Smith, 1797 (Lepidoptera: Noctuidae), infesting maize crops (*Zea mays* L., 1753) in upper Casamance

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ABSTRACT

The invasion of the pest, *Spodoptera frugiperda* in Senegal in 2017, has increased pest pressure on crops. The excessive use of pesticides leads to harmful effects on the environment. Thus, the objective of this study is to compare the effectiveness of biopesticides with that of chemical molecules currently used on *S. frugiperda*. The work was carried out at the support center for Pre-extension and Multilocal Experimentation of Velingara, in Haute Casamance, in a Fisher block system. The efficacy of biopesticides (*Bacillus thuringiensis* var *kurstaki*, and *Spodoptera frugiperda* Multiple Nucleopolyhedrovirus (SfMNPV)) as well as that of the hydro-ethanolic extract of *Ocimum gratissimum* was evaluated. It was compared to that of an absolute control and a combination of chemical molecules, Emamectin benzoate 20 g/l combined with Lufenuron 80 g/l (EBL) used as a reference control. The results showed that the three bio-insecticides *B. thuringiensis*, SfMNPV and *O. gratissimum* extract are toxic on *S. frugiperda* larvae with efficacy rates of 70%, 52% and 64%, respectively. However, SfMNPV is less effective than the reference control. All these bio-insecticides have also effectively reduced the damage of the pest on plants, especially *B. thuringiensis*, which has an effectiveness equivalent to that of EBL. As for the damage to the harvested ears, *B. thuringiensis* and *O. gratissimum* have a suitability comparable to EBL. However, SfMNPV, although as effective as other bio-insecticides, is less marked than EBL in reducing ear damage. This study demonstrates the effectiveness of bioinsecticides used on *S. frugiperda*.

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INTRODUCTION

Corn (*Zea mays* L., 1753) is one of the main staple crops in sub-Saharan Africa (SSA). It is used in many forms, especially in food and animal feed. Maize is a major source of calories, contributing about 19% of per capita energy intake on average (OECD/FAO, 2018). Due to rapid population growth, the demand for maize is increasing more and more in SSA (Ekpa *et al.*, 2018). In Senegal, as in most countries of the Sahel, it is one of the main food crops (Bassene, 2014). It occupies a very important place in household food consumption with levels of 15 kg/head/year or more (Niang *et al.*, 2017). Its production in the 2018/2019 agricultural season is estimated at 410,364 t, an increase of 16% compared to the previous year and 63% compared to the average of the last 5 seasons (DAPSA, 2018).

However, maize cultivation is limited, among other things, by many abiotic and biotic constraints (Bassene, 2014). Currently, it is strongly threatened by the Fall Armyworm (FAW), *Spodoptera frugiperda* Smith, 1797 (Lepidoptera: Noctuidae). The invasive pest in Africa since 2016, was found in Senegal in 2017 (Ndiaye, 2017; Brevault *et al.*, 2018). In emergency response to the invasion of *S. frugiperda* different chemical insecticides have been recommended by African governments (Kumela *et al.*, 2018; Baudron *et al.*, 2019). However, these recommended insecticides have effects on non-target organisms and risks to the environment. Especially since maize is a crop intended for consumption, it is therefore a public health problem (Sisay *et al.*, 2018). In addition, repeated and prolonged use of synthetic chemical insecticides can lead to the selection of resistant populations. Faced with these constraints, it is necessary to find alternatives to these insecticides (Yarou *et al.*, 2017). Active ingredients of bacterial, viral and plant origin are often used for this purpose.

It is in this context that the present study aims to compare the effectiveness of biopesticides on *Spodoptera frugiperda* with that of chemical molecules currently used.

MATERIALS AND METHODS

Presentation of the study site

Localization

The trial was carried out at the Support Point for Pre-Extension and Multilocal Experimentation (PAPEM) in Vélingara, a department in the Kolda region (ANSD, 2015) (Fig. 1). Agro-ecologically, the Kolda region corresponds to Haute Casamance or Fouladou.

