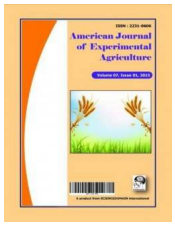

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Yield Performance of Maize Treated with Neem Seed Extracts against Stem Borers

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Authors' contributions

This work was carried out in collaboration between all authors. Author JAW designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors DLD and EPD reviewed the experimental design and all drafts of the manuscript. Authors JAW, SY and RZ managed the analyses of the study. Author JAW performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Maize is cultivated throughout the ecological zones of Nigeria, and it is found with a high yield potential in savanna regions. It is cultivated under a broad range of climatic conditions. Maize is the most cost-effective and highest yield plant resource in the world. It serves as a material for the production of livestock forage; fodder and feed in sub-Saharan Africa. Lepidopteran stem borers are a major pest of maize and can cause losses between 10-70% in maize. Field bioassays were conducted to determine efficacies of neem seed kernel extracts in the control of maize stem borers. The results showed that neem seed kernel extracts significantly (*P*=0.05) reduced stem borer damage on maize plants in terms of dead hearts and stem borer holes; reduced the infestation and development of the stem borers and also significantly (*P*=0.05) increase grain yield by 6.98% (Neem Seed Oil), 5.63% (neem seed powder), and 4.45% (neem seed aqueous extract) above the control (untreated). The order of the efficacy of neem seed kernel extracts is: NSO>NSP>NSAE. It is

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suggested that neem as biopesticide, may be suitable as alternative to synthetic pesticides which are not eco friendly, and toxic to users, for the management of maize stem borers, especially in Nigerian.

Keywords: Biopesticides; neem; maize; stem borer.

1. INTRODUCTION

Maize (*Zea mays* L.) belongs to the Family of *Poaceae*. It is cultivated worldwide both for local and commercial purposes [1]. Maize remains one of the most important cereal crops worldwide [2], and it is also ranked third after rice and wheat in both production and consumption worldwide [3]. In Nigeria, maize crop is the first among the cereal crops grown [3]. Cultivated throughout the ecological zones of Nigeria, maize is also demonstrated with a high yield potential in savanna regions [4]. It is the most cost-effective and highest yield plant resource in the world [2]. It serves as a material for the production of livestock forage, fodder and feed in sub-Saharan Africa [2], and a raw material for manufacture of many industrial products [5] and recently being used as biofuel [5].

The most important field pests of maize are lepidopterous stem and cob borers belonging to the families of Noctuidae and Pyralidae [6]. Several species of maize stem borers have been reported worldwide. The most common ones are *Sesamia calamistis* (Lepidoptera: Nuctuidae), *Eldana saccharina* (Lepidoptera: Pyralidae), *Busseola fusca* Fuller (Lepidoptera: Noctuidae) and *Chilo partellus* (Lepidoptera: Pyralidae).

Maize stem borers have been reported to cause great damage and yield losses across Africa [7-12] The losses could result from the mechanical damage caused by the maize stem borers to the maize plants (consistent feeding in the stem at different growth stage, which subsequently result in weakness of the plants and making them more prone to lodging- stem breaking and dead heart), and will produce no grain [13] Therefore, feeding activities can cause fenestration, thereby reducing the photosynthetic area of the leaves that result to poor yield [14]. Generally, the yield losses due to stem borers range from 10 to 100% [15]. Damage resulting from stem borer infestation on maize plant can cause between 20-40% losses during cultivation, and 30-90% at post harvest and storage [11,12]. In Nigeria, 14.0% yield loss for early maize as a result of stem borer activities was recorded [16]. Ogemah [17] reported that increased damage on young maize plants is as result of the soft nature of the stems and leaves. Controlling these insect pests is difficult because most part of their life cycles is spent inside the plant which serves as a physical protection to insecticide application [18].

Some agronomic or cultural practices can make the maize crops susceptible to stem borers' attack. Therefore, stem borer's attacked on maize crop can be checked by manipulating the agronomic practices such as depth of planting, sowing dates, soil amendment, water and soil management, deep ploughing in order to destroy insects and pathogens in the soil [14]. In northern guinea savanna in Nigeria, crops like sorghum and maize are not sown later than late June to ensure good yield [19]. Deep planting can make the seeds to rot while shallow planting predisposes the seeds to predation by rodents, birds, termites etc [14]. Leaving the maize in the field for a long time after maturity will increase yield losses from pest's activities, while deep ploughing, harrowing and good ridging ensure steady water percolation, and exposes eggs and diapausing pupae of pests to dessication by sun. Maize left over in the field after harvest is a source of pests' attack in the next planting season, hence, removal and burning of the stalks will ensure protection of crops [14]. Synthetic insecticides have been used extensively in the past by farmers for the control of stem borers, but however, they have not been effective in the control of stem borers and are environmentally not friendly [20]. Synthetic insecticides are known to destroy the ecosystem, and also generally not affordable to local farmers especially in Nigeria.

