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EVALUATION OF FALL ARMYWORM (*Spodoptera frugiperda* J. E. SMITH) INFESTATION AND EFFICACY OF NEEM EXTRACTS IN MAIZE (*Zea mays* L.)

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Abstract
Maize is an important cereal crop in Nigeria. Fall Armyworm (FAW) is one of the most important field insect pests of maize. This study was carried out to evaluate the impact of FAW infestation on maize plants and efficacy of neem extracts in the management of FAW in maize in Federal Capital Territory (FCT), Abuja in 2018. Field experiment was carried out from July to December 2018 at the Teaching and Research Farm of the Faculty of Agriculture, University of Abuja, Abuja, Nigeria, where two maize varieties were assessed for incidence and percentage leaf area damaged. Data collected was analyzed using Generalized Linear Model with multivariate assumptions using SPSS Version 21. Treatment means were separated with Student Newman Keuls Test (SNK) at $p \leq 0.05$. Highest number of FAW larvae (1.35±0.09) and incidence (20.30±1.02) were obtained from the control; the lowest was recorded from plants treated with Lambdacyhalothrin (0.05±0.06), followed by Neem oil (0.10± 0.05). Neem extracts reduced foliar damage to maize compared to the untreated control. Non-treated control plants showed extensive leaf injury compared to the synthetic insecticide and neem extract treated plants. There was no significant difference ($p \geq 0.05$) between the two maize varieties and interaction effect of variety and treatments in terms of the parameters scored. Findings from this study shows the efficacy of neem extracts in the treatment of Fall Armyworm infesting maize on the field and recommends the use of the neem extracts as an eco-friendly insecticide option for control of Fall Armyworm infestation in Nigeria.

Keywords: **Maize, Neem extracts, Fall Armyworm, Infestation, Incidence**

Introduction

Maize is among the ten most important world crops in terms of its nutritional, food and economic value (Bruce, 2005). In sub-Saharan Africa (SSA), it is grown across diverse agro-ecological zones where over 208 million people depend on the crop for food. Maize has been of great importance in providing food for man, feed for livestock and raw materials for agro-based industries (Kehinde, 1999). The crop accounts for almost half of the calories and protein consumed in Eastern and Southern Africa, and one-fifth in West Africa (Macauley, 2015). In Nigeria, Maize is ranked as the second most important cereal (Kehinde, 1999). Despite the importance of maize, the average maize yield in Africa is one of the lowest in the world (Ragasa *et al.,* 2014).

McCann, (2006) reported widespread hunger since the 1980s and attributed it to decreased maize production due to several biotic and abiotic constraints. Maize production is greatly limited by climatic and edaphic factors, non-replacement of low yielding cultivars, birds (especially bush fowl, *Francolinus bicalcaratus*), and weeds and diseases (caused by fungi, bacteria, viruses and plant parasitic nematodes). Also, insect pests are recognised as one of the most important biotic limiting factors to maize production (Pimentel, 2007). The yield potential of maize is greatly affected by insect pests, causing losses at 13.5% of its production annually as a staple crop (DeGroote *et al*., 2002) and damages caused by insect pests accelerates infection with disease causing organisms that occur through transmission of their spores which lower the quality of the grains (Osipitan *et al.,* 2011).

Fall Armyworm (*Spodoptera frugiperda*) is a polyphagous pest, highly destructive plant eating insect with a wide host range, attacking more than 80 plant species and causing massive economic loss (Prasanna *et al*., 2018). The pest was first observed in Africa in 2016 (Goergen *et al., 2016*), and since then, it has continued to ravage maize fields at an alarming rate. The infestation has been confirmed in more than 30 African countries including Nigeria (FAO, 2018). Maize plants are susceptible to the insect attack during practically all stages of its development cycle, and severe losses usually occurs when the whorl is destroyed, reducing photosynthetic area and compromising the grain yield. The insect attack occurs from plant emergence to tasseling and silking. Infestations during the mid to late whorl stage of maize development can cause yield losses of 15-75% when 55-100% of the plants are infested with Fall Armyworm (Hruska and Gould, 1997).

Attacks by the FAW have major implications for the food availability and industrial output in Nigeria. The alarming rate of its´ increase and presence in all parts of the country has made the FAW a major concern for agricultural sector stakeholders. Hence, to meet the demand for maize, it is necessary to tackle the problem of maize yield loss due to FAW. The potential increase in use of synthetic pesticides is hazardous due to its negative impacts and direct increased costs of production on the farmers and the indirect negative impacts on human health, environmental contamination, development of insect resistance to pesticides, and often pest resurgence. Hence, there is need to substitute these synthetic insecticides with botanical ones to bring about effective insect control with minimal damage to non-target organisms, environment and human. This research evaluated the impact of Fall Armyworm infestation and effect of aqueous powder from neem plant parts on maize under field conditions in Abuja.

