BIOLOGICAL VERSUS CHEMICAL CONTROL OF FALL ARMYWORM AND LEPIDOPTERA STEM BORERS OF MAIZE (*ZEA MAYS*)

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ABSTRACT

Insect pests are serious constraints to production of maize. There is little information on the control measures against those insects in Cameroon. This study was carried out to identify the different species of fall armyworm and stem borers of maize and test the efficacy of different control methods. The maize variety ATP (Acid Tolerant Population) was used in a randomized complete block design. Synthetic insecticides, lambda cyalothrine and cypermethrin, were applied at one and two weeks intervals at the recommended doses of 2 L/ha and 1.5 l/ha respectively. Bio insecticides: Neem oil (*Azadirachta indica*), and aqueous extracts of *Chenopodium ambrosioides* leaves were applied weekly at the doses of 1.40 L/ha and 6.80 L/ha respectively. The different larvae recorded were the fall armyworm (*Spodoptera frugiperda)* and stem borers (*Busseola fusca* and *Sesamia calamistis*). All the treatments used in this study had significant effects on the number of pupae, the tunnels and the number of perforations on stems of the maize. The Neem oil at one-week interval was more effective in reducing the incidence (81, 21%) and severity (61, 54%) at 76 Days After Planting of the attack by the caterpillars as well as on the number of larvae (14, 82%) throughout the trial.

Key words: maize, insecticides, stems borers, *Spodoptera frugiperda,* Fall army worm

RESUME

*LUTTE BIOLOGIQUE ET CHIMIQUE CONTRE LES CHENILLES LÉGIONNAIRES ET LES LÉPIDOPTERES FOREUSES DE TIGE DU MAÏS (*ZEA MAYS*)*

*Les insectes ravageurs constituent une contrainte sérieuse dans la maïsculture au Cameroun, cependant il existe peu d'informations sur les méthodes de lutte contre la chenille légionnaire d'automne (*Spodoptera frugiperda*) et les lépidoptères foreurs de tiges du maïs. Cette étude a été menée dans le but d'identifier les différentes espèces de foreurs de tiges et de chenilles légionnaires du maïs, et de tester l'efficacité de différentes méthodes de lutte. La variété de maïs ATP (*Acid Tolerant Population*) a été utilisée, dans un dispositif en blocs complètement randomisés. Les insecticides de synthèse, lambda cyalothrine et la cypermethrin, ont été appliqués à une et à deux semaines d'intervalle aux doses recommandées de 2 L/ha et 1,5 l/ha respectivement. Les bio-insecticides : huile de Neem (*Azadirachta indica*) et l'extrait aqueux des feuilles de (nom commun ? harmonisez comme indiqué pour le neem)* Chenopodium ambrosioides *ont été appliqués à une semaine d'intervalle aux doses de 1,40 L/ha et 6,80 L/ha. La chenille légionnaire du maïs* Spodoptera frugiperda *et les foreurs de tiges (*Busseola fusca *et* Sesamia calamistis*) ont été inventoriées. Tous ces insecticides ont eu un effet significatif sur le nombre de pupes, les galléries et le nombre de trous sur les tiges du maïs. L'huile de Neem a été la plus efficace dans la réduction de l'incidence (81, 21%) la sévérité de l'attaque par les chenilles (61,54%), ainsi que sur le nombre de larves (14,82%) pendant toutes les périodes.*

***Mots clés** : Maïs, Insecticides, Foreurs de tiges,* Spodoptera frugiperda*, chenille légionnaire d'Automne.*

INTRODUCTION

Maize (*Zea mays* L.) is the most cultivated cereal in the world followed by rice and wheat (FAO 2017a) for its high nutritional value because of its carbohydrate content. (Undie *et al.* 2012; FAO 2017a).

It is the most important cereal in Cameroon and it is grown across the five agro-ecological zones. In Cameroon, maize has a wide range of uses: in the fresh form, it can be roasted and boiled; in the dry form (approximately 15% moisture content), the grain can be crushed to produce flour. Also the maize kernels can be used for the production of beer and starch (Agora, 2007).