However, in recent times much attention has been given to biopesticides especially in controlling insect pests both in the field and in the store. The use of botanicals for the control of agricultural pests are considered to be environmentally friendly and also reduce the cost of insecticides in pest management [11]; besides they are cheap, readily available and affordable which is an important factor for farmers in developing countries, especially, Nigeria. Although, biopesticides are barely effective as synthetic chemicals in their wild type forms, the use of synthetic insecticides by farmers will

alleviate the growing public concerns regarding the effects of synthetic pesticides on human health [21]. More so, the interest in the use of biopesticides is on the increase in the recent years particularly in cropping system, where the use of natural enemies are being emphasized as a major component of integrated pest management [22]. The efficacies of botanicals are largely demonstrated in insect management and have been advocated for use by resource poor farmers [23].

The neem tree *Azadirachta indica* A. Juss (Meliacceae), has been widely studied because it presents a great number of compounds with insecticides properties which can effectively reduce the population of several insect pests [24]. It is generally believed that the bioactivity of neem is due to its complex limonoids that suppressed the feeding, growth and reproduction aspects of the pest insects [25], and thus have been used in many integrated pest management programs [26]. Therefore, in this study, the effects of neem seed kernel extracts in the control of damage and yield losses cause by maize stem borers were evaluated.

2. MATERIALS AND METHODS

2.1 Study Location

The study location is Bazza, in Michika Local Government Area, located on 13º12'E to 13º34'E and 10º22'N to 10º45'N. The average annual rainfall of Michika is 753.5 mm, and characterized by two climatic seasonal patterns, the wet season which runs between May to October and the dry season which runs between November to April [27]. The heaviest rain is experienced between July and August. During the rainy season, the relative humidity is high [28]. Highest temperature of about 34ºC is recorded in the months of March and April, while lower temperature of about 15ºC is experienced in the months of December and January. Michika is also typical characteristic of the Sudan savanna, with low grasses and scattered trees.

2.2 Source of Treatments (Neem Seed Extracts)

The neem seed treatments were produced as follows:

2.2.1 Neem seed powder (NSP)

The neem seeds collected were sun-dried for seven (7) days and decorticated to remove the kernels. The kernels were ground into fine powder in large quantity using electric blender and were stored in a bottle with screw cap top under laboratory conditions.

2.2.2 Neem seed oil (NSO)

A portion of the powder was mixed thoroughly while adding hot water in little quantity. The mixing continues until oil comes out of the dough. This was collected and was stored in a bottle with screw cap top under laboratory conditions.

2.2.3 Neem seed aqueous extract (NSAE)

75 g portion of the powder sample was subsequently reconstituted by soaking it in a litter of distilled water. It was allowed to stand for about 24 hours and thereafter, filtered through double folds of Muslin cloth to obtain the filtrate. This filtrate formed the aqueous neem seed extract [29].

2.3 Source of Maize Seeds

Clean maize seeds were obtained from a farmer in Bazza. The seeds were treated using Dress Force (20% imidacloprid, 20% metalaxyl-M, 20% WS Tebuconazole) before planting.

2.4 Experimental Design

The experimental design used was 4 x 4 factorial arranged in a Randomized Complete Block Design (RCBD), with four replicates. The size of each plot is 6 m x 2 m as shown below:

Replicate 1	Replicate 2	Replicate 3	Replicate 4
NSAE	NSO	NSP	CTRL
NSP	CTRL	NSAE	NSO
NSO	NSAE	CTRL	NSP
CTRL	NSP	NSO	NSAE

Where CTRL = Control (Untreated)

2.5 Preparation of Land and Sowing

A portion of land was cleared in a farm field in Bazza in July, 2013. It was subsequently ploughed and harrowed to soften the land. The number and size of plots used for the experiment was measured from the ploughed and harrowed farm land as shown above before planting. The planting took place immediately after the land preparation. About 3 to 4 seeds were planted per hole, but after germination, they were subsequently thinned to two per hill, and urea fertilizer was applied at three weeks and six weeks interval after planting [30].

