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Bio-efficacy of two plant-based insecticides in the control of Fall Armyworm Spodoptera frugiperda (J.E. Smith) (Lepidoptera: Noctuidae) on sweet maize (Zea mays convar. Saccharata)

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Abstract- Fall armyworm (FAW) (Spodoptera frugiperda) invasion is a serious threat to maize production in Nigeria. The study investigated the efficacy of two plant-based insecticides in controlling FAW in both laboratory and field experiments at the National Horticultural Research Institute, Ibadan, Nigeria (N07o24'12.0'' E003o50'58.2'') in 2021. Honey King Sweet maize was used while treatments imposed were two bio-insecticide; NIHORT-Lyptol (Cineole), NIHORT-Raktin (Azadirachtin), Caterpillar force (Emamectin Benzoate 5% WDG) (check) and control replicated five times using complete randomized design in the laboratory bioassay and randomized complete block design in the field experiment. Emamectin Benzoate was outstanding with larval FAW mortality of 39% obtained at 12 hours and 86% at 24 hours after application. NIHORT-Lyptol was however comparable in activity to the check with 31% and 51% larval mortality at12 and 24 hours, respectively and >60% mortality within 72 hour-period. NIHORT-Raktin was not as effective as other insecticide as 18% and 36% mortality were recorded at 12 and 24 hours, respectively, after exposure while no larval mortality was recorded in the control plots. Lowest leaf damage (11%) was observed on Emamectin Benzoate treated field followed by NIHORT-Lyptol (16%). Significant increase in cob length (22.30cm) and grain yield (1679 kg/ha) was obtained in Emamectin Benzoate-treated plots followed by NIHORT-Lyptol (20.40cm) and dry grains (1339kg/ha). The study showed that the indigenous plant-based insecticide (NIHORT-Lyptol) was effective in controlling FAW and is therefore, a promising environmentally friendly bio-insecticide which could be incorporated into the management of FAW in Nigeria.

Keywords: Armyworm, NIHORT-Lyptol, NIHORT-Raktin, Sweet maize, Caterpillar force

I. INTRODUCTION

Fall armyworm (FAW, Spodoptera frugiperda (J.E. Smith), Lepidoptera: Noctuidae), a major agricultural pest in the Americas, is newly invasive in Africa. Southern armyworm, *S. eridania* (Stoll) is a relatively minor agricultural pest in the Americas, which has also just been reported from Africa (Goergen, 2018). Fall armyworm is a highly mobile species indigenous to tropical and sub-tropical regions of North, Central and South America. While FAW caterpillars can potentially feed on over 100 species of plants from a wide range of families (CABI, 2018a), in the field they mainly attack members of the Poaceae family, causing major damage to economically important cultivated grasses such as maize, rice, sorghum and sugarcane as well as other crops including cabbage, beet, peanut, soya bean, alfalfa, onion, cotton, pasture grasses, millet, tomato, potato and cotton (CABI, 2018a, Pogue, 2002). In its native range, it is often considered the most important pest of maize, for example in Brazil (Sisay *et al.,* 2019). In 2016 it was first reported in West Africa (Cock, Beseh, Buddie, Cafá, & Crozier, 2017; Goergen, Kumar, Sankung, Togola, & Tamò, 2016), and by the end of 2017 it had spread to over 30 countries across tropical and southern Africa as well as to Madagascar, Seychelles and Cabo Verde. It was first reported in Nigeria in the year 2016 in the South-Western Nigeria. The nature of damage and its potential yield loss has necessitated the need for

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researching into more environmentally friendly control for the management of Spodoptera frugiperda on sweet maize fields.

II. MATERIALS AND METHODS

Experimental procedure

A bioassay on the fall armyworm (FAW) was conducted in the bio-pesticide Center laboratory of National Horticultural Research Institute, Ibadan (N07º24'12.0'' E003º50'58.2'') in June 2021. The experiment was laid out in a complete randomized design (CRD) with five replicates. There were three treatments and one control. The treatments included two biopesticides, NIHORT-Lyptol (Cineole), NIHORT-Raktin (Azadirachtin) and Caterpillar force (Emamectin Benzoate 5% WDG) (Synthetic check) while distilled water was used in control treatment. The bio-pesticide were applied at the manufacturer recommended rate: NIHORT-Lyptol at 200ml/litre of water, NIHORT-Raktin at 200ml/ litre of water and Caterpillar force (Emamectin Benzoate 5% WDG) at 0.4 grams/ litre of water.

