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Research Article

Identification of *Spodoptera frugiperda* (Lepidoptera: Noctuidae), effects of farmer's management tools and Neem Oil Doses on fall armyworms in the Mangoun locality, Foumbot Subdivision, Cameroon

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Abstract

The abusive use of chemical insecticides poses a threat to humans. The use of botanical insecticides in combating crop pests is now an alternative. This study aimed to evaluate the damage caused by fall armyworms (FAW) in relation to planting dates, maize varieties, insecticides in farmers' fields and the effect of neem oil doses for their control in the Noun department. Neem oil at three doses (3, 5, 7 L/ha) was compared with a synthetic insecticide, Emamectin benzoate. The experiment was conducted using a randomized complete block design with five treatments replicated five times. Total number of leaves per plant, and number of leaves, whorls, and stems attacked were recorded. Results indicated an average attack rate of 20.29 ± 1.27%. However, leaf infestation rates varied among farmers depending on the variety used, planting date, and insecticide application. The 7 L/ha neem dose had the greatest impact on FAW, followed by the moderate dose (5 L/ha) and then the lowest dose (3 L/ha). Leaf infestation rates at the end of the experiment were 21.69 ± 0.89%, 16.66 ± 1.60%, and 9.89 ± 1.30% for neem3, neem5, and neem7 respectively. Neem7 showed effectiveness comparable to that of synthetic insecticide. Therefore, neem at 7 L/ha presents an alternative solution for combating FAW.

Keys words: *Spodoptera frugiperda*; *Azadirachta indica*; maize, farmers management tools; Noun division

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Résumé

L'utilisation abusive des insecticides chimiques est une menace pour l'homme. L'emploi des insecticides botaniques dans la lutte contre les insectes ravageurs des cultures est aujourd'hui une alternative. Cette étude a été d'évaluer les dégâts causés par les chenilles légionnaires d'automne (CLA) sur des parcelles en fonction des dates de semis en champs de producteurs et l'effet des doses d'huile de neem pour son contrôle dans le département du Noun. L'huile de neem à trois doses (3,5,7L/ha) a été comparée à un insecticide de synthèse, l'Emamectine benzoate. Il a été réalisé selon un plan en blocs complets randomisés, comprenant cinq traitements répétés cinq fois. Le nombre total de feuilles par plant, le nombre de feuilles, de flèches et de tiges attaquées ont été notés. Les résultats indiquent que le taux moyen d'attaque a été de 20,29 ± 1,27%. Cependant, le taux d'infestation des feuilles varie d'un producteur à l'autre en fonction de la variété utilisée, de la date de semis et de l'utilisation ou non d'un insecticide. La dose de neem (7Lha) a eu le plus grand impact sur la CLA, suivie par la dose moyenne (5L/ha) et enfin la dose (3L/ha). Les taux d'infestation foliaire à la fin de l'expérience a été de 21,69 ± 0,89%, 16,66 ± 1,60% et 9,89 ± 1,30% pour neem3, neem5 et neem7 respectivement. Le neem7 a montré une efficacité comparable à celle de l'insecticide de synthétique. Par conséquent, le neem à 7L/ha est une solution alternative de la lutte contre la CLA.

Mots clés : *Spodoptera frugiperda*; *Azadirachta indica*; maïs, emamectine benzoate; département du Noun

Introduction

Hoopen and Maïga (2012) said that cereal is the most widely grown globally in terms of quantity and area, especially in sub-Saharan Africa (SSA) where it surpasses wheat and rice, maize's significance in global food security. Macauley (2015) shown that in Africa, particularly in SSA, maize plays a central role as a staple food, akin to rice or wheat in Asia. In Cameroon, maize holds the primary position among cereals both in cultivation and consumption, far ahead of rice, wheat, and sorghum, providing sustenance for two out of every three Cameroonians, approximately 16 million people.

However, maize production faces numerous phytosanitary constraints, such as diseases and pests, which have a negative impact on yields, particularly from stem and ear borers. Studies conducted on the prevalence of stalk borers in maize across Sub-Saharan Africa, notably in Cameroon, have identified three primary species of significant economic importance: *Busseola fusca*, *Eldana saccharina, and Sesamia calamistis*. IITA (2016) and Moustapha et al. (2017) reported that *Spodoptera frugiperda,* an exotic species has been found in several countries, including Nigeria, Benin, Niger, and Togo. Its damage to maize in these countries is already substantial despite its recent arrival. Baldi et al. (2003) said that globally, the control of these pests is predominantly achieved through the use of synthetic insecticides. However, despite their effectiveness, many of these insecticides develop resistance in target organisms and pose significant risks as potent toxins to treated plants, animals, and users.

Fisk et al. (2001) and Oliva et al. (2001) were researchers who showed that, besides their inherent toxicity, these insecticides are largely persistent (resistant to chemical, photochemical, and biological degradation), accumulate in the environment, and bioaccumulate in humans through the food chain, thereby causing various severe pathologies and physiological disorders. Epidemiological studies conducted among farming families or those residing near treated crops have established a connection between pesticide exposure and a consistent rise in the incidence of certain illnesses.

Dewailly et al. (2000), Greenlee et al. (2003) and Menegaux et al. (2006) also said that these include reduced immunity, reproductive disorders, neurocognitive developmental dysfunctions, congenital anomalies, leukemia, brain tumors, other childhood cancers, and neurological disorders.

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In developing countries, Mawussi (2008) reported that personal protective measures are frequently inadequate or absent, and these countries bear the brunt of poisonings, accounting for 99% of fatalities.