2.6 Method of Treatments Application

The application of treatments started four weeks after planting, and it continued subsequently after three days interval for ten times application in all (30 days), as described below:

NSP: 20 g of the NSP was applied manually using hands, and it was applied on the leaves and whorl of the maize plants.

NSO: 20 mls of the NSO was applied using hand pump. It was applied on the entire plants' stem as well as the leaves.

NSAE: 20 mls of the NSAE was also applied using hand pump separately from the one for NSO, but similar method.

2.7 Data Collection

Data were collected on the following parameters for each treatment: Dead hearts, borer holes, yield quantity, percentage yield gained and number of stem borer (larvae, pupae and adults), as follows: Number of dead hearts were recorded as observed over time; the borer holes count was done prior before harvest-the entire maize stems were stripped off their covering leaves and were observed for the incidence of borer holes. The number of maize cobs were also counted and recorded during harvest. The maize cobs were shelled and dried to constant weight in an oven at 30℃ to 35℃ before weighing the yield quantity in grams (g), while the percentage yield gained was determined by subtracting the amount of the control yield from the treatment yield, and subsequently calculating the percentage. Number of stem borers were also noted and recorded by uprooting the maize plants and dissecting each of the stems for the incidence of stem borers at different life stages (larval, pupal and adult), immediately after the cobs were harvested.

2.8 Data Analysis

Data collected were subjected to One-way analysis of variance (ANOVA) and Duncan's New Multiple Range (DMR) Test was used to establish the mean differences at 5% level of probability, using SPSS Version 16.0.

3. RESULTS

Table 1 shows the incidence of dead hearts and borer holes on the experimented maize plants. The result shows that there is no significance difference between the treatment (Neem extracts) and the control (untreated) in the incidence of dead hearts at 5% probability level. Although the neem extracts showed some promising effects especially in NSO and NSAE where no dead heart (0.00±0.00) was recorded respectively. The number of borer holes noted on the stem of the maize plants followed similar trend with the results noted for dead hearts incidence, as the control recorded the highest (4.25±1.17). NSO and NSAE were also superior in the reduction of the incidence of borer holes just as in the case of the incidence of dead hearts.

Table 1. Incidence of dead hearts and borer holes on the maize plants

Treatments	No. dead hearts	No. of borer holes
CTRL	0.75 ± 0.96^{a}	4.25 ± 1.71^{b}
NSP	0.50 ± 0.58^{a}	2.75 ± 0.96^{ab}
NSO	0.00 ± 0.00^{a}	1.50 ± 1.29^{a}
NSAE	0.00 ± 0.00^{a}	1.75 ± 1.50^{a}

Values are means of four replicates. Means carrying the same superscript alphabet along the columns are not significantly different at 5% probability level

In Table 2, the number of stem borer infestation is shown. There is no significance difference (P=0.05) between the neem extract treated maize plants and the control (untreated) maize plants in the infestation of both the larval and pupal stages. Meanwhile, in the adult stage, the control recorded a significantly higher (3.50±1.00) number of adult stage infestation than the neem treatments as shown.

There is a significance relationship between the stem borer's incidence and the grain yield performance. Although, there is no significance

difference (*P*=0.05) in the number of maize cobs recorded during the harvest between the control and the neem seed treated plots, plots treated with neem seed extracts produced significantly higher quantity of grain yield than the untreated plots (control) as shown in Table 3. Percentage yield gained also indicated the efficacy of the neem seed kernel extracts in protecting the maize plants in the field. Neem seed oil recorded a percentage yield gained of 6.98±6.0, followed by NSP (5.63±4.49), and then NSAE (4.45±2.38).

4. DISCUSSION

The results showed that neem seed extracts were effective in protecting the maize plants from maize stem borers' infestation. The studies revealed that maize plants treated with neem seed extracts recorded fewer or no dead hearts when compared with the control (untreated) as shown in Table 1. Although the neem treatments and the control did not differ significantly, the control had the highest (0.75±0.96) incidence of dead hearts. Similar trend was seen in the case of borer holes infestation by the maize stem borers. The neem seed kernel treatments were able to suppress the stem borers from tunneling the stems of the maize plants when compared with the control (untreated) as shown in Table 1. As reported by Ogah et al. [21], dead heart (damaged shoot) produce no grain, hence, it corroborates with the present result where the number of dead hearts recorded correlates with the yield performance.