Rearing and maintaining Fall armyworm larvae

Larvae of fall army worm were collected into a plastic jar from an unsprayed infested three weeks old maize field in Ido local government of Oyo State. The larvae were brought to the entomology laboratory in NIHORT and placed individually in a well-ventilated insect jar to prevent cannibalism and were fed with young maize leaves. The pre-pupal stage was transferred to a plastic jar containing topsoil for pupation. The pupae were later collected and kept in a moistened Petri dish in an oviposition cage. A 20% sugar solution was diluted and placed in a Petri dish inside the oviposition cage to serve as food for newly emerged adults. Wax paper was kept at the corners of the cage to serve as an oviposition media. After four days, old egg batches were collected from the oviposition cages and placed in plastic jars. The eggs were continuously monitored daily for hatching; as soon as the first instars emerged, they were provided with young tender maize leaves while the temperature and relative humidity of the experimental area was daily monitored.

Topical application of treatments on fall armyworm larvae

The method employed was the leaf dip bioassay. The leaves of a 20 days old hybrid sweetcorn variety (Honey King) measuring 6cm was harvested and immersed in aqueous solution each of the biopesticide for 10 seconds and distilled water was used for the control. Treated leaf bits were air dried and transferred into plastics vials. Ten 3rd instar larvae were released into each vials containing the treated leaves. The maize leaves were changed every other day. Larval mortality was monitored at an interval of 12, 24, 36, 48, 60 and 72h after treatment application. A larva was considered dead when motility is not noticed when touched with a camel brush. The mortality (%) was assessed corrected by using the formular below.

Percentage (%) Mortality = Number of dead larvae ÷ Number of larvae introduced X 100

Table 1: Treatments used for laboratory and field experiments

Treatments (a.i)	Market name	Formulation	Dose/lit water (M.R)
Cineole	NIHORT-Lyptol	Liquid	200ml
Azadirachtin	NIHORT-Raktin	Liquid	200ml
Emamectin Benzoate 5 % WDG)	Caterpillar force	Powder	0.4gm
Control	Distilled water	-	Gently dipped

Note: a.i: active ingredient; M.R: manufacturer recommendation

Field evaluation of biopesticides for control of Fall army worm

To further examine the potency of the different biopesticide used in the bioassay against fall armyworm on sweet maize on the field, a field experiment was carried out during the raining season of year 2021 at Block B experimental field of National Horticultural Research Institute, Ibadan (N07º24'12.0'' E003º50'58.2''). The experiment was laid out in Randomized Complete Block Design (RCBD) with four treatments and replicated four times, each experimental plot measured 5.0m x 5.0m and inter-plot spacing of 1.5m to prevent insecticide drift. Honey King maize variety was sown at spacing of 75cm x 20cm on 28th of June, 2021 and ten plants were tagged per plot for data collection. All agronomic practices were carried out except insect pest control measures. Treatment application commenced at the first observation of larvae on leaves. Spraying was targeted at the apical leaves and was continued fortnightly till fruiting. The number of larva(e) and damaged plants were counted from tagged plants after each application. Numbers of damaged and undamaged leaves were recorded. The cob length and grain weight and yield were also recorded from each net plot and converted into kg/ha. The mean percentage larval mortality and means numbers of *S. frugiperda* larvae obtained from the laboratory were subjected to one-way analysis of variance (ANOVA) using a generalized linear model. The percent larval mortality data of synthetic insecticides was transformed using an arcsine transformation to normalize the variance. The significant level was set at ($p < 0.05$), and the means were separated using Tukey's honest significant different test.