Materials and Methods

Research Location

The experiment was conducted between July and December 2018 at the Teaching and Research Farm of the Faculty of Agriculture, University of Abuja, Federal Capital Territory (FCT), Abuja, Nigeria. This location is on Longitude and Latitude of 8.98° N, 7.18° E respectively and elevation of 273m above sea level. The average annual rainfall in the FCT is 1350mm (Balogun, 2001).

Samples

Two maize varieties (SAMMAZ – 39 and SUWAN -1- SR) obtained from Institute for Agricultural Research (IAR), Zaria, Lambdacyhalothrin obtained from Jubaili Agrochemicals Abuja, Neem plant parts obtained from National Research Institute for Chemical Technology (NARICT), Zaria were used for this study.

Experimental Design

A 2 x 7 Factorial fitted into a Randomized Complete Block Design (RCBD) with three replications was used (Table 1). The experimental plot was divided into three blocks, each block contained 14 plots. Plots size measured 3.75m X 2.75m with plant spacing of 0.25m x 0.75m. Distance between replications was 1m and between each plot 0.5m, with a total plot size of 15.25m x 47m and 42plots.

Table 1: Factorial treatment combinations of two varieties of Maize and Seven Neem extract levels

Treatments level (kg/ha)	Combination	
	(V1)	(V2)
Water (N0) (Control 1)	V1N0	V2N0
Lambdacyhalothrin (N1) (Standard control check)	V1N1	V2N1
Neem Oil (N2)	V1N2	V2N2
Neem Leaf extract (N3)	V1N3	V2N3
Neem Stem extract (N4)	V1N4	V2N4
Neem Root extract (N5)	V1N5	V2N5
Neem Seed extract (N6)	V1N6	V2N6

Cultural Practices

The land was properly tilled with the use of plough and then harrowed. The field was laid out using ranging poles, and lines. Maize seeds were sown, using 2 seeds per hill at a spacing of 25cm x 75cm. Atrazine and Glyphosate were applied at rate of 2.5kga.i/ha, a day after sowing for weed control. Following germination, seedlings were thinned down to one plant per hill at two weeks after sowing, maintaining the strongest plant in each hole. The experimental plots were manually weeded twice before harvest. Maize plants were subjected to the following groups of treatments; Water (control), Lambdacyhalothrin (synthetic insecticide), Neem oil, Neem leaf extract, Neem stem extract, Neem root extract, and Neem seed extract. The synthetic insecticide (at recommended dosage) and botanicals were sprayed four (4) times, at seven-day intervals, starting at the third week after sowing using a plunger hand sprayer. NPK 15:15:15 and urea were applied at the 5th and 8th week after sowing at the rate of 5g/plant stand. The cobs were harvested when they were mature and completely dried. Each plot was harvested separately and bagged per replicate for postharvest data collection.

Data Collection

Data was collected on germination percentage, incidence, number of larva and percentage leaf area damaged.

Germination percentage

Germination percentage was estimated three weeks after sowing, by counting the number of seeds that germinated and expressed as a percentage of the total number of seeds sown .

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds sown}} \text{x}100$$

Incidence

Incidence was estimated by counting the number of plants that were infested by close observation and expressed as a percentage of the total number of plants observed.

$$\text{Incidence (\%)} = \frac{\text{Number of infested plant}}{\text{Total number of plants observed}} \text{x}100 \text{ (Berger, 1980)}$$

Number of larvae

This was carried out by carefully opening the plants stem (whorl) and counting the number of larvae found on them and the value carefully recorded.

Percentage leaf area damaged

The percentage leaf area damaged was determined by outlining the damaged leaf on a graph and calculating the squares. The values obtained were expressed as a percentage of the leaf area.

$$\text{Percentage leaf area damaged (\%)} = \frac{\text{Leaf area damaged}}{\text{Leaf area}} \text{x}100$$

Data Analysis

Data of the parameters collected was subjected to General Linear Model with multivariate assumptions using SPSS Version 21 and means were separated using Student Newman Keuls Test (SNK) at $p \leq 0.05$.