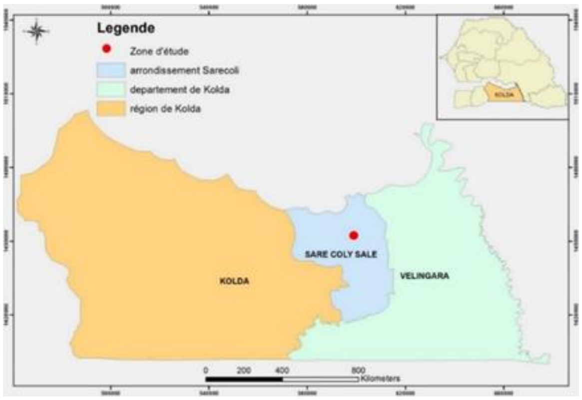

Fig. 1. Localisation de la zone d'étude

It is located in the northern zone. Like the Middle and Lower Casamance, Upper Casamance belongs to the natural region of Casamance, one of the six agro-ecological regions of Senegal. It is characterized by forests, rivers and streams (Sané *et al.*, 2008 ; HEA-Sahel, 2014).

In terms of climate, Haute Casamance is located in the southern Sudanian zone. It is characterized by a dry season and a rainy season. The latter begins for the most part in the second half of June and ends during the first half of October. Haute Casamance is considered to be one of the rainiest regions in Senegal (Sané *et al.*, 2008). Average rainfall varies from 700 to 1300 mm with maximum intensity in August and September. The lowest average monthly temperatures are recorded between December and January and vary from 25 to 30°C, the highest between March and September with variations of 30 to 40°C (ANSD, 2015).

In Haute Casamance, the relief is made up of sandy-clayey sandstone forming plateaus (ANSD, 2015). The soils are strongly ferruginous and noticeably clayey (Akpo *et al.*, 2000).

Experimental equipment

Plant material

The suwan variety of *Zea mays* L. was used as a host plant during the study. The plant is 200 cm tall, marked by the presence of a spike well covered with spathes and whose kernels are orange-yellow in colour. Maturity takes place between 90 and 100 jas giving a yield of 3 to 4 t/ha. This variety is grown during the rainy season (ISRA, 2012; CEDEAO-UEMOA-CILSS, 2016).

Active ingredients used

Bacillus thuringiensis var. *kurstaki* (Btk), *Spodoptera frugiperda* Multiple Nucleopolyhedrovirus (SfMNPV) and the hydro-ethanol extract of *Ocimum gratissimum* were used as bioinsecticides to be evaluated. The active ingredients Emamectin benzoate 20 g/l in combination with Lufenuron 80 g/l (EBL) were the reference combination.

The different doses of insecticides used are 0.15 l/ha; 1.5 l/ha; 0.1 l/ha, 58.59 l/ha for (EBL), Btk, SfMNPV and *O. gratissimum* respectively. For the first three products, the doses are applied according to the manufacturer's recommendations.

Methods

Experimental design

The experimental design chosen for this study is a complete randomization block or Fisher block of five (05) objects with four (04) replicates, with an area of 890 m2. This area was made up of 20 elementary plots. Each elementary plot had 5 crop lines of 10 m. Each row and plot had 50 and 250 maize plants respectively out of a total of 5000 plants. The cultivation pattern was 80 cm x 20 cm, i.e. a spacing of 80 cm between the rows and 20 cm between the pockets. The spacing between the blocks was 1.5 m. The objects in comparison were: the one made up of the plots not subjected to any foliar application, the one treated with an insecticide based on Emamectine benzoate 20 g/l + Lufenuron 80 g/l, the one treated with *Bacillus thuringiensis* var. *kurstaki*, that of those treated with *Spodoptera frugiperda* Multiple Nucleopolyhedrovirus (SfMNPV) and that of those treated with the hydro-ethanol extract of *Ocimum gratissimum*.