The stem borers are serious biotic constraints in cereals production across Africa causing between 20 and 40% of yield losses during the cultivation period, and between 30 to 90% during storage (Wahedi *et al.* 2016). The losses may result from mechanical damages of the grains. The feeding habits of these insects can reduce the photosynthetic surface area of the leaves, which results in low yields. Lepidoptera larvae feed on the aerial parts of maize. The feeding nature of the Lepidoptera larvae can cause growth disruption (dead hearts), interupt translocation of nutrients, cause the deformation of grains etc (kfir *et al.* 2002). The damages on the grains caused by stem borers can also expose the grains to infestations pre and post-harvest by beetles during storage, infections by *Aspergillus flavus* Link and *Fusarium verticillioides* SACC (Nirenberg) and the subsequent contaminations by mycotoxins such as aflatoxins and fumonisins (Ndemah and Schulthess 2002).

Fall army worm is a voracious pest and polyphagous in nature (Pogue, 2002). Unlike most of the other insect species of *Spodoptera* in Africa, the mandibles of the fall armyworm are comparatively strong, with saw-tooth and cutting edge. Theses charactristics facilitates the cutting and chewing of the maize plants (Pogue, 2002). In addition, the adult females of *S. frugiperda* directly lay their eggs on the maize (Sarmento *et al.* 2002) leading to economic losses.

In 2016, the fall armyworm (*Spodoptera frugiperda*) invaded tropical Africa beginning from West Africa and spread up to South Africa and is now in at least 38 African countries including Cameroon (Abrahams *et al.* 2017; Stokstad 2017; Cock *et al.* 2017 Fotso *et al*., 2019). In one year, an estimated 300,000 hectares of maize in sub- Saharan Africa was severely damaged by this pest that attack both the leaves and the ears resulting in dramatic yield losses (Wild 2017). The young larvae feed on the inside of the folded leaves of maize plants. Older larvae may cut the base of the plant. Mature plants are subjected to an attack on reproductive organs (silk and tassel) (Jarrod *et al.* 2011; Goergen *et al.* 2016). The insect pest consumes leaves of maize and penetrates the maize funnel filling it with faeces of larvae. At the beginning of the season, the feeding habits of the larvae causes serious damages to the young plant, by destroying its meristem causing the dead heart of maize. At high densities, the older larvae can act as army and migrate in the form of bands, but they often remain in the surroundings on wild grasses if present.

Although the control of these insect pests with synthetic insecticides remains until today the most widespread practice, it is often ineffective and the frequent misuse of these insecticides has led to the emergence of insect resistance to several classes of pesticides (Goergen *et al.* 2016). It has become, thus, necessary to evaluate new products on the effectiveness in controlling this pest.

Recently, attention is being given to the use of bio pesticides in controlling insect pests both in the field and during storage. This is regarded as environmentally friendly and reduces the cost of production. It is readily available and easily affordable, which is an important factor for the farmers in developing countries (Maddoni *et al.* 2006). The objective of this study was to assess the effectiveness in using synthetic insecticides, bio pesticides, most especially Neem oil from neem (*Azadirachta indica*) and the aqueous extracts of leaves of *Chenopodium ambrosioides* in controlling these pests. The specific objectives were to (i) identify the different species of fall armyworm and stem borers of maize, and (ii) test the effectiveness of different biological products in controlling the incidence and severity of the attack by these pests.

MATERIALS AND METHODS

SITE OF STUDY

This study was conducted in the western region of Cameroon, at the Institute of Agricultural Research for Development (IRAD), Dschang from April to November 2017. It is located between latitudes 5°25' and 5°30' north, and between longitudes 10°0' and 10°5'. It is at an elevation of 1380m above sea level. It has an equatorial type of climate, characterized by an average annual temperature of 20.8°C with thermal amplitude of 2°C. The precipitation varies between 1433 and 2137mm per year. This ecology is characterized by a short dry season, which goes from mid-November to mid-March, and a long rainy season that runs from mid-March to mid-November.

PREPARATION OF EXTRACTS

Neem Oil Extract

the seeds of neem collected were washed with tap water and then dried in the sun for seven (7) days and ground with a mortar and pistle. The seeds were separated from the pulps and crushed into powder using an electrical chopper and then sieved using a sieve. The powdery extracts were stored in the dark in the laboratory in hermetically closed boxes. A part of the powder (4Kg) was mixed carefully while adding hot water. The mixture was continued until oil was obtained from the paste. The latter was then collected and stored in a bottle with screw cap in laboratory conditions. 1% liquid soap was added as an emulsifier before application with a spayer at a rate of 1.40 L/ha at 7 days interval as from 33 DAP.