As a result, the use of plants with pesticidal properties that degrade in the environment and pose no threat to human health is proposed as an alternative for safeguarding not only crops but also users and their surroundings.

In recent years, Schmutterer (1990), Kontodimas et al. (2004), Athanassiou et al. (2005), Isman (2006), and Kavallieratos et al. (2007) have undertaken numerous studies and investigations on the insecticidal effects of various plant extracts, with *Azadirachta indica*, commonly known as neem, emerging as particularly promising. Several global studies have already explored the insecticidal activity of neem.

However, in Africa, research specifically on neem's insecticidal properties, particularly in Sub-Saharan Africa (SSA), remains limited, said Nukenine et al. (2011a). Despite neem's introduction in Cameroon in 1947, reported Yengué and Callot (2002), its insecticidal properties are not well documented, despite its widespread use in treating various ailments, said Tourneux and Yaya (1998) and Noumi and Anguessin (2010).

Laboratory studies conducted by Nukenine et al. (2011a; 2011b) and Tofel et al. (2015; 2016) in the Far North region of Cameroon have shown that neem products (oil and powder) significantly reduce populations of *Sitophilus zeamais* and *Callosobruchus maculatus*, the main pests affecting stored maize. However, achieving effective pest control throughout the plant's growth cycle in the field is challenging due to various stages where pests, including stem and ear borers, can significantly reduce yields. Currently, pest control in fields often relies on the indiscriminate and uncontrolled use of synthetic insecticides, posing health risks to users and the environment.

Therefore, there is a critical need for field studies testing the insecticidal properties of botanical extracts (non-toxic to humans and the environment) against these pests. This work aims to verify the presence of the fall armyworm and the already known maize stem borers; subsequently, to assess the effect of farmer's knowledge (sowing dates, maize varieties and insecticides) on pest incidence; and finally, to test different doses of neem oil on these pests. The overall objective is to contribute to increasing national maize production by adhering to cultural control (sowing dates, maize varieties) and using neem oil as a botanical insecticide alternative to chemical insecticides.

Materials and methods

Study site

The study was conducted in Mangoun, a village located in the Foumbot subdivision, at an altitude of 1,100 meters, with a latitude of 5°30' north and longitude of 10°37' east. Foumbot subdivision is situated within the Noun division, 27 kilometers from the town of Bafoussam and 48 kilometers from the tourist town of Foumban, in the West Cameroon region. It is intersected by National Road No. 6, which connects Bafoussam and Foumban.

The commune of Foumbot lies in the tropical Sudano-Guinean climate region typical of the western part of the country. It experiences a bi-modal climate with a rainy season from mid-March to mid-November and a dry season from mid-November to mid-March, characterized by minimal rainfall and high evapotranspiration rates. Annual precipitation in the commune ranges from 2,500 to 5,000 mm. The average annual temperature is approximately 21°C, with highs reaching 32°C and lows dropping to 14°C. Relative humidity averages over 80%, peaking in August and September.

The study employed two types of sampling. Initially, field sampling covered approximately 200 m² plots belonging to 40 producers, focusing on caterpillar identification, evaluation of cultivated varieties, and the impact of sowing dates on pest incidence. Subsequently, a trial was conducted at the Institute of Agricultural Research for Development station in Foumbot to assess the efficacy of three different doses of neem oil

Plant Material

The plant material used in this study is a hybrid maize variety, CHH 101 (Cameroon Highland Hybrid 101) (Figure 1), developed by the Institute of Agricultural Research for Development (IRAD). It is a simple hybrid (crossed from two parent lines), with a growth cycle of 125 to 130 days and a potential yield estimated at 9-10 tonnes per hectare. The kernels are yellow in color, and the variety is well-adapted throughout Cameroon, including both low and high altitude regions.

CHH 101 is primarily cultivated for its ability to retain a sweet flavor for several days after harvesting, as well as its tolerance to biotic stresses caused by pests and diseases, and abiotic.

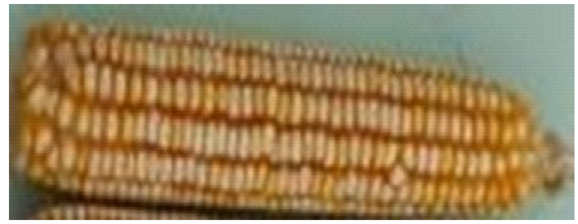

Figure 1: Maize variety CHH 101 (Source: IRAD Foumbot)

Insecticide equipment

Neem oil was purchased from a retailer in the Far North. Three doses were evaluated (3L/Ha, 5L/Ha and 7L/ha) for 400 L of water. The primary active ingredient in neem oil is azadirachtin, which disrupts the lifecycle of insects by inhibiting feeding, reproduction and growth. These doses were compared with emamectin benzoate (EMACOT), the active ingredient most commonly used by producers in the area. It is an insecticide used on market garden crops. EMACOT is a larvicidal insecticide, which acts by ingestion, composed of emamectin benzoate (50g/kg) which can be used as a preventive or curative treatment. It has good persistence of action (around 15 days), as well as good resistance to leaching.

Experimental Set-up

The experimental setup was implemented in a maize plot cultivated by a farmer adhering to the technical guidelines prescribed by the research. It was established as a randomized complete block design, with each block measuring 100 m². There were five treatments per block: three doses of neem (3L/ha, 5L/ha, and 7L/ha), one dose of synthetic insecticide, and a control that received no treatment. The experiment included five replications, covering a total area of 750 m². Each elementary plot measured 20 m² and was separated from adjacent plots within a block and between blocks by an alley consisting of two rows of seedlings, to account for drift during insecticide applications. Each elementary plot had five rows of maize plants spaced 0.80 m apart, with the plants within each row spaced 0.5 m apart.