Phytosanitary treatment

Extraction of Ocimum gratissimum molecules: The leaves were harvested in the morning at the Agricultural Research Center (CRA) in Tambacounda. Preparation begins 24 hours before application. It was carried out as follows: weighing on an electronic scale (Accuracy = 0.01), rinsing and pounding of the leaves with a mortar before mixing them in a solvent containing 70% ethanol (96%) and 30% water. This mixture was filtered after being left to rest for 12 hours. For 1 kg of fresh leaves, a volume of 4 l of hydro-ethanolic solution was used. For this study, a mass of 0.25 kg was used for each application. This resulted in a solution applied at a rate of 58.59 l/ha.

Carrying out processing: Insecticide treatments were applied from the 30th to the 75th day after maize emergence using a knapsack sprayer with sustained pressure dispensing 60 to 150 litres of spray per hectare.

Three (03) sprayers were used to carry out the foliar applications: one (01) for the chemical; one (01) for biopesticides and one (01) for botanical extract.

A total of six (06) foliar (T) applications were made, at 07-day intervals, with the products to be evaluated and the reference product. As each elementary plot has 5 lines, the 3 plants have been treated to avoid product drift. Similarly, to avoid the degradation of the products by ultraviolet rays, the applications were made at the end of the day.

Sampling : Observations were made weekly to monitor the effect of different active ingredients on *S. frugiperda* caterpillars. They took place the day before each treatment and 3 days after. The methodology adopted consisted of sampling 30 plants per elementary plot, on the 3 central lines, according to the fictitious diagonal method. A group of 10 consecutive plants was chosen from each row. Therefore, during each observation a number of 600 out of 3000 plants was sampled. Observations focused on:

1. The number of live *S. frugiperda* caterpillars when examining the entire plant;
2. The number of plants attacked: the plant is considered attacked if it has skeletal leaf patches, whitish spots, small squares or attacked spikes.

To estimate the impact of the caterpillars, at harvest, according to the different objects compared, ten (10) ears were randomly taken from the central line of each elementary plot. The ears attacked among the 10 selected were counted.

Data processing

Parameters studied: The sampling carried out made it possible to determine the following parameters:

Biological efficiency : It expresses the rate of reduction in infestations and/or damage due to pests after application of insecticides. It is estimated according to the following formula:

Biological Efficacy = [(Average Pest Infestation Level, Untreated Plot – Average Infestation Level on Treated Plot) *100/Average Infestation Level on Untreated Plot].

Impact of attacks : It expresses the rate of damage due to pests. It is estimated according to the following formula:

Attack incidence = (number of plants attacked*100) / total number of plants observed.

Statistical analysis

The records of the numbers of caterpillars and plants attacked, from the various observations, were entered using the Microsoft Office Excel 2016 spreadsheet and the curves drawn from the R software version 3.5.2. The statistical tests were also carried out using the R software.

Thus, comparison tests were carried out in order to find out whether or not there are significant differences between the means of the different treatments. The test was done using a generalized linear mixed model for a two-to-two comparison of the modalities. The Poisson distribution, which allowed the data to be adjusted as best as possible, was applied.

Previously, the Shapiro-Wilk normality test and the Leven variance homogeneity test were applied to the data. The analysis focused on the average number of caterpillars observed on the 30 plants and the average number of plants attacked. The difference is considered significant when the probability (p) is less than 5% ($p < 0.05$), highly significant when $0.01 < p < 0.001$ and very highly significant when $p > 0.001$.

RESULTS

Biocidal effect of different bioinsecticides on *Spodoptera frugiperda*

Analysis of the results reveals that foliar applications, with the bacterial synthesis *Bacillus thuringiensis* var. *kurstaki* (Btk), *Spodoptera frugiperda* Multiple Nucleopolyhedrovirus (SfMNPV) viral synthesis and *Ocimum gratissimum* hydroethanol extract kept *Spodoptera frugiperda* infestation low. The average number of caterpillars per 30 plants is statistically higher in untreated plots (2.83±2.81) (Fig. 2).