III. RESULTS

Mortality of fall army worm larvae at different hours after application

The data in table 2 indicated that significantly highest percent mortality was observed in the treatment Caterpillar force @ 0.4grams/litre (39.68). The next best treatment was NIHORT-Lyptol @ 200ml /litre which caused 31.97 percent mortality while treatment NIHORT-Raktin @ 200ml /litre caused 18.47 percentage mortality and the control (distilled water) recorded no mortality 12 hours after exposure to treated leaves. The same trend observed at 12 hours after exposure continued till 24 hours exposure time with significantly increased mortality percentages. The treatment Caterpillar force @ 0.4grams/litre resulted into 86.40 percentage mortality followed by NIHORT-Lyptol @ 200ml /litre which caused 51.41 mortality and NIHORT-Raktin @ 200ml /litre reducing the population by 36.87percentage. The same trend observed at 12 hours after exposure continued till 24 hours exposure time with significantly increased mortality percentages. The treatment Caterpillar force @ 0.4grams/litre resulted into 86.40 percentage mortality followed by NIHORT-Lyptol @ 200ml /litre which caused 51.41 mortality and NIHORT-Raktin @ 200ml /litre reducing the population by 36.87 percentage. At 36 hours after exposure to treated leaves there was no increase in both Caterpillar force and NIHORT-Lyptol treatment except on NIHORT-Raktin treatment which increased mortality to 47.40 percentage. The mortality was monitored at 48, 60 and terminated at 72 hours, there were continuous increase as seen in table 2 where treatment Caterpillar force @ 0.4grams/litre gave the highest mortality rate (86.40 percent) followed by NIHORT-Lyptol at 200ml /litre (69.00 percent) and the least was NIHORT-Raktin (69.00 percent mortality) at 72 hours after exposure to the treated leaves.

Efficacy of NIHORT-Bio-pesticides and Synthetic Insecticide larvae population and percentage leaf damage

Table 3 shows that significantly highest percent mortality was recorded on the 6m^2 plots sprayed with Caterpillar Force Emamectin Benzoate 5 % WDG (5.34 larvae) which was significantly different from the population observed on plots under NIHORT-Lyptol protection (7.75 larvae) followed by plots under NIHORT-Raktin protection which recorded an average of 8 .75 larvae per maize stand in a 6m^2 area. The experiment also shows the percentage leaf area damage on sweet corn planted on each experimental plot, a significant higher reduction of 11.67 % leaf area damage was observed on the plot sprayed with Caterpillar Force Emamectin Benzoate 5 % WDG at 0.4grams/litre followed by NIHORT-Lyptol at the rate of 200ml /litre with a damage reduction of 16.29%.

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Yield and yield component of sweet maize as affected by biopesticide application

The data in table 4 shows significantly increase in the length of maize cob produced by the plots under Caterpillar Force Emamectin Benzoate 5 % WDG (22.30cm) protection and was significantly different from length of maize cobs produced by the two plant based biopesticide; NIHORT-Lyptol (20.40 cm) and NIHORT-Raktin (18.94cm) respectively. The grain weight per treatment was measured to determine the effect of different treatments on 100- grain weight, it was observed that Caterpillar Force Emamectin Benzoate 5 % WDG and NIHORT-Lyptol biopesticide compared favourably with each other weighing 19.41 grams and 19.05 grams respectively with the control plot weighing the least (14.65 grams). The highest total yield in kilograms per hectare was recorded on Caterpillar Force Emamectin Benzoate 5 % WDG treated plots weighing 1679kg/ha followed by NIHORT-Lyptol protected plots weighing 1339kg/ha and the control plot weighing the least 768.34kg/ha

Table 2: Mean percentage mortality of FAW larvae at different hours after application of pesticides in laboratory bioassay

Percentage larval mortality hours after application						
Treatments	12 hrs	24 hrs	36 hrs	48 hrs	60 hrs	72 hrs
NlHORT-Lyptol	31.97±8.67b	51.41±6.15b	51.41±4.11b	60.12±2.15b	68.07±1.45b	69.00±1.11b
NIHORT-Raktin	18.47±9.16c	36.87±7.43c	47.40±3.76c	47.40±3.76c	47.40±3.76c	49.00±2.13c
Cater-Fc	39.68±6.78a	86.40±0.00a	86.40±0.00a	86.40±0.00a	86.40±0.00a	86.40±0.00a
Control	0.00±0.00d	0.00±0.00d	0.00±0.00d	0.00±0.00d	0.00±0.00d	0.00±0.00d
LSD (P<0.05)	18.56					