Chenopodium ambrosioides aqueous extract

The leaves of *Chenopodium ambrosisoides* obtained were dried in an oven at ambient temperature (60°C) and crushed in order to obtain a fine powder. The powdery extract obtained from the leaves was kept in glass containers. The aqueous extract was obtained by mixing 10g of the powder in 100ml of distilled water. The mixture obtained was later filtered with the aid of wattman filter paper and applied with a spayer at a rate of 6.80 L/ha at 7 days of interval as from 33 DAP.

Variety of maize used

The variety of maize used was Acid Tolerant Population (ATP). It is a synthetic variety of maize with an average life cycle of 115 days and the seed color is yellow. It is generally adapted to acid soils of the western highland regions of Cameroon.

Experimental design

The experimental design used was a completely randomised block design with three replications, six treatments (lambda Cyalothrine 2, Cypermethrine 2, lambda Cyalothrine 1, *C. Ambrosioides, A. indica,* Cypermethrine 1, and the control) (Table 1).

Table 1: Experimental design layout.

Schéma du dispositif éxpérimental.

Blok 1	Block 2	Block 3
LAMBDA CYALOTHRINE 2	CYPERMETHRINE 2	C. ambrosioides
CYPERMETHRINE 2	C. ambrosioides	A. Indica
LAMBDA CYALOTHRINE 1	CONTROL	CYPERMETHRINE 1
C. ambrosioides	LAMBDA CYALOTHRINE 2	CYPERMETHRINE 2
A. Indica	CYPERMETHRINE 1	CONTROL
CONTROL	A. Indica	LAMBDA CYALOTHRINE 1
CYPERMETHRINE 1	LAMBDA CYALOTHRINE 1	LAMBDA CYALOTHRINE 2

1 refers to application at one-week interval and 2 refers to two-week interval application.

Land preparation and cultural practices

The plots were prepared according to conventional methods. The plot size was 10 m x 10 m with a plant density of 560 plants per plot. The maize was sown at the recommended spacing of 75 x 50 cm with 2 seeds per hill. The blocks were separated by a 4m gap while the experimental plots were separated by a 2m gap. Weeding was carried out at three weeks and two months after planting. 10 plants per plot were randomly selected and labeled before data collection. NPK fertilizer (14-24-14) was applied two weeks after planting and urea four weeks after planting at doses of 200kg/ha and 100kg/ha respectively.

The data relating to attacks by the pests were collected on weekly and two week's interval, starting from 33 days after seeding (DAS) of the maize because it is at this stage that the plants were more attractive and vulnerable for colonization by stem related pests (ICIPE 2013).

SAMPLES COLLECTION FOR CULTURING AND IDENTIFICATION

After collecting the samples in every treatment they were taken to the entomology laboratory for dissection, culturing and identification (Figure 1 and 2)

a b c d

Figure 1: sampling collection and culturing of insect larvae in the laboratory ; a : plant samples b : collection of larvae c : culturing larvae with maize stem d : culturing of larvae with maize leaves.

Collecte des echantillons et élévage des spécimens au laboratoire ; a : échantillons b : collecte des spécimens c : élevage des spécimens avec les tiges de maïs d : élevage des spécimens avec les feuilles de maïs.

a b c

Figure 2: *larvae identified during the trial ; a : Busseola fusca b : Spodoptera frugiperda c : Sesamia calmistis.*

Spécimens identifiés au cours expérimentation ; a : Busseola fusca b : Spodoptera frugiperda c : Sesamia calmistis.

DATA COLLECTION

Given that the eggs hatch four days after they are laid, 10 plants per plot were selected randomly at fourth week after the emergence at two weeks interval. The insects were sectioned while the leaves and the sheaths of the plant were removed carefully in order to observe the eggs, larvae and pupae, which could be found in the various parts of the plants. The stems of plants were carefully dissected with a sharp blade to collect all the larvae and pupae found in various parts of the stem. These larvae were then placed in Petri dishes for identification. Each batch of eggs, larvae and pupae were properly labeled against the plant and the plot. The data on the number of eggs, larvae, pupae, perforations on the stems as well as the number and the length of the tunnels were summarized to calculate the level of the damage.