Results and Discussion

Growth performance of Maize

Table 2 shows the effect of treatments (Lambdacyhalothrin, neem oil, neem leave extract, neem stem extract, neem root extract, neem seed extract and non-treated control) on the growth performance of maize infested by FAW in Abuja, in 2018. Prior to week 3, the trial on the field was not subjected to the treatment with any botanicals or the synthetic insecticide. The parameters scoring at 3 weeks after sowing (WAS) showed no significant difference ($p \geq 0.05$) for plant height. Number of leaves was highest (9.17± 0.14) with control, and lowest (8.47± 0.11) with neem leave extract. After the parameter scoring in 3 WAS, the trial was subjected to treatments with both botanicals and synthetic insecticide. At 6 WAS, treatment with neem stem extract recorded significantly higher (181.80cm) plant height, while control recorded the lowest (150.77cm). For number of leaves, treatment with neem root extract had the highest (11.55), while control still recorded the lowest (10.33). At week 9, neem root extract recorded the highest (196.23cm) plant height and control recorded the lowest (178.42cm). Number of leaves was highest (11.07) with neem oil, while control (9.85) recorded the lowest. Germination percentage and stem girth of the plants was not significantly different ($p \geq 0.05$) among the treatments. However, for leaf area, Lambdacyhalothrin had the highest (602.68cm^2), while control recorded the lowest (466.06 cm^2).

Table 3 shows the rates of infestation and damage caused by FAW on treated maize in Abuja. At 3 WAS. FAW incidence showed the highest (1.35) number of larvae was obtained from the non-treated control plants, and lowest (0.12) from plants treated with Lambdacyhalothrin. At 6 WAS, the non-treated control plants recorded the highest incidence (20.30%), number of larva (0.43) and lowest incidence and number of larvae from the rest of the treatments which were not significantly different ($p \geq 0.05$) from each other. In week 9, the non-treated control plants also had the highest incidence (18.50%), while plants treated with Lambdacyhalothrin, neem oil, neem leave extract had the lowest values that were not significantly different ($p \geq 0.05$) from each other. FAW larvae were not seen on the plants at 9 WAS. The highest (50.35%) percentage leaf area damaged was obtained from the non-treated control plants, while the plants treated with Lambdacyhalothrin had the lowest (28.67%).

This study provides information on the impact of FAW infestation on maize and effect of treatment with neem extracts in Nigeria. The infestation of FAW larvae of different instars had the highest population at the vegetative stage of the maize plants creating windows on the leaves of the plant and also feeding on the whorl, with fresh sawdust-like frass on the plants. Also established was a drastic decrease of infestation at the silking stage of the maize following Rajin *et al*. (2000) who reported that the infestation of stem borer was predominant from early seedling stages to maximum seedling stage and decreased gradually with increase in the growth of the plant. The high and consistent rainfall recorded could also be responsible for the reduction in the number of larvae. Some plants recovered due to the compensating ability of maize and less insect damage were observed with the plant's maturity.

Higher infestation levels (incidence) was recorded from the 6 WAS with a decrease after the 9 WAS. This may be because of treatment applied when compared to the untreated maize plants. The neem extracts used during the study lowered the incidence of FAW larva on leaves, number of larva and percentage leaf area damaged than the untreated maize. The results show that neem extracts have effect in protecting the maize plants from FAW infestation; this is in line with Tavares *et al*. (2010) who reported that Neem oil has anti-feeding effect and increased larval mortality on Lepidoptera. Formentini *et* *al*. (2016) also reported its effect on Hemiptera as causing early death of nymphs due to inhibition of development and ecdysis defects. Li *et al*. (2003) stated its effect on Hymenoptera as decreasing food intake, reducing larval and pupal development, and larvae death during the molting process. The infestation by FAW translated to the increase in incidence on the leaves and number of damaged leaves recorded at 6 WAS, while reduction of infestation was obtained in the treated maize plants. The established damages on the foliar part of maize caused reduced photosynthetic area which resulted to yield loss in the non-treated maize plants when compared to the treated maize plants.

The increase in maize growth in terms of leaf area, plant height and stem girth treated with neem extract established with efficient growth, decreased insect population and number of damaged leaves. This could be attributed to the active ingredient in neem (Azadiractin) which repelled the insect that would have impaired the normal growth activities in maize.

Conclusion

From this study, it was observed that the vegetative stage of the maize plants experienced the peak population of Fall Armyworm larvae, and drastic decrease at the silking stage. The impact of the infestations therefore translated to increased crop losses and increased pesticide application. The efficacy of the aqueous neem powder extracts compared with the use of the synthetic pesticide, Lamdacyhalothrin portrays the adoption of neem powder as an environmentally healthy option for the management of infestation of Fall Armyworm in Nigeria. This suggests the application of neem extract as an eco-friendly option for the control of Fall Armyworm infestation in Nigeria.