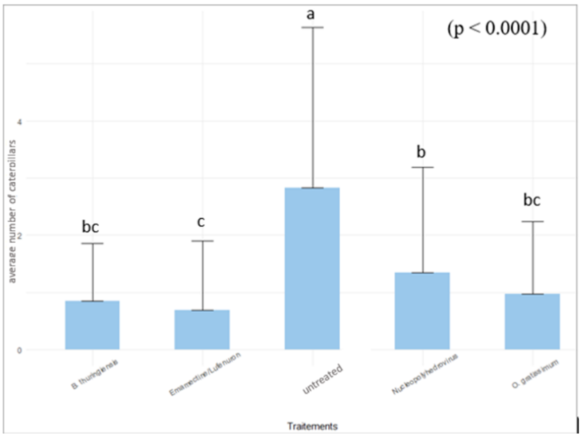

Fig. 2. Average track levels for different objects

On the other hand, it was significantly lower in the treated plots ($p < 0.0001$) with Emamectin benzoate associated with Lufenuron (EBL) (0.70±1.21 caterpillars on average), Btk (0.85±1.01), *O. gratissimum* (0.98±1.26) and SfMNPV (1.35±1.26). Thus, there is no significant difference between EBL, Btk and *O. gratissimum* ($p > 0.05$). SfMNPV (1.35) maintains the level of infestation in the same way as other biopesticides but is statistically less effective than the chemical EBL.

Biological efficacy of natural compounds for the management of *S. frugiperda*

Applications of Emamectin benzoate + Lufenuron reduced armyworm infestation levels by 76% (Table 1). For bio-insecticides, Btk also has an efficacy of 70% while SfMNPV has a lower rate, compared to the others. This viral synthesis reduced the infestation by 52%. As for the hydorthanol extract of *O. gratissimum,* it recorded a 65% ability to reduce the level of infestation (Table 1).

Table 1. Biological efficacy of the different active ingredients on the caterpillar *Spodoptera frugiperda*

Treatments	Biological Efficacy (%)
Emamectin + Lufenuron	76
Bacillus thuringiensis	70
Nucleopolyhedrovirus	52
O. gratissimum	65

Impact of *Spodoptera frugiperda* larvae on the crop

Impact of attacks on corn plants

The analysis of Table 2 reveals that the number of plants attacked in the untreated plots is significantly higher than that recorded in the treated plots ($p < 0.0001$).

Table 2. Level of damage to the plant in the different treatments bio-insecticides

Treatments	Averages	Impact (%)
Emamectin + Lufenuron	0.88±0.80 c	2,93
B. thuringiensis	1.42±1.27 bc	4,73
Nucleopolyhedrovirus	1.96±1.56B	6,53
O. gratissimum	1.56±1.04B	5,20
Untreated	4.17±3.19 to	13,90
P<0.0001 (very highly significant)		

Indeed, Btk (1.42±1.27), SfMNPV (1.96±1.56) and *O. gratissimum* (1.56±1.04) statistically have the same ability to reduce damage to plants. However, EBL (0.88±0.80) reduces damage significantly better than SfMNPV and *O. gratissimum* even though it has the same efficiency as Btk.

The incidence corresponds to the rate of plants with damage caused by *Spodoptera frugiperda*. Thus, the untreated plots have the highest incidence (13.90%) in contrast to the treated plots where it is 4.73% for Btk, 5.20% for *O. gratissimum* and 6.53% for SfMNPV. For the reference control (BLT), an incidence of 2.93% was noted.

Impact on corn cobs at harvest

The results (shown in Table 3) show that the number of attacked ears is significantly higher in the untreated plots (7.00±2.45) compared to the treated plots ($p < 0.0001$). Also, the reduction of the impact of the caterpillar on maize cobs by *O. gratissimum* and Btk is statistically as important as that of EBL ($p > 0.05$). SfMNPV has the same efficacy as other bio-insecticides. However, it is significantly less effective than the chemical EBL.