Assessment of disease incidence

The disease incidence was assessed every two weeks on all plants in each treatment from the third week after emergence of seedlings according to the different stages of development of maize following the formula below:

$$\text{Incidence of the attack}(\%) = \frac{(\text{ number of plant attacked})}{total\ number\ of\ plant\ inspected} \times 100$$

$$\text{Pourcentage of attack reduction }(\%) = 100 - \frac{(\text{Treatment Incidence})}{Control\ Incidence} \times 100$$

Assessment of disease severity

The index of disease severity was determined every two weeks on twenty plants chosen at random by the percentage of the affected leaf surface using the scale provided in Table 2.

Table 2: Scale of severity of the attacks on the leaves.

Echelle de sévérité des attacques sur les feuilles.

Scale	1	2	3	4	5	6	7	8	9
FS (%)	<5	5-10	10-12.5	12.5-25	25-37.5	37.5-50	50-62.5	62,5-75	75-100

FS : Foliar surface attacked

Assessment of the proportion of dead heart

The proportion of dead hearts was evaluated from the third week at two weeks' interval in each plot using the following formula:

$$\text{proportion of dead heart }(\%) = \frac{(\text{ numberof plants with dead heart})}{total\ number\ of\ plant\ inspected} \times 100$$

ANALYSIS OF DATA

The data obtained were subjected to analysis of variance (ANOVA) using the software Stat graphics version 16. The mean values of the treatments were compared using the Fischer's test of Least Significance Difference (LSD).

RESULTS

DIFFERENT SPECIES OF FALL ARMYWORM AND STEM BORERS OF MAIZE IDENTIFY DURING THE TRIAL

After culturing the insects in the laboratory, the main stem borers found in the different parts of the maize plant were: African stem borer (*Busseola fusca*) and pink stem borer (*Sesamia calmistis). Busseola fusca* was the most frequent (Figure 2) and the most observed in all the treatments.

Effect of insecticides on fall army worm and stem borer larvae (*Busseola fusca*, and *Sesamia calmistis)* on maize stems and leaves:

Table 3 shows the number of stem borers and fall armyworm larvae on maize stems and leaves for each type of insecticide. The results show no significant difference between the number of larvae in the different treatments and the control at 33 days after planting ($p \geq 0.05$). However, from 75 DAP, no larva was found in the leaves and stems of maize for all treatments as compared to the control which showed significant high number of larvae (2.06, 0.43, 0.16 and 1.86) at 75, 89, 94 and 109 days after planting.

Table 3: Number of larvae on maize stems and leaves according to differents treatments.

Nombre de larves dans les tiges et les feuilles du maïs en fonction des differnts traitements.

Treatments	33 DAP	47 DAP	61 DAP	75 DAP	89 DAP	94 DAP	109 DAP
A. indica	4.06±1.07[a]	0.43±0.2[b]	0.3±0.17[b]	0±0[a]	0±0[a]	0±0[a]	0±0[a]
C. ambrosioides	4.50±1.20[a]	3.66±1.69[a]	3.13±1.53[a]	0±0[a]	0±0[a]	0±0[a]	0±0[a]
Control	3.7±0.9[a]	5.8±4.08[a]	5.60±4.08[a]	2.06±0.74[b]	0.43±0.03[b]	0.16±0.02[b]	1.86±0.19[b]
Cypermethrine 1	4.03±1.3[a]	1.23±0.19[b]	0.96±0.22[b]	0±0[a]	0±0[a]	0±0[a]	0±0[a]
Cypermethrine 2	4.60±0.4[a]	4.93±4.07[a]	4.66±0.90[a]	0±0[a]	0±0[a]	0±0[a]	0±0[a]
Lambda Cyalothrine 1	4.83±1.7[a]	3.73±1.75[a]	3.70±1.60[a]	0±0[a]	0±0[a]	0±0[a]	0±0[a]
Lambda Cyalothrine 2	5.20±2.71[a]	4.1±0.38[a]	3.66±0.18[a]	0±0[a]	0±0[a]	0±0[a]	0±0[a]

The values are expressed in average more or less of standard deviation in three repetitions. In the same column and for each treatment, values followed by the same letter are not significantly different at $p \leq 0.05$ Fischer's LSD.