Preparing insecticide sprays and phytosanitary treatments

The technical itinerary for maize cultivation was followed. The neem spray was prepared using a mixture of neem oil, water and a small amount of detergent (10g). The doses applied were 3L, 5L and 7L of neem oil per 400L of water per hectare; i.e. 30 ml, 50 ml and 70 ml of neem oil per 4L of water per 100 m^2 respectively, the surface area occupied by each treatment in the experimental set-up.

The preparation of the insecticide spray consisted of diluting a quantity of the marketed formulation with a specific quantity of water in accordance with the manufacturer's instructions, i.e. 250 g/ha of EMACOT (10g in a MATABI 15 L pressure maintained knapsack sprayer), i.e. 2.5 g per 100 m^2, which represented the surface area covered by the insecticide treatment.

Phytosanitary treatments

A total of three applications of plant protection products (neem and EMACOT) were made to the crop in the six-week interval from 21 days after sowing (24 May 2017), at a rate of one application every fourteen days.

Identification of *Spodoptera frugiperda*

Caterpillar collection

The first stage in identification is the collection of caterpillars. This was carried out in the fields of 40 producers surveyed in the Mangoun locality, focusing on plants showing symptoms of borer presence: specifically, symmetrical holes in the leaves, sawdust on the plant surface (particularly on the spire, where the caterpillar develops), and black spots on the stems, indicative of galleries. The caterpillars were handled with soft forceps, placed in slightly modified plastic bottles to keep them alive, labeled with the number of caterpillars collected, and brought back to the laboratory for identification.

Caterpillar identification

The caterpillars brought back from Mangoun were identified in the entomology laboratory of the research unit in phytopathology and agricultural zoology (UR_PHYZA) of the Faculty of Agronomy and Agricultural Sciences of the University of Dschang. Identification was based on a comparison of the specific morphological characteristics of *Spodoptera frugiperda* caterpillars described in the literature (King & Saunders, 1984, Georgen *et al.*, 2016) with those of caterpillars collected in the Mangoun locality. To do this, a WILD M3B light microscope (magnification x 10) and a desk lamp were used to accurately observe the characteristic features of *Spodoptera frugiperda*. Only caterpillars displaying the three main characteristics of *Spodoptera frugiperda, i.e.* the presence of an inverted Y (yellow in colour) on the head extending over the rest of the body, the absence of black dots on the metathorax and the presence of four black dots on the last abdominal segment forming a square, were identified as those of *Spodoptera fruigiperda.*

Evaluation of damage caused by faw armyworms

The incidence of stem borer damage in Mangoun was estimated for 40 maize producers, based on a sample of 200 m^2 of land per producer and 20 plants per randomly selected plot. A survey form was drawn up to record information such as the number of plants attacked per plot out of the 20 sampled, the number of leaves and internodes attacked per plant, and the number of locusts, aphids and snails present in the plot. Additional information such as the area cultivated, the variety used, the use of insecticides and the sowing date was also recorded in order to highlight a possible relationship between these parameters and the level of damage observed.

The rate of infestation on leaves, spires and stems was thus deduced using the formulae:

Infestation rate (leaf) (%) = total number of attacked leaves × 100 / total number of sampled leaves

Infestation rate (arrows) (%) = total number of attacked arrows × 100 / total number of arrows sampled

Infestation rate (stems) (%) = total number of stems attacked × 100 / total number of stems sampled

Evaluation of the efficacy of neem oil

Data were collected every fourteen days from 21 days after sowing (data collected before the start of insecticide application, references for assessing the effectiveness of treatments) and always preceded each phytosanitary treatment. In each elementary unit of the system and on ten plants per unit, the total number of leaves on a plant, the number of leaves and internodes attacked was recorded in a data collection form similar to that used to assess damage in the locality.

Statistical Analysis

The data obtained were entered and processed using Excel software and then analyzed using JMP version 8.0.2 statistical software. This involved creating columns for treatment, block, number of plants, and response variables. Percentage data were arc-sine transformed prior to analysis. Basic descriptive statistics were calculated to understand the data distribution within each block and treatment group, including means, variances, and standard deviations.

The basic model for an RCBD was used ($Y_{ij} = \mu + \tau_i + \beta_j + \epsilon_{ij}$ where Y_{ij} is the response variable for treatment i in block j; μ is the overall mean; τ_i is the treatment effect; β_j is the block effect and ϵ_{ij} is the random error term). An ANOVA (analysis of variance) was performed to partition the total variance into components attributable to treatments, blocks, and error. When the ANOVA indicated significant treatment effects, Tukey's HSD test and Student's t-test at a 5% significance level were used to determine which specific treatments differed from each other.

Results

Identification of *Spodoptera frugiperda*

A total of 126 caterpillars were collected from the fields of 40 producers in Mangoun.

Analysis of the morphological characteristics of these caterpillars revealed that they were *Spodoptera frugiperda*. Of the 126 caterpillars observed, 51 were identified as *Spodoptera frugiperda*, corresponding to a percentage of 40.47% of the total caterpillar population collected: a fairly high value for a species recently introduced and detected in Africa.

Distribution of producers and evaluation of damage caused by faw armyworm depending on the varieties grown in mangoun

Distribution of producers by variety grown

Figure 2 shows the distribution of producers in Mangoun according to the varieties grown. It shows that producers in Mangoun mainly grow two varieties: CHC 201 (Figure 3), also known as KASSAI, a composite variety (tolerant to altitude leaf diseases and stripe) that is by far the most popular with farmers, as it is grown by 31 of the 40 producers surveyed, and CHH 101 (Figure 3), a hybrid variety grown by only 9 of the 40 producers surveyed.