Table 3. Spike damage level in different treatments bio-insecticides

Treatments	Averages	Impact (%)
Emamectin + Lufenuron	2.75±0.5c	27,50
B. thuringiensis	3.75±0.96bc	37,50
O. gratissimum	3.50±1.00bc	35,00
Nucleopolyhedrovirus	5.00±1.63b	50,00
Untreated	7.00±2.45a	70,00
P<0.0001 (very highly significant)		

The incidence in the control plots is 70.00%. It is lower in the treated treatments where it is 27.50%, 35.00%, 37.50% and 50.00% in EBL, *O. gratissimum*, Btk and SfMNPV treatments respectively.

DISCUSSION

The study conducted at the Vélingara experimental station, in the agro-ecological zone of Haute Casamance, consisted of comparing the effectiveness of the biocides *Bacillus thuringiensis* var. *kurstaki* (Btk), *S. frugiperda* Multiple Nucleopolyhedrovirus (SfMNPV) and the hydro-ethanolic extract of leaves of *Ocimum gratissimum* on the fall armyworm, *Spodoptera frugiperda* to those of the chemical molecules currently used, in particular the combination of Emamectine benzoate + Lufenuron.

In this survey, the products evaluated showed good insecticidal activity against the invasive pest, *S. frugiperda*.

The average number of caterpillars on plots treated with *Bacillus thuringiensis* Var. *kurstaki* is significantly lower than that of the untreated plot (P<0.0001). This could reflect a reduction in the number of larvae by the insecticide Btk. These results are consistent with those of Monnerat *et al.* (2007), by Pinto *et al.* (2010), by dos Santos *et al.* (2021) and Priyanka *et al.* (2021) who have found toxicity in many isolates of *B. thuringiensis* (Bt) whose strain *B. thuringiensis kurstaki* with regard to *S. frugiperda*. Indeed *B. thuringiensis* is a bacterium that secretes toxins with insecticidal effects such as Cry which is very effective against lepidoptera *S. frugiperda* (Koch *et al.*, 2015 ; Silva *et al.*, 2016; Martínez de Castro *et al.*, 2017). The study of dos Santos *et al.* (2009) found that the most toxic Cry proteins for *S. frugiperda* are Cry1Aa, Cry1Ab and Cry2Aa. After ingesting the bacteria, the proteins bind to specific receptors in the insect's gut, oligomerize and form spores in the cell membranes of the gut. This results in osmotic shock, lysis and the eventual death of the intestinal epithelial cell, and therefore of the caterpillar (Koch *et al.*, 2015). These observations are consistent with the results obtained which show the effectiveness of the Btk biocide with a 70% reduction capacity in the number of caterpillars.

Just like *B. thuringiensis,* the application of *S. frugiperda* Multiple Nucleopolyhedrovirus (SfMNPV) in *Z. mays* had a significant effect on the decrease in the number of *S. frugiperda*, with a biological efficiency of 52%. These results confirm the work of Vieira *et al.* (2012), by Erayya *et al.* (2013), by Cuartas-Otálora *et al.* (2019), and those of Lei *et al.* (2020).

Nucleopolyhedroviruses are pathogenic viruses in most lepidoptera. SfMNPV is specifically effective on *S. frugiperda* in whom it leads to death and then liquefaction. Indeed, after ingestion of SfMNPV, the polyhedron dissolves in the middle intestine where the released virions will penetrate and multiply in the intestinal cells before invading the others. Following the infection, the insect dies, the tissues rupture, releasing the adhesion polyhedra of virions (Vieira *et al.*, 2012 ; Erayya *et al.*, 2013).