Effect of insecticides on the incidence of dead hearts due to fall army worm and stem borers (*Busseola fusca*, *Sesamia calmistis)*.

Impact of dead hearts on maize plants as a result of the type of insecticide is presented in Table 4. Results showed that maize treated with lambda cyalothrine 1 had significantly low percentage of dead hearts incidence (38 %) as compared to the control and the other treatments, at 34 days after planting (DAP). At 48 and 62 DAP, *A. indica*, Cypermethrine 2 and lambda cyalothrine showed low incidence of dead hearts (0%; 34%; 45%) as compared to the control and the other treatments. *A. indica* extract was more effective in reducing the incidence of dead hearts during the entire period of the experiment, followed by lambda cyalothrine 1 and lambda cyalothrine 2 respectively. Despite the fact that no significant difference was observed between cypermethrin 2 and the control at 34 DAP, nevertheless, there was a significant reduction in the incidence of the disease at 48 DAP and 62 DAP respectively.

Table 4: Incidence of dead hearts on maize plants according to differents treatments.

Incidence des cœurs morts sur les plants de maïs en fonction des differnts traitements.

Treatments	34 DAP	48 DAP	62 DAP
A. indica	0.23±0.01[a]	0.01±0.01[a]	0±0[a]
C.ambrosioides	0.38±0.04[ab]	0.25±0.02[bc]	0.2±0.03[bc]
Control	0.65±0.08 [d]	0.38±0.09[c]	0.33±0.09[c]
Cypermethrin1	0.60±0.02[cd]	0.30±0.03[bc]	0.25±0.03[bc]
Cypermethrin2	0.58±0.07 [cd]	0.17±0.02[ab]	0.11±0.02[ab]
Lambda cyalothrin1	0.36±0.04 [ab]	0.15±0.08[ab]	0.10±0.08[ab]
Lambda cyalothrin2	0.45±0.10 [bc]	0.18±0.08[ab]	0.13±0.08[ab]

The values are expressed in average more or less of standard deviation in three repetitions. In the same column and for each treatment, values followed by the same letter are not significantly different at P $\leq$ 0.05 Fischer's LSD.

Effect of insecticides on the severity of fall armyworm and stem borers (*Busseola fusca*, *Sesamia calmistis)* attack on maize leaves:

Results showed that Neem extracts followed by lambda cyalothrine 1 and cypermethrin 1 significantly decreased the severity of the attack on maize leaves during the entire period of the experiment as compared to the control (p$\leq$ 0.05). However, plants treated with *Chenopodium ambrosioides* extract; lambda cyalothrine 2 and cypermethrin 2 showed no significant difference as compared to the control on the severity of maize leaf attack (Table 5).

Table 5: Severity of stem borers and fall armyworm attacks on the maize leaves according to different treatments.

Sévérité des attaques des foreurs de tiges et des chenilles légionnaire d'automne sur les feuilles de maïs en fonction des differnts traitements.

Treatments	34 DAP	48 DAP	62 DAP	76 DAP
A.indica	10.85±1.07[a]	20.75±0.43[a]	4.61±1.44[a]	3.26±1.44[a]
C.ambrosioides	20.25±3.74[bc]	24.41±1.80[ab]	21.86±8.58[bc]	20.51±8.58[bc]
Control	25.71±5.74[c]	28.83±4.52[b]	23.91±7.34[c]	22.56±7.34[c]
Cypermethrin1	16.25±1.70[ab]	21.75±0.90[a]	7.85±0.72[ab]	6.50±0.72[ab]
Cypermethrin2	17.11±1.88[abc]	22.25±1.15[a]	23.61±1.65[c]	22.26±1.65[c]
Lambda cyalothrin1	12.43±1.52[ab]	20.50±0.25[a]	9.45±3.14[ab]	8.10±3.14[ab]
Lambda cyalothrin2	17.23±2.61[abc]	22.00±1.25[a]	24.43±2.86[c]	23.08±2.86[c]

The values are expressed in average more or less standard deviation in three repetitions. In the same column and for each treatment, values followed by the same letter are not significantly different at P $\leq$ 0.05 Fischer's LSD.