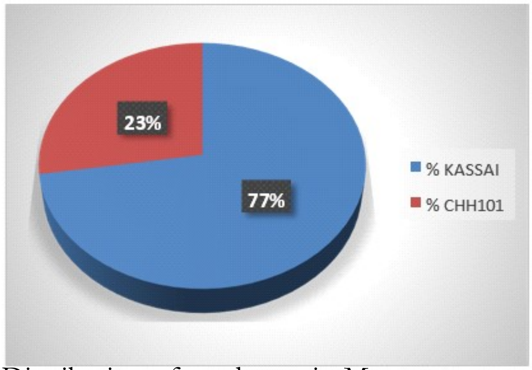

Figure 2: Distribution of producers in Mangoun according to varieties grown

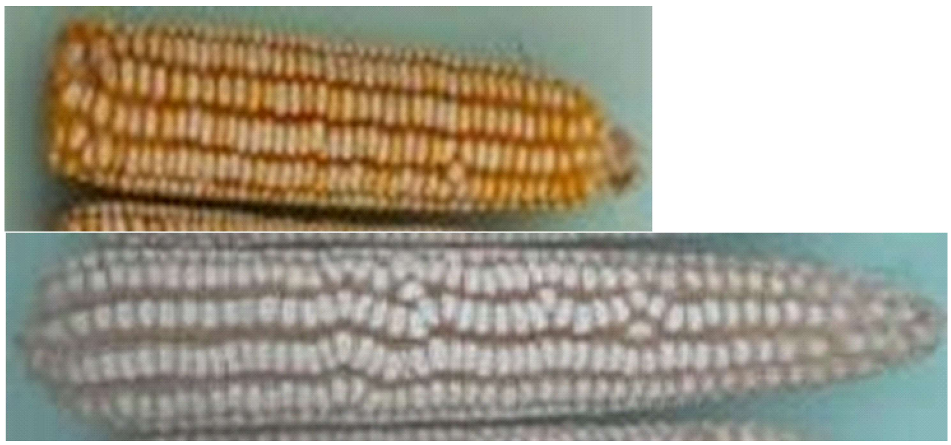

Figure 3: Maize varieties grown by farmers in Mangoum: (A) CHH 101, (B) CHH 201

Evaluation of faw armyworm damage depending on the Varieties grown

Table 1 shows the average plant infestation rates according to the varieties grown in the Mangoun locality. However, there was a significant difference (F=18.24, df=1, PÂ0.0001) between the two varieties grown mainly by producers. The table shows that the composite variety CHC 201 suffers the most damage, as its infestation rate is much higher than that of the hybrid variety CHH 101. Consequently, the CHC 201 variety was the most susceptible to stem borer attacks. However, there was no difference between the average infestation B rates of the arrows (F= 2.87, df=1, P=0.0906) and the stems of the two varieties.

Table 1: Average infestation rates of plant parts according to varieties grown in Mangoun locality

Varieties	Number of plants sampled	Means ± standard deviation of the infestation rate on the plant (%)		
		Leaves	**Arrows**	**Rods**
CHC 201	620	23,32 ± 1,06[a]	46,09 ± 1,35[a]	3,22 ± 0,17[a]
CHH 101	180	14,09 ± 1,47[b]	40,36 ± 2,25[a]	0 ,00± 0,00[a]
Total	800	18,70 ± 1,26	43,23 ± 1,80	1,61 ± 0,00

Means followed by the same letters in the same column are not significantly different using the Tukey test (P=0.05).

Distribution of producers and evaluation of faw armyworms damage according to sowing date

Distribution of producers according to sowing date

The data from our survey enabled us to group producers into two categories: those sowing between 15 March and 15 April, and those sowing after 15 April (Figure 4). The figure shows that 75% of producers respect the cropping calendar.

Evaluation of faw armyworms damage according to sowing date

Table 2 shows the average plant infestation rates according to the sowing period adopted by the producers. Overall, the infestation rate of leaves and arrows was relatively high in the locality: nevertheless, the analysis showed a significant difference (F= 22.44, df=1, P=0.0001) between the two sowing periods. The table shows that the ideal sowing period for maize is between 15 March and 15 April, when faw armyworms damage is significantly lower. However, there was still no significant difference between the average stalk infestation rates between the two sowing periods.

Distribution of producers and evaluation of faw armyworm damage according to insecticide used

Distribution of producers by insecticide used

The survey carried out in Mangoun showed that the majority of local farmers grow maize without using insecticides (Figure 5).

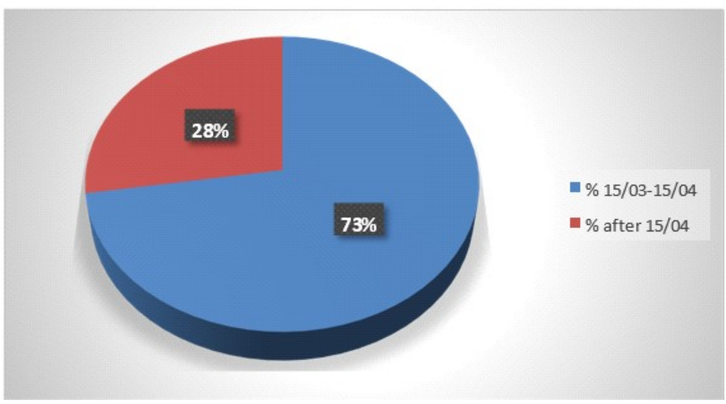

Figure 4: Distribution of producers in Mangoun according to sowing periods

Table 2: Average infestation rates of plant parts according to sowing period in Mangoun locality

Sowing date	Number of plants Sampled	Means ± standard deviation of infestation rate on the plant (%)		
		Leaves	**Arrows**	**Rods**
15March-15April	580	20,00 ± 1,04[a]	43,55 ± 1,34[a]	3,44 ± 0,18[a]
After 15April	220	24,53 ± 1,74[b]	48,10 ± 2,33[b]	0,00 ± 0,00[a]
Total	800	22,26 ± 1,39	45,82 ± 1,83	1,72 ± 0,09

Means followed by the same letters in the same column are not significantly different using the Tukey test (P=0.05).