This therefore, confirms the effectiveness of neem seed kernel, especially in the control of stem-borers activities on maize plants, since maize plants treated with neem kernel extracts significantly recorded fewer dead hearts. Neem seed kernel extracts have been reported as an antifeedant and insect growth regulator against many insect pests [31]. This agrees with Bhanukiran and Panwar [32], who reported the control of pests of several field crops and stored products using neem derivative. The growth regulatory effect is the most important physiological effect of neem on insects. It is because of this property that neem has emerged as a source of insecticides [21]. Antifeedant activity of neem seed kernel has been attributed to the tetranortriterpenoid and azadirachtin, in the extract [33,34].

In Table 2, the results revealed that there is no significance difference (*P*=0.05) between the neem extracts and the control (untreated) in the number of infestation of both the larval and pupal stages. And in the adult stage, the control recorded a significantly higher number of adult stem borers more than the neem seed treatments. Therefore, the control (untreated) maize crops is in a danger of recording higher yield loss as a result of the stem borer's infestation. The neem seed kernel treated maize crops recorded fewer stem borers and therefore the reason for the increased yield as shown in Table 3 is further confirms the efficacy of neem seed kernel as a growth regulator against insect pests [31]. The insecticidal activities of the neem seed suppressed the development of the stem borers in maize and therefore could be the reason for the fewer number of adult stem borers recorded when compared with the control.

Table 2. Stem borer infestation on maize plants

Treatments	Stem borers		
	Larval stage	Pupal stage	Adult stage
CTRL	2.75±2.22^{a}	1.50±1.29^{a}	3.50±1.00^{b}
NSP	2.50±1.00^{a}	1.75±0.96^{a}	1.25±1.26^{a}
NSO	0.75±0.96^{a}	1.25±1.89^{a}	1.75±1.26^{ab}
NSAE	1.25±1.26^{a}	2.00±0.82^{a}	1.50±1.00^{a}

Values are means of four replicates. Means carrying the same superscript alphabet along the columns are not significantly different at 5% probability level

Table 3. Effect of stem borer infestation on the yield performance of maize

Treatment	No. of maize cobs	Yield quantity (g)	% Yield increase
CTRL	3.00±0.82^{a}	18.30±1.71^{a}	0.00±0.00^{a}
NSP	4.00±1.16^{a}	23.38±4.12^{b}	5.63±4.49^{ab}
NSO	3.75±3.20^{a}	24.48±3.66^{b}	6.98±6.08^{b}
NSAE	3.25±0.50^{a}	22.18±2.35^{ab}	4.45±2.38^{ab}

Values are means of four replicates. Means carrying the same superscript alphabet along the columns are not significantly different at 5% probability level

Although there is no significance difference in the number of maize cobs recorded between the control and the neem seed kernel treatments, the control recorded the least (3.00±0.82). Similar results were also shown for the yield quantity and percentage yield gained. Percentage yield gained also showed the efficacy of neem seed kernel extracts in protecting the maize plants in the field (Table 3). Neem seed oil recorded a percentage yield gained of up to 6.98%, is an indication of the importance of the use of botanicals in protecting maize in the field against stem borer infestation, which could result in yield lost as shown from the result of this studies. This also revealed that neem seed kernel can be sustainably used locally by farmers to ensure greater yield performance especially in Nigeria. This agrees with the work of Ande et al. [35], where *Calymperes afzelii* Sw. significantly (*P*=0.05) reduced stem borers infesting maize plants in Ilorin Nigeria, and subsequently registered higher maize yield when compare with the control (untreated).

The result generally showed the efficacy of neem seed kernel extracts in the control of stem borers of maize. This also agrees with Bhanukiran and Panwar [32] and Ogah et al. [21], who reported neem seed kernel, reduced the infestation as well as the activities of stem borers on rice. It also corroborates the findings of Okirikata and Anaso [36] and Anaso [37], where neem kernel powder significantly protected sorghum against pink stalk borer (*Sesamia calamistis* Homps) in Nigeria Sudan Savanna, as well as whorl larva, stem borer and panicle insect pests of sorghum in Nigeria respectively.

5. CONCLUSION

It is suggested that neem as biopesticides, may be suitable as alternatives to synthetic pesticides which are not eco friendly toxic to users, for the management of maize stem borers, especially in Nigerian. The result also showed that there will be a substantial yield increase if stem borer infestation and activities can be protected in the field, especially with biopesticides, such as neem.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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