Effect of insecticides on the incidence of fall armyworm (*Busseola fusca)* and stem borers (*Sesamia calmistis*) attack on maize plants:

Table 6 represents the level of incidence of the stem borers and fall armyworms attack on maize evaluated per treatment and per plot. There was no significant difference between the various insecticides and the control at 34 and 48 DAP. However, from 62 to 76 DAP, all the treatments had significantly reduced pest's incidence as compared to the control. Neem extract was the most effective treatment with the est percentage of attack redction (81, 21% at 76 Days After Planting).

Table 6: The Incidence of the attack by stem borers and fall armyworm on maize according to different treatments.

Incidence de l'attaque par les foreus de tige la chenille légionnaire d'Automne sur le maïs en fonction des differents traitements.

Treatments	34 DAP	48 DAP	62 DAP	76 DAP
A.indica	61.48±8.52[a]	62.60±8.68[a]	13.71±4.08[a]	11.41±3.91[a]
C.ambrosioides	55.29±7.22[a]	56.73±7.73[a]	61.32±14.63[bc]	53.84±15.03[cd]
Control	67.79±10.93[a]	69.39±10.96[a]	89.33±7.02[d]	92.62±5.94[e]
Cypermethrin1	76.60±9.54[a]	78.00±9.71[a]	39.74±4.58[b]	30.96±6.91[abc]
Cypermethrin2	73.63±11.15[a]	75.28±11.65[a]	45.59±7.86[b]	36.60±9.79[bcd]
Lambda cyalothrin1	66.78±11.42[a]	68.37±11.52[a]	36.47±1.26[ab]	27.56±1.28[ab]
Lambda cyalothrin2	61.66±15.07[a]	63.01±15.15[a]	74.84±10.35[cd]	61.15±6.35[d]

The values are expressed in average more or less of standard deviation in three repetitions. In the same column and for each treatment, values followed by the same letter are not significantly different at $p \leq 0.05$ Fischer's LSD.

Influence of insecticides on maize yield parameters:

Insecticide application significantly ($p \leq 0.05$) improved growth and yield parameters of maize as compared to the control (Table 7). However, no treatment showed significant difference on 1000-grain seed weight.

The plots treated with the Neem oil extract significantly reduced the pest incidence on the cobs (27. 33); similar result was observed on the number of eggs present in the cobs (10.66) in relation to the control and all the insecticides. However, all the insecticides relatively reduced the pest incidence (number of cobs attacked by pests) compared to the control which registered the highest value (57.0). As regards the impact on the cobs by the eggs, there was no significant difference among the treatments compared to the control, except lambda cyalothrine applied at two weeks' interval that recorded value greater than that of the control.

Table 7: Effect of insecticides on the maize yield parameters according to differents treatments.

Effet des insecticides sur les paramètres de rendement du maïs en fonction des differents traitemnes.

Type of insecticides	Number of cobs	Impact of the attack on the cobs	cobs with eggs	Proportion of attacks on the seeds	1000 grain-seed weight (kg)	Yield (T/ha)
A.Indica	387.0±11 .55[b]	27.33±1.20[a]	10.66±1.33[a]	1.0±0[a]	0.68±0.09[a]	6.98±0.62[b]
C. ambrosioides	336.66±27.15[a]	56.66±17.36[b]	23.0±4.73[ab]	4.66±2.67[a]	0.60±0.04[a]	5.11±0.70[a]
Control	308.33±12.35[a]	57.0±4.93[b]	27.66±6.74[b]	6.33±3.33[a]	0.67±0.03[a]	4.58±0.94[a]
Cyperméthrine1	336.66±42.06[a]	43.66±4.98[ab]	23.0±6.08[ab]	2.33±0.67[a]	0.71±0.06[a]	5.87±0.77[ab]
Cypermethrine2	366.33±36.76[a]	45.33±2.96[ab]	20.66±4.41[ab]	2.66±0.88[a]	0.71±0.09[a]	6.92±0.90[b]
Lambda cyalothrine1	337.0±16.70[a]	49.33±11.92[ab]	23.66±0.88[ab]	3.0±1.00[a]	0.6±0.06[a]	5.46±0.67[ab]
Lambda cyalothrine2	356.33±30.55a	54.66±6.12[b]	32.66±6.36[b]	3.33±1.33[a]	0.74±0.03[a]	5.74±0.31[ab]

The values are expressed in average more or less of standard deviation in three repetitions. In the same column and for each treatment, values followed by the same letter are not significantly different at $p \leq 0.05$ Fischer's LSD.