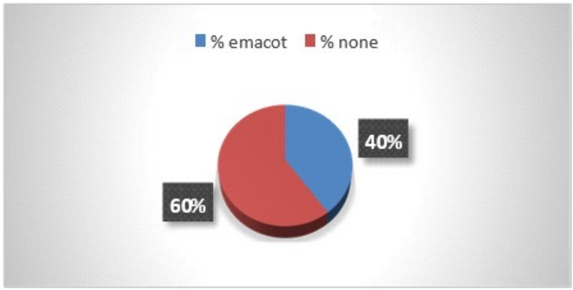

Figure 5: Distribution of producers in Mangoun according to insecticides used

Evaluation of damage caused by faw armyworms depending on the insecticide used

Table 3 summarises the plant infestation rates according to whether or not the farmers applied plant protection products. In general, leaf and arrow infestation rates were relatively high in Mangoun: however, analysis of the differences in these rates between the two farming practices showed that there was a significant difference (F=38.35, df=1, PÂ0.0001) between leaf and arrow infestation rates. This shows that plots cultivated without insecticides have a relatively high infestation rate compared with treated plots: the "insecticide/no insecticide" ratio of leaf infestation rates, with a value of 1.98 (approximately equal to 2), shows that the infestation rate in untreated plots is twice as high as that in treated plots. The infestation rate on stems, as in previous cases, was low at around 2%.

Table 3: Average infestation rate of plant parts according to pesticide used in Mangoun locality

Insecticide used	Number of plants sampled	Mean ± standard deviation of the infestation rate on the plant (%)		
		Leaves	**Arrows**	**Rods**
No	480	26,52 ± 1,26[a]	50,07 ± 1,61[a]	4,16 ± 0,22[a]
EMACOT	320	13,34 ± 1,07[b]	36,91 ± 1,53[b]	0,00 ± 0,00[a]
Total	800	19,93 ± 1,16	43,49 ± 1,57	2,08 ± 0,11

Means followed by the same letters in the same column are not significantly different using the Tukey test (P=0.05).

Evaluation of the efficacy of neem oil on faw armyworms

Evolution of the infestation rate according to treatments and days after sowing

The evolution of the infestation rate over the course of the experiment varied from one treatment to another and depended on the days after sowing (Table 4).

In fact, in the control plot, a continuous increase in the incidence of faw armyworm on maize was observed from the first data collection (21 days after sowing) to the third data collection (49 days after sowing). It also appears that from this point onwards, the infestation rate tends to remain constant, as it changed very little two weeks after the third collection of data. Nevertheless, the infestation rate is still quite high compared with the other treatments.

The three doses of neem tested showed different trends in the rate of infestation.

The neem3 treatment (3L/ha) showed an increasing infestation rate from the first collection to the second, followed by a relatively large drop in the infestation rate 49 days after sowing, which nevertheless increased again two weeks later (63 days after sowing).

The neem5 treatment, for its part, showed an increasing trend in incidence from the first collection to the second and tended to remain constant from that point onwards before dropping slightly 63 days after sowing. It can be deduced from these results that the neem dose of 5 L/ha only begins to have an effect after two applications, since at this stage it considerably reduces the rate of infestation, without being effective because it does not reduce it. It is not until 63rd days after sowing that the infestation rate drops, and even then, only slightly, so neem applied at a dose of 5 L/ha is only effective after three applications.

Finally, the last dose of neem tested (7L/ha) appeared to be the most promising, as it showed considerable efficacy from the second application and presented the smallest increase in the infestation rate between the first and second collections (the period during which none of the three treatments had any effect), 15.71 ± 1.52%, 9.87 ± 2.15% and 8.69 ± 2.39% respectively for the neem3, neem5 and neem7 treatments.

The synthetic insecticide EMACOT, unlike all the other treatments, shows a decreasing trend in the rate of infestation from the first phytosanitary treatment and tends thereafter to become constant. As a result, the synthetic insecticide only needs to be applied once to be effective against maize faw armyworm.

Generally speaking, depending on the treatment and the days after sowing, the infestation rate decreases from control to synthetic insecticide, via the three doses of neem (3L, 5L, 7L/ha).

Infestation rate according to treatments at the end of the experiment

The results of the analysis of the data from the experimental set-up (Table 5) show a significant difference between the treatments compared with the control. With the exception of Neem3 (3L neem/ha), all the other treatments (Neem5, Neem7 and EMACOT) significantly reduced the incidence of maize stem borers on leaves compared with the control. Of the three doses of neem tested, the best results were obtained with the highest dose (7 L of neem/ha), which had the lowest infestation rate, followed by the Neem5 treatment, which had a fairly high incidence, and finally the Neem3 treatment, which was completely ineffective and had the highest infestation rate. This shows that the effectiveness of neem is proportional to the dose of neem applied. In other words, the higher the dose, the greater its effect on borers; consequently, there is less damage to the plants.