The effectiveness of hydroethanolic extract of *Ocimum gratissimum* in the control of *S. frugiperda* was found to be very markedly different between the treated plot (0.98±1.26) and the absolute control (2.83±2.81). In general, this effectiveness can be explained by the nature, chemical structure and action of its terpene constituents, including thymol (Benabdelkader, 2012; Kobenan *et al.*, 2018). In fact, studies have shown the presence of *O. gratissimum* active compounds such as p-cymene, γ-terpinene and thymol which are monoterpenes (Tchoumbougnang *et al.*, 2009; Kobenan *et al.*, 2018; Monteiro *et al.*, 2020). Monoterpenes are known for their insecticidal power. They are thought to act on the central and peripheral nervous system, particularly at the level of gamma-aminobutyric acid (GABA) and acetylcholinesterase receptors, which have synaptic function, and the octopaminergic system, interfering with neuromodulation and insect hormones (Zhou *et al.*, 2008; Gonzalez-Coloma *et al.*, 2013). The results obtained confirm those of Kul *et al.* (2013) and Yarou *et al.* (2018) that prove the high toxicity of the main constituent of *Ocimum gratissimum*, thymol, on lepidoptera *Chilo partellus, Helicoverpa armigera*, *Tuta absoluta* and *Spodoptera litura,* species of the same genus as *S. frugiperda*. More recent studies by Monteiro *et al.* (2020) shows the insecticidal power of thymol on *S. frugiperda*. These same authors and Chowdhary *et al.* (2018) have been able to show that thymol acts as an acute toxic substance, deterrent to egg-laying, ovicide, larvicide and repellent. More broadly Cruz *et al.* (2016) and Monteiro *et al.* (2020) confirm the toxicity of *O. gratissimum* on *S. frugiperda* through its oil, where instead of thymol only there is a synergy of monoterpenes (92.1%) and sesquiterpenes accentuating the biocidal effect of *Ocimum gratissimum*.

The two-by-two mean comparison test carried out showed that statistically there is no difference between *Bacillus thuringiensis* (70%), *Ocimum gratissimum* (65%) and the reference control Emamectin benzoate associated with Lufenuron (EBL). The absence of any significant difference between the two bio-insecticides and the synthetic product indicates that the molecules contained in these bio-insecticides, although of a different nature (microbial, plant-based), have a biocidal activity equivalent to or close to that of the combination of chemical molecules (Emamectin, benzoate + Lufenuron). That lack of difference is also explained by the fact that those active ingredients (microbial and plant) belong to the group of biopesticides as highlighted by Bateman *et al.* (2018). These authors define and divide biopesticides into three groups, namely: biochemical biopesticides such as insect growth regulators (Lufenuron) and fermentation products (Emamectin benzoate); microbial biopesticides and macrobials. The molecule Emamectine benzoate is the result of the fermentation of a bacterium *Streptomyces avermitilis*. It has been synthesized in chemical formulation (Ioriatti *et al.*, 2009; Guo *et al.*, 2016).

However, the results indicate that Emamectine benzoate + Lufenuron (with 76% biological efficacy) acts significantly better on the reduction of caterpillars, pests, pests, etc. *Spodoptera frugiperda* Multiple Nucleopolyhedrovirus (which reduces infestation by 52%). This difference is thought to be due to the presence of fairly advanced larvae (L4-L6) in the test plots. However, SfMNPV is almost effective only on young instar larvae (L1, L2 and L3).

Indeed Rios-Velasco *et al.* (2012) specify that mortality is even higher (65.05%) in the first instar (L1) larvae. On the other hand, the combination (Emamectin benzoate + Lufenuron) is very toxic on old larvae where mortality can reach even 100% with Emamectin benzoate only (El-Sheikh, 2015; Metayi *et al.*, 2015 ; Eldesouky *et al.*, 2019). On the other hand, the bio-efficacy of nucleopolyhedroviruses under real-world conditions is sometimes limited by the germicidal action of ultraviolet radiation, sunlight and the substrate environment and thus reduce the power of viruses to kill the pest (Armenta *et al.*, 2003 ; Cuartas-Otálora *et al.*, 2019).