DISCUSSION

The main stem borer encountered in the different parts of the maize were the African stem borer, *Busseola fusca*, and the pink stem borer, *Sesamia calmistis* with *Busseola fusca* being the most frequent. *B. fusca* was the most common stem borer in all treatments observed throughout the experiment. This is in agreement with the results obtained by Ndemah & Schulthess (2002) who found five predominant species of stem borers in the forest zone of Cameroon and the savannah belt with *Busseola fusca* and *Sesamia calmistis* being among.

The results in this study show that among the pests identified, the most occurring one was *Spodoptera frugiperda* throughout the duration of the study. This could be because the adult larvae of *S. frugiperda* become cannibalistic and possess the ability to dominate interspecific and intraspecific competitors (Goergen *et al.* 2016). *S. frugiperda* has a capacity of remarkable dispersion which has probably evolved as a strategic part of its life cycle (Goergen *et al.* 2016; Belay 2011). *S. frugiperda* has the ability to migrate and reproduce rapidly (Murua and Virla 2004; belay 2011; Capinera 2014; Abrahams *et al.* 2017). These different capabilities have made it to be regarded as a great threat to cereal production. The frequent use of synthetic pesticides at very high levels has led to the emergence of insect populations resistant to most of the classes of pesticides (Adamczyk *et al.* 1999; Abrahams *et al.* 2017; Stokstad 2017) being used today. Consequently, this has promoted the use of genetically modified maize (Storer *et al.* 2010).

After hatching, the larvae of *S. frugiperda* is neonatal and feeds inside the host plant and thus develops under the protection of the leaves of the maize which makes their treatment difficult and inappropriate (Siebert *et al.* 2008; Jarrod *et al.* 2011; FAO 2017b; Goergen *et al.* 2016). Thus, *S. frugiperda* is considered as the most important pest of maize in Brazil (Sarmento *et al.* 2002) the third largest maize producer in the world after the United States and China.

Most of the insecticides used had repellent properties against adults, which prevented the pest from laying eggs on the one hand and ovicidal activities on the otherhand. *Chenopodium ambrosioides* L. is a plant specie important as both a repellent (Mazzonetto 2002) and a deterent insecticide (Tavares and Vendramim 2005) for the control of storage insect pests belonging to different families of Anobiidae, Bostrichidae, Bruchidae, Curculionidae and Tenebrionidae. The properties of the biological constituents of the Neem plant have been demonstrated to delay the development of embryos at different growth stages. It has anti feeding effects which may delay postembryonic development and increase mortality rate between moults. Also, the late embryonic development is disrupted causing varying degrees of incomplete ecdysone, infertility and the eggs become sterile (Chandler *et al.* 2011).

The absence of larvae in the leaves and stems of maize from 75 DAP in all treatments except the control could be explained by the fact that the insecticides used have been effective in the fight against the insects by preventing the larva from feeding on various parts of the plant.

There is a significant difference between most of the treatment and the control except cypermethrin 1, on the incidence of dead hearts between the different periods. This study revealed that maize plants treated with neem oil controled dead heart when compared with the control treatment. Although no significant difference was observed between cypermethrin 2 and the control treatment at 34 DAP, there was nevertheless a significant reduction in the incidence of the disease at 48 and 62 DAP. This confirms however, the effectiveness of neem oil, especially in the control of the activity of the insects on the maize plant since the maize plants treated with neem oil had significantly low number of dead hearts. The extracts have been referred to as effective against several pests (Hasan and Nedim 2004). Our results agree with the findings of Ogah *et al.* (2011), who successfully controlled pests in several field crops by using Neem seed kernel. The regulating effect on the growth of most insects by Neem is the most important physiological effect of neem on insects. It is because of this property that neem emerged as a source of insecticide (Ogah *et al.* 2011). The insecticidal properties of neem have been attributed to tetranor-triterpenoides and azadirachtin it contains (Nathan *et al.* 2005).