At the end of the experiment, the best results were obtained by the synthetic insecticide EMACOT, which had the lowest infestation rate of the 5 treatments, followed very closely by the Neem7 treatment. In fact, analysis of the value derived from the difference in their infestation rates (0.22%) showed that it was not significantly representative. It was therefore concluded that the EMACOT treatment and the Neem7 treatment had the same effect on maize stem borers.

Analysis of the infestation rate data on the arrows follows the same logic as that described above, and ranks the control treatment in descending order of incidence, followed by the Neem3, Neem5, Neem7 and EMACOT treatments.

As observed in the assessment of the infestation rate in the 40 producers' fields surveyed, the infestation rate at stem level in the experimental plot was zero, indicating the absence of damage to the stems.

Table 5: Average infestation rates according to the different treatments

Treatments	Number of plants sampled	Means ± standard deviation of the infestation rate on the plant (%)		
		Leaves	**Arrows**	**Rods**
Control	200	26,31 ± 1,90[a]	41,52 ± 2,20[a]	0,00 ± 0,00[a]
Neem3	200	21,69 ± 0,89[a]	39,27 ± 2,08[ab]	0,00 ± 0,00[a]
Neem5	200	16,66 ± 1,60[b]	34,34 ± 1,75[bc]	0,00 ± 0,00[a]
Neem7	200	9,89 ± 1,30[c]	31,01 ± 1,44[c]	0,00 ± 0,00[a]
EMACOT	200	9,67 ± 0,88[c]	29,11 ±1,20[c]	0,00 ± 0,00[a]

Means followed by the same letters in the same column are not significantly different using the Tukey test (P=0.05).

Discussion

Analysis of the morphological characteristics of caterpillars collected in Mangoun revealed the presence of *Spodoptera frugiperda*, a new caterpillar species already reported in 2016 in Nigeria, Sao Tomé, Togo, Malawi, South Africa, Benin, Zambia, Ghana, Namibia, and Mozambique. This information has been reported by IITA (2016) and CABI (2017). The presence of this species in Africa, which was previously confined to the tropical and subtropical zones of the Americas, is thought to be due to the facilitation and liberalization of trade between countries. Seymour et al. (1985) stated that the larvae of butterflies can be transported by air freight or other means, on vegetables or fruit, as well as on certain ornamental plants. Its rapid spread in sub-Saharan Africa is thought to be due to climatic conditions similar to those of its origin, as well as the ability of this species to travel very long distances. Indeed, Hama et al. (2016) recorded migrations of over 2,000 km on the American continent.

The results of the analysis of infestation rate data in Mangoun showed that the overall incidence in the locality was 20.29 ± 1.27%, which is a fairly high value that could potentially lead to very high yield losses. In fact, according to studies carried out by Bosque-Pérez & Schulthess (1998), localities in which an incidence of between 10 and 70% is recorded are considered to be areas of major damage in which yield losses of at least 20% should be expected. The incidence in Mangoun varies from one producer to another, depending on the variety used, the sowing date and whether or not insecticide was used. The results showed that the hybrid variety CHH 101 had a lower infestation rate than the composite variety CHC 201. This could be explained by the presence of a certain vigour developed by the hybrid variety. Van Rensburg et al. (1987) showed that the choice of oviposition in noctuids is linked to the vigour of the host plants. However, despite the high infestation rate of the CHC 201 variety, it is the most widely grown by producers. This can be explained by the fact that producers can re-use its seeds over several growing seasons, which they cannot do with the hybrid variety. In addition, hybrid varieties cost more and are not sufficiently well known to producers, hence the need for extension. However, neither of the two varieties grown by Mangoun farmers was resistant to maize FAW, as each variety still has a fairly high incidence (between 10 and 70%). In terms of sowing dates, producers sowing between 15 March and 15 April had the lowest infestation rate compared with those sowing after 15 April. This would be due to the fact that the latter complied with the sowing date prescribed by the research. Depending on whether or not insecticides were used, producers cultivating without insecticides had the most stem borer damage compared with those who treated their plots. This can be explained by the larvicidal properties of the insecticide (EMACOT), which helps to control FAW not only preventively but also curatively; hence the need to supplement insecticide treatment with the plant's physiological responses in order to control these caterpillars.

The results from the experimental plot showed that the evolution of damage depends on the treatments and the days after sowing.

Throughout the experiment, the control showed an ever-increasing infestation rate curve, stabilising slightly at the end. This result could be explained by the development of a defence mechanism in the plant in response to the infestation of stem borers, a mechanism which slows down the activity of the borers without cancelling it out.

Of the three doses of neem tested, none had any effect from the first application. This result can be explained by the mode of action of neem oil, which has an anti-appetent effect. This mode of action is progressive and depends on the dose and frequency of application, as the effect is only seen from the second application onwards. However, only the highest dose showed a significant reduction in damage at the end of the experiment compared with the reference value, probably due to its high azadirachtin content compared with the other treatments.

As for the insecticide, it showed a decreasing trend in the rate of infestation from the first application. This result can be explained by the immediate effect of emamectin benzoate on the larvae of FAW.