At the beginning of the infestation, damage is observed at the level of the foliage and then at the level of the panicle in formation. Then, in the heading stage, the caterpillars migrate to the ears. They penetrate the ears through the bristles or pierce the husks on the side or bottom of the ears.

The reduction in damage observed in the treated plots would first result in a significant reduction in the number of caterpillars, thus limiting the damage rate.

On average, *Bacillus thuringiensis*, *Spodoptera frugiperda* Multiple Nucleopolyhedrovirus and *Ocimum gratissimum* statistically have the same ability to reduce the damage caused by the ravager to plants. This result can be explained by the fact that bio-insecticides such as *O. gratissimum* have a food deterrent action thanks to the presence of thymol (Kul *et al.*, 2013).

Btk and SfMNPV, by also invading intestinal cells, prevent the caterpillars from taking up food before they die. However, the greater efficacy of Emamectin Benzoate + Lufenuron compared to *O. gratissimum* and SfMNPV to reduce damage would be due on the one hand to the combination of the two active ingredients. Indeed, these active ingredients are effective for older caterpillars, unlike SfMNPV (El-Sheikh, 2015; Metayi *et al.*, 2015; Eldesouky *et al.*, 2019). However, these caterpillars cause more damage to the crop than young caterpillars.

On the other hand, both molecules are fast-acting and therefore kill the pest before it has time to cause significant damage.

The calculated incidence follows the same trend with approximately the same incidence in objects *Ocimum gratissimum* (5,20%) and *Bacillus thuringiensis* (4,73%). The lowest damage rate is recorded with EBL. An incidence of 13.90% was noted in the untreated control. This impact is low compared to that obtained following the work of Baudron *et al.* (2019) in Africa, which show an incidence of *S. frugiperda* from 32% to 48% in the fields of *Zea mays*. This difference is certainly due to the fact that the study of Baudron *et al.* (2019) was carried out in a real environment where many conditions such as weeding are not respected for the most part. However, weeding reduces the incidence as highlighted by these last authors.

The present study shows the effectiveness of bio-insecticides *Bacillus thuringiensis*, *Spodoptera frugiperda* Multiple Nucleopolyhedrovirus and *Ocimum gratissimum* to reduce the number of ears attacked at harvest in the same way as the combination of chemical molecules (Emamectin, benzoate + Lufenuron). This effectiveness of biopesticides is, in part, linked to their mode of action. These insecticides, like EBL, act by contact and or ingestion (Erayya *et al.*, 2013; Koch *et al.*, 2015; Ochou *et al.*, 2018). Thus, thanks to these actions, the biocidal substances can reach the caterpillar that feeds inside the ear, once out and in contact with the external husks or foliage. The less proven efficacy of SfMNPV compared to EBL would certainly be linked to the sensitivity of the Nucleopolyhedrovirus to ultraviolet radiation which does not allow the caterpillar inside the ear to be in contact with the virulent SfMNPV virus. Especially when the insecticide has taken enough time for the insecticide to come into contact with the caterpillar.

CONCLUSION

At the end of this study, the results obtained indicate that the invasive pest *Spodoptera frugiperda* was well controlled by the application of the biocides *Bacillus thuringiensis* var. *kurstaki, Spodoptera frugiperda* Multiple Nucleopolyhedrovirus and the hydro-ethanolic extract of leaves of *Ocimum gratissimum*.

B. thuringiensis and *O. gratissimum extract* have shown an ability to control the number of caterpillars in the same way as the chemical insecticide (Emamectin benzoate + Lufenuron).

It also emerges from the study that the damage caused by armyworm on maize plants as well as on ears was significantly reduced by the various bio-insecticides. *Bacillus thuringiensis* and *Ocimum gratissimum extract*, which are as effective as Emamectine benzoate in combination with Lufenuron, can better reduce the damage of the pest.

Thus, the results obtained are important and mean that the bio-insecticides used would constitute a solid basis in the search for alternatives to chemical control.

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