The Neem treatments used in this study registered very little number of larvae (11.41), which was reflected in the increased grain yield as shown in Table 5, confirming further the effectiveness of Neem oil as the insect growth regulator (Hasan and Nedim 2004; Ogah *et al.* 2011).

As regards the effectiveness of different treatments versus the incidence of the pests, the results show a varied reduction of the population of fall armyworm from 10 to 90% and from 90 to 100% concerning stem borers. Ndemah and Schulthess (2002) reported similar results on the effectiveness of the insecticide carbofuran on the number of larvae, which apparently depend on the time when the pest attacked the plant, and not the frequency of application of chemicals. There was, therefore, no clear trend in terms of the timing of application. Our findings presented in Tables 4 and 5 where the attacks were more severe before 62 DAP corroborates with the fact that fall armyworm can attack maize at all stages of the life cycle of the plant with the most severe attack usually on young plants (Tindo *et al.* 2017). These results are consistent with those of other researchers (Sémeglo 1997; Ndemah *et al.* 2000) who reported significant reduction of pest infestation with early application of chemicals against *B. Fusca* and *S. Calamistis.* The two species usually lay eggs on plants that have not yet reached the reproductive phase and attack plants at early growth stage. One more time the effectiveness apparently depends on the time when the pest attacked the plant and not the frequency of application of chemicals. The present work in which the incidence was found to be relatively high throughout the duration of the the sampling Corroborates with Tindo *et al.* (2017) where the impact of infestation by *Spodoptera frugiperda* in the different regions of Cameroon varied between 25% and 75%.

The number of ears recorded in the control plots was lower than the other treatments though there was no significant difference. Wahedi *et al.* (2013) have reported similar results on the performance of maize, demonstrating the effectiveness of different types of insecticides used in the protection of maize in the field. The oil from the seeds of Neem and the aqueous extract of *Chenopodium ambrosioides* had recorded (6.98) and (5.11) in grain yield respectively which represents a percentage gained yield of 2.45% and 0.53% respectively in relation to the control which recorded (4.58%). This is an indication of the importance of the use of bio insecticides in the protection of maize against the insect pests in the fields, which could otherwise result in serious yield loss as demonstrated in the present study. This also reveals that subsistence farmers could use these extracts locally in a sustainable manner to boost maize production. Our results are in agreement with those of Ande *et al.* (2010) where *Calymperes afzelii* significantly reduced the infestation of maize stem borers in Nigeria.

Generally, the results of this study show the effectiveness of all these different types of insecticides used in controlling stem borers and fall armyworm. This is also in agreement with the results of Ogah *et al.* (2011) who reported that the extracts of Neem significantly reduced the infestation of stem borers in rice. This also supports the results of other researchers (Okirikata and Anaso 2008; Anaso 2010) who reported that the powder of this plant significantly protected sorghum against pink stalk borer (*Sesamia calamistis* Homps) and stem borers in Nigeria.

CONCLUSION

This study revealed that African stem borer was the main stem borer found in the trial site with *Busseola fusca* and *Sesamia calmistis,* being the most frequent. *B. fusca* was the most common stem borer in all treatments observed during the experiment.

Fall armyworm and stem borers of maize are the most important pests causing enormous losses to yield. Various control methods have been tested against the two insect pests to reduce the number of pupae, tunnels and perforations on the maize plant. From among the insecticides used in this study, Neem oil at the concentration of 1.40 L/ha at 7 days interval was the most effective in reducing the incidence and the severity of the attack by the caterpillars as well as the number of larvae and the proportion of dead hearts. It also reduced the impact of the attack on ear and the number of eggs on the maize ears. This study demonstrated that the different types of insecticides used in this experiment had a positive impact on maize production by significantly reducing the incidence and the severity of fall armyworm and stem borer's attacks. This was reflected in increased yield performance of the maize. However, bio insecticide, Neem oil applied at one week's intervals had the highest yield performance. Based on these preliminary results, the Neem oil extract can be recommended for the control of fall armyworm and the two stem borer species

(*B. fusca and S. calmistis).*

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