At the end of the experiment, the neem5, neem7 and EMACOT treatments all showed a significant difference in infestation rate compared with the control. These results therefore support the efficacy of neem and EMACOT against FAW. In fact, the results obtained with neem are based on the anti-appetent and anti-nutritive properties of neem oil, which considerably reduce caterpillar feeding, leading to a loss of water and weight and subsequent death. These results corroborate those of Haasler (1984), Melamed-Madjar et al. (1989) and Isman (1993) who showed that neem oil caused a reduction in the rate of weight gain in *Manduca Sexta*, *Sesamia nonagroides* and many other Noctuidae respectively. Studies carried out by Barnby & Klocke (1987) also showed that a diet rich in azadirachtin led to a reduction in feeding, weight gain and the rate of biomass conversion in *Heliothis virescens*. The results also showed that, in order of effectiveness with neem, the neem7 treatment came first, followed by the neem5 treatment, and finally the neem3 treatment, which was completely ineffective. This result can be explained by the quantity of azadirachtin contained in each treatment, since the higher the dose, the more azadirachtin it contains, which is the active ingredient in neem oil, and therefore the more effective the treatment. This result is endorsed by Mondedji et al. (2016), who showed that the efficacy of hydro ethanoic extract of neem leaves on *Plutella xylostella* is proportional to the dose of extract applied. The lack of effect in the neem3 treatment could be explained by a very low concentration of azadirachtin in this dose not acting on FAW.

The insecticide EMACOT appeared to be the most effective, but with a non-significant difference compared with the neem7 treatment. This result shows that faw armyworms have not yet developed resistance to emamectin benzoate, so all chemical products containing this active ingredient would be effective against the caterpillars.

Conclusions

At the end of this study on the identification of *Spodoptera frugiperda*, the effects of farmer management practices, and the effectiveness of neem oil doses on fall armyworms (FAW), aimed at assessing the damage caused by FAW and the effectiveness of neem oil on them, the following findings emerged:

Spodoptera frugiperda, a species of maize borer recently detected in Africa, is present in one of the largest maize production regions in Cameroon in relatively high proportions. The infestation rate in Mangoun varies among producers and depends on the maize variety grown, the sowing date, and whether plant protection products are used. The results showed that the composite variety CHC 201 was more susceptible to FAW attacks than the hybrid variety CHH 101. The most favorable period for growing maize was between March 15 and April 15, and the use of an insecticide in maize cultivation was necessary as it significantly reduced the level of plant damage caused by borers.

Neem oil is effective against FAW in the field. However, its effectiveness varies according to the dose applied. The results showed that the highest dose of neem (7L/ha) had the greatest impact on FAW, followed by the medium dose (5L/ha) and the lowest dose (3L/ha), which had no effect. Consequently, the effectiveness of neem is proportional to the dose of oil applied. The study also showed that neem oil is comparable in efficacy to the synthetic insecticide (which gave the best results) most widely used by producers. Neem should therefore be used to combat *Spodoptera frugiperda* , with the aim of reducing the risks associated with the use of synthetic pesticides, to which not only producers but also consumers and the environment are exposed.

References

Athanassiou, C. G., Kontodimas, D. C., Kavallieratos, N. G. and Anagnou-Veroniki, M. (2005). Insecticidal effect of NeemAzal against three stored-product beetle species on rye and oats. Journal of Economy Entomology 98, 1499–1505.

Baldi, I., Lebailly, P., Mohammed-Brahim, B., Letenneur, L., Dartigues, J. F.and Brochard, P. (2003). Neurodegenerative diseases and exposure to pesticides in the elderly. American Journal of Epidemiology 157(5), 409-414.

Barnb, M.A. and Klocke, J.A. (1987). Effects of azadirachtin on the nutrition and development of the tobacco budworm, *Heliothis virescens* (Fabr.) (Noctuidae). Journal of Insect Physiology 33, 69–75.

CABI (2017). Scientists discover new crop-destroying Armyworm is now “spreading rapidly” in Africa. Wallingford, UK.

Dewailly, E., Ayotte, P., Bruneau, S., Gingras, S., Belles-Isles, M. and Roy, R. (2000). Susceptibility to infections and immune status in Inuits infants exposed to organochlorines. Environmental Health Perspectives 108, 205-211.

FAO (2017). Fall armyworm outbreak, a blow to prospects of recovery for southern Africa. Rome, Italy. (www.fne.asso.fr/, September 2007).

Fathima, S. K. (2004). Investigations on the biology and management of *Phomopsis azadirachtae* on neem. University of Mysore, Mysore, India.

Fisk, A.T., Hobson, K. A. and Norstrom, R. J. (2001). Influence of chemical and biological factors on trophic transfer of persistent organic pollutants in the northwater polynya marine food web. Environmental Science and Technology 35, 732–738.

Greenlee, A. R., Arbuckle, T.E. and Chyou, P. H. (2003). Risk factors for female infertility in an agricultural region. Epidemiology 14(4), 429-436.

Haasler, C. (1984). Effects of aqueous neem seed kernel extracts on the post-embrionic development of the tobacco hornworm, *Manduca sexta*. Natural Pesticides from the Neem Tree and Other Tropical Plants Proceedings of the Second International Neem Conference, Rauischholzhausen, 25–28 May 1983 (ed. By R. Schmutterer and K. R. S. Ascher) Germany, 321-330.

Hoopen, M. and Maïga, A. (2012). Production et transformation du maïs. CTA, 1-32.

IITA. (2016). First report of outbreaks of the "Fall Armyworm" on the African continent. IITA, Bulletin, No. 2330.

Moustapha, K, Traoré, V. S. E., Sérémé,, D., Neya B. J., Brugidou, C., Barro, N. and Traoré, O. (2017). *Imperata* yellow mottle virus: An Emerging Threat to Maize, Sorghum and Pearl Millet in Burkina Faso. Agricultural Sciences 8 (5), DOI: 10.4236/as.2017.85030.