Table 2: Effect of Treatments on the Growth Performance of Maize Infested by Fall Armyworm during the growing season in Abuja, Nigeria

Treatment		Control	Lambdacyhalotrin	Neem oil	Neem leave	Neem stem	Neem root	Neem seed
Plant height (cm)	**Week3**	75.05± 6.88^{a}	75.38± 8.66^{a}	70.72± 7.25^{a}	77.97± 7.88^{a}	89.87± 6.22^{a}	71.03± 5.78^{a}	89.00± 6.80^{a}
	Week6	150.77±2.77^{a}	160.77±2.57b	179.95± 1.66^{c}	175.23± 1.57^{c}	181.80± 1.88^{c}	172.75± 2.60^{c}	
	Week9	178.42±1.77^{a}	195.68±1.88^{b}	195.87± 1.81^{b}	191.73± 1.80^{b}	192.10± 1.18^{b}	196.23± 1.29^{b}	193.67± 1.11^{b}
No of leaves	**Week3**	9.17± 0.14^{b}	9.00± 0.12^{ab}	8.87± 0.02^{ab}	8.47± 0.11^{a}	8.95± 0.24^{ab}	8.83± 0.04^{ab}	8.73± 0.41^{ab}
	Week6	10.33±0.16^{a}	11.05± 0.18^{b}	11.53± 0.17^{b}	11.28± 0.15^{b}	11.43± 0.12^{b}	11.55± 0.21^{b}	11.20± 0.18^{b}
	Week9	9.85± 0.18^{a}	10.67±0.15^{b}	11.07± 0.25^{b}	10.72± 0.10^{b}	10.52± 0.12^{b}	10.57± 0.18^{b}	10.73± 0.19^{b}
Germination (%)		94.44± 2.23^{a}	95.83± 1.03^{a}	93.89± 1.13^{a}	92.05± 2.13^{a}	96.67± 1.53^{a}	93.89± 2.03^{a}	95.84± 1.83^{a}
Stem girth (cm)		6.03± 0.14^{a}	6.06± 0.24^{a}	6.75± 0.11^{a}	6.53± 0.15^{a}	6.86± 0.17^{a}	6.69± 0.22^{a}	6.56± 0.21^{a}
Leaf area (cm^2)		466.06± 20.19^{a}	602.68± 21.22^{b}	577.77± 21.29^{b}	577.92± 22.90^{b}	558.43± 19.09^{b}	596.60± 19.95^{b}	568.83± 20.29^{b}

Data are mean values of triplicate determinations± Standard Error of Means (SEM). Means in the same column with different alphabets are significantly different P≤0.05

Table 3: Rates of Infestation and Damages Caused by Fall Armyworm on Treated Maize during the growing season in Abuja, Nigeria

Treatment		Control	Lambda	Neem oil	Neem leave	Neem stem	Neem root	Neem seed
Incidence %	**Week3**	0± 0.00	0± 0.00	0± 0.00	0± 0.00	0± 0.00	0± 0.00	0± 0.00
	Week6	20.30± 1.02^{b}	3.48± 1.14^{a}	4.37± 1.15^{a}	6.83± 1.21^{a}	7.72± 1.12^{a}	6.63± 1.11^{a}	6.33± 1.10^{a}
	Week9	18.50± 0.52^{c}	4.60± 0.53^{a}	4.63± 0.51^{a}	5.08± 0.52^{a}	7.07± 0.61^{b}	6.87± 0.71^{b}	7.65± 0.61^{b}
No of larva	**Week3**	1.35± 0.09^{b}	0.12± 0.10^{a}	0.15± 0.08^{a}	0.32± 0.09^{a}	0.33± 0.09^{a}	0.32± 0.08^{a}	0.23± 0.09^{a}
	Week6	0.43± 0.05^{b}	0.05± 0.06^{a}	0.10± 0.05^{a}	0.17± 0.10^{a}	0.17± 0.07^{a}	0.13± 0.06^{a}	0.18± 0.08^{a}
	Week9	0± 0.00	0± 0.00	0± 0.00	0± 0.00	0± 0.00	0± 0.00	0± 0.00
% Leaf area damaged		50.35± 1.15^{e}	28.67± 1.17^{a}	31.64± 1.12^{ab}	34.12± 1.11^{bc}	37.03± 1.14^{cd}	36.72± 1.13^{cd}	38.76± 1.15^{d}

Data are mean values of triplicate determinations± Standard Error of Means (SEM). Means in the same column with different alphabets are significantly different P≤0.05

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