Means followed by the same letter(s) in a column are not significantly different at (p<0.05). Note: Cater-Fc: Caterpillar Force (Emamectin Benzoate 5 % WDG)

Table 3: Effect of NIHORT Bio-pesticides on population of *Spodoptera frugiperda* larvae and leaves damage on Sweet maize in the open field

Insecticides	Larvae/6m²	% Damaged leaves	% Undamaged leaves
NIHORT-Lyptol (Cineole)	7.75b	16.29b	83.71b
NIHORT-Raktin (Azadirachtin)	8.75c	18.34c	81.66c
Cater Fc (Emamectin Benzoate 5 % WDG)	5.34a	11.67a	88.33a
Control	15.92d	27.30d	72.30d
LSD (P<0.05)	2.97	6.63	6.19

Means followed by same letter(s) in a column are not significantly different at ($p<0.05$). Note: Cater-Fc: Caterpillar Force

Table 4: Effect of insecticides on Yield and yield component of sweet maize

Insecticides	Cob length (cm)	100-grain weight (grams)	Grain yield (kg/ha)
NIHORT-Lyptol (Cineole)	20.40b	19.05a	1339b
NIHORT-Raktin(Azadirachtin)	18.94c	17.54b	1126c
Cater-Fc (Emamectin Benzoate 5% WDG)	22.30a	19.41a	1679a
Control	18.43d	14.65c	768.34d
SD (P<0.05)	0.66	0.73	57.8

Data were subjected to analysis of variance (ANVOVA) and significant means were separated using Least Significant Differences (LSD) at P<0.05. Note: Cater-Fc: Caterpillar Force

Fig 1. Treatment plot

Fig 2: No control plot

Fig 3: Stem damage

Fig 4: Lab Bioassay

IV. DISCUSSION

From this study, all treatments (biopesticides and Synthetic) resulted into significant mortality of *S. frugiperda* larvae compared to control. Developmental duration is a key factor for the completion of life cycle of insects and reproduction (De Loo, 2011). Synthetic insecticides application has been the major means of control for insects on open field especially the invasive fall army worm of sweet maize in Nigeria. Recently, many researchers around the world have been investigating the different management strategies against FAW in field and laboratory to develop registered pesticides. From this experiment, Emamectin Benzoate 5% WDG resulted into the highest immobility and eventual death of 39% and 86% *S. frugiperda* larvae 12- and 72-hours post-treatment respectively, this result aligns with findings of Kulye *et al*, 2001 who observed *S. frugiperda* susceptible to spinetoram across field samples. Usmani and Knowles, 2001 also reported that cypermethrin caused 76.7% mortality to the larvae of corn earworm, *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae). However, eucalyptus based biopesticide (NIHORT-Lyptol) shows promising level of control and was next to Emamectin Benzoate with a 12- and 72-hours post-treatment mortality rate of 31% and 69% mortality rate respectively. Plant essential oils can exert significant effects on insect behaviour, reproduction, and survival, and are therefore considered to be ideal green pesticides (Pavela and Benelli 2016; Cetin *et al*., 2007 ; Masetti, 2016). El- wakeil, 2013 discovered that the higher the rate of lipophilicity in a plant compound, the stronger the ability of essential oil to penetrate the insects. The significant level of mortality observed from Azadirachtin based NIHORT-Raktin also aligns with findings of Barbosa *et al*., 2015 reported that Azadirachtin as biopesticides produced deformed pupae and adults as a result of its insect growth regulator properties. Plant based biopesticides are attracting global attention as new tools to kill or suppress pest populations including insects. The significant lower leaf damage and increase yield can be attributed to the level of protection confer on the sweet maize plant by the different insecticide

V. CONCLUSION AND RECOMMENDATION

Given that plant based biopesticides such as NIHORT-Lyptol and NIHORT-Raktin had significant effects on the mortality of *S. frugiperda* larvae, these are seen as lower risk choices for pest management and good avenue for further studies. Integrating this result into crop management can help keep pest levels under control, with the percentage reduction in mortality fewer generation will be recorded in a crop cycle thus reducing the need to apply other pesticides which will enhance quality food for consumption. It will therefore be recommended that the combination of both biopesticide be looked into for its efficacy in controlling *S. frugiperda* larvae.

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