Isman, M. B. (1993). Growth inhibitory and antifeedant effects of azadirachtin on six noctuids of regional economic importance. Pesticide Science 38, 57–63.

Isman, M. B. (2006). Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Annual Review of Entomology 51, 45–66.

Kavallieratos, N. G., Athanassiou, C. G., Saitanis, C. J., Kontodimas, D. C., Roussos, A. N., Tsoutsa, M. S. and Anastassopoulou U. A. (2007). Effect of two azadirachtin formulations against adults of *Sitophilus oryzae* and *Tribolium confusum* on different grain commodities. Journal of Food Protection,70, 1627–1632.

Kontodimas, D., Kavallieratos, N. G., Mantzoukas, S., Athanassiou, C. G. and Anagnou-Veroniki, M. (2004). Effect of *Beauveria bassiana, Vertcillium lecanii, Bacillus thuringiensis ssp.* tenebrionis and Azadiractin compounds on *Sitophilus oryzae* (L.) and *Tribolium confusum* Jacquelin du Val in stored rye. In : Abstracts of 37th annual meeting of the society for invertebrate pathology, 7th international conference on *Bacillus thuringiensis*, Helsinki, 94-95.

Macauley, H. (2015). Les cultures céréalières : riz, maïs, millet, sorgho et blé. Centre internationnal de conferences Abdou Diouf, Dakar, Senegal, 1-74.

Malgwi, A. M., Adamu, H. 2013. Effects of foliar applied carbofuran on damage and yield of some sorghum varieties/cultivars caused by stem borer, *Busseola fusca* Fuller (Lepidoptera: Noctuidae) in Biu, Borno State, Nigeria. ARPN journal of science and technology 3 (9).

Mawussi, G. (2008). Bilan environnemental de l'utilisation de pesticides organochlorés dans les cultures de coton, café et cacao au Togo et recherche d'alternatives par l'évaluation du pouvoir insecticide d'extraits de plantes locales contre le scolyte du café (*Hypothenemus hampei Ferrari*). Université de Toulouse France, 1-172.

Melamed-Madjar, V., Meisner, J. and Ascher, K. R. S. (1989). Effects of neem on the corn borer, *Sesamia nonagrioides* Lefebvre (Lepidoptera: Noctuidae). Zeitschift fur Planzenkrankheiten und Pflanzenschutz. 96, 521–525.

Menegaux, F., Baruchel, A., Bertrand, Y., Lescoeur, B., Leverger, G., Nelken, B., Sommelet, D., Hemon, D. and Clavel, J. (2006). Household exposure to pesticides and riskof childhood acute leukaemia. Occupational and Environmental Medicine 63 (2), 131-134.

Mondedji, D., Nyamador, W. S., Amevoin, K., Ketoh, G. K. and Glitho, I. A. (2014). Effets d'extrait hydroéthanolique de feuilles de neem

(*Azadirachta indica* A. Juss) sur *Plutella xylostella* (Lepidoptera : Plutellidae) et *Lipaphis erysimi* (Hemiptera : Aphididae) dans la production du chou au Sud du Togo. The *International Journal of Biological* and *Chemical* Sciences 8(5), 2286-2295.

Noumi, E. and Anguessin, B. (2010). Insecticides and ethnomedicine of HIV/AIDS at Tokombere (Far North Cameroon). Indian Journal of Traditional Knowledge 9, 730–735.

Nukenine, E. N., Tchiegang, C., Mekouo, T. A. A., Tofel, H. K., Obeng-Ofori, D. and Alder, C. (2011). Efficacy of Calneem derived from Ghanaian neem seeds and seed oils from two locations in Cameroon against *Sitophilus zeamais* (Coleoptera : Curculionidae) on maize. International Journal of Tropical Insect Science 31(4), 225–234.

Nukenine, E. N., Tofel, H. K. and Adler, C. (2011). Comparative efficacy of NeemAzal and local botanicals derived from *Azadirachta indica* and *Plectranthus glandulosus* against *Sitophilus zeamais* on maize. Journal of *Pest* Science 84, 479-486.

Oliva, A., Spira, A.and Multigner, L. (2001). Contribution of environmental factors to the risk of male infertility. Human Reproduction. 16(8), 1768-1776.

Schmutterer, H. (1990). Properties and potential of natural pesticides from the neem tree, *Azadirachta indica*. Annual Review of Entomology 35, 271–297.

Seymour, P.R., Roberts, H., Davis, M. E. (1985). Insects and other invertebrates found in plant material imported into England and Wales, 1984. Reference Book, Ministry of Agriculture, Fisheries and Food, UK.

Tofel, H. K., Nukenine, E. N., Stähler, M. and Adler, C. (2015). Insecticidal efficacy of *Azadirachta indica* powders from sun- and shade-dried seeds against *Sitophilus zeamais* and *Callosobruchus maculatus*. Journal of entomology and zoology studies 3(1), 100-108.

Tofe, H. K., Nukenine, E. N., Stähler, M. and Adler, C. (2016). Degradation of azadirachtin A on treated maize and cowpea and the persistence of *Azadirachta indica* seed oil on *Callosobruchus maculatus* and *Sitophilus zeamais*. Journal of Stored Products Research. 69, 207-212.

Tourneux, H. and Yaya, D. (1998). Dictionnaire peul de l'agriculture et de la nature (Diamare, Cameroun), suivi d'un index français-fulfulde. Karthala/CTA/CIRAD, Paris/Wageningen/Montpellier.

Yengue, J. L and Callot, Y. (2002). L'arbre et la ville dans la région de Maroua (l'Extrême-Nord Cameroun). Sècheresse 13, 157–162.