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Crop Protection

Bio-pesticidal efficacy of selected botanicals extracts and mixtures against Spodoptera frugiperda infestation on maize under field conditions

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A two-location field trial was conducted to study the bio-pesticidal efficacy of methanolic seed extracts from three botanicals, *Khaya senegalensis*, *Hyptis suaveolens* and *Azadirachta indica* and their mixtures, in controlling infestation of the FALL armyworm, *S. frugiperda*, in maize. Field trials were conducted at two locations under a Randomized Complete Block Design (RCBD) with four replicates. Treatments include individual extracts (2.5% w/v), mixtures (50:50), a synthetic insecticide check (Emamectin benzoate 5.0 % WDG), and an untreated control. Combined analysis across locations showed that all botanical treated and synthetic check plots had significantly reduced larval counts, foliar damage incidence and severity compared to the control. Moreover, treated plots exhibited significantly higher cob weight, 1000 grain weight, and overall grain yield, resulting in enhanced yield protection. Among the treatments, the Hyptis + Neem mixture provided the highest yield protection (26.5%) compared to the standard check (25.4%). These findings suggest that methanolic botanical extracts, particularly in combination, represent a promising component for integrated pest management (IPM) strategies against *S. frugiperda* in maize cultivation.

Keywords: Maize, *Spodoptera frugiperda*, botanicals extracts, Field trial, IPM

INTRODUCTION

The Fall Armyworm (FAW), Spodoptera frugiperda (J.E. Smith) (Lepidoptera: Noctuidae), a highly polyphagous pest native to the Americas, infests over 80 plant species including maize, sorghum, and sugarcane (Prasoona et al., 2022; Prasanna et al., 2018). First reported in Africa in 2016 in West and Central Africa, it has since spread across nearly all Sub-Saharan countries, causing significant yield losses particularly in maize (FAO, 2017; Siazemo and Simfukwe, 2020). In Nigeria, FAW was initially detected in Oyo and Ogun states in 2016 and since become widespread (Goergen et al., 2016; Kamara et al., 2020). Without control, FAW could cause annual maize losses of 8.3–20.6 million tons, equivalent to 21–53% of production in major producing countries (Abrahams et al., 2017).

Botanical extracts such as neem (Azadirachta indica), chili, and black pepper (Piper guineense) have shown pesticidal effects against FAW and other insect pests (Kammo et al., 2019; Clovis et al., 2020). Other plants, including mahogany (Khaya senegalensis), African bush tea (Hyptis suaveolens), and hot pepper (Capsicum frutescens), are also reported to possess insecticidal properties, though evidence against FAW remains limited (Kareru et al., 2013; Baidoo and Mochiah, 2016). Combining botanicals may enhance efficacy and represents a potential avenue for sustainable FAW management.

Extraction of bioactive compounds largely depends on solvents, with methanol frequently used due to its efficiency in isolating flavonoids, terpenoids, phenolics, and alkaloids (Spigno et al., 2007; Carrera et al., 2012; Dieu-Hien et al., 2019). Methanol has been shown to provide high yields and strong biological activity, justifying its use in studies on plant-based pesticides.

MATERIALS AND METHODS

Collection, preparation and extraction of plant material

Khaya senegalensis seeds were collected from within A.B.U premises. Matured fruits that had fallen naturally were gathered and decorticated to retrieve seeds. Hyptis suaveolens seeds were collected from fallow land in Dan-Magaji community, Zaria Kaduna state, while Azadirachta indica seeds were collected from dried fruit stones found under canopies in Dutse, Jigawa state. The collected seeds were washed with tap water to remove debris, shade dried to complete dryness, and then ground separately into fine powder using laboratory blender. The powdered samples were stored under dry conditions pending extraction.

Extraction was conducted at the Mycotoxicology Laboratory, Department of Crop Protection, A.B.U. Zaria. A cold maceration extraction method was used: for each species, 2 kg each of the ground seed powder was soaked in 6 L methanol in an aspirator bottle for 48 hours. After maceration, the extract was decanted through a cotton-wool-lined filter aspirator tap into conical flasks. The filtrate was concentrated under reduced pressure using a rotary evaporator until a viscous crude extract was obtained. The crude extract was then reconstituted by dissolving 100 ml in distilled water containing 0.1 % tween 80 (as an adjuvant; acting as emulsifier, sticker and suffocant) to yield a working concentration of 2.5 % w/v. for the synthetic control, Emamectin benzoate (5.0 % WD) was diluted following manufacturer's recommendation of 10.0 g in 15 L of water.

Experimental site

Field trials were conducted during the 2023 cropping season at two locations: the Research farm of Institute for Agricultural Research (IAR), ABU Samaru, Zaria (latitude 110 10' 0" N, longitude 70 37' 60" E) and at the dam site of Bakori town, Bakori Local Government Area, Katsina State (latitude 110 33' 20.12" N, longitude 70 25' 27.08" E).

Treatments and experimental design

The experiment employed a Randomized Complete Block Design (RCBD) with four replications. Eight treatments were evaluated: extracts of Khaya, Hyptis, Neem, Khaya + Neem, Hyptis + Neem and Khaya + Hyptis, all at 2.5% w/v. A standard check: Emamectin benzoate 5% WDG (manufacturer's recommendation dose) and a control (no spray). Each experimental units (plots) measured 6.0 m x 4.5 m (27 m2), comprising six ridges spaced at 0.75 m. Plots within blocks were separated by 1.5 m alleys. Standard agronomic practices (seed dressing, sowing, weeding, and fertilization) were followed uniformly across plots.

Treatment application (spraying)

Treatments were applied using a calibrated 1L hand-held sprayer. Spraying commenced at three weeks after sowing and was repeated at weekly intervals, for a total of four applications. Sprays administered in the late evening to coincide with the active period of FAW.

Data collection and evaluation

From the four central ridges, forty maize stands per plot were randomly selected for weekly assessment. Data collection occurred one day before the first spray and one week after each subsequent spray over four weeks. The following parameters were recorded:

Foliar damage incidence: number of infested stands with characteristic symptoms of leaf damage, rolling and presence of frass, were taken. The percentage incidence was then calculated using the formula:

Percent incidence = (Number of damaged stands / Total number of stands inspected) × 10

Larvae count: number of larvae present in the whorl and on the foliage per selected stand.

Foliar damage severity: visual rating scale using a modified scale based on Davis and Williams (1992) as cited in Prasanna et al. (2018).

At harvest, Number and severity damaged cobs were noted for cobbbs from central rows. Cob and kernel damage were rated using a 1 to 9 visual rating scale (protocol from CYMMYT, 2020 via Mbaidiro and Onzo, 2020).

Cob weight (kg ha-1), 1000 grain weight (kg) and overall grain yield (t ha-1) were determined. yield per plot was calculated and extrapolated to hectare basis using standard formula (Raheja, 1976; Aliyu et al., 2011):

Yield (kgha-1) = (a × 10,000/ b × 1000)

Where; a = sample yield (g) and b = plot size (m2)

Percentage avoidable yield loss was assessed using the formula below by Adamu (2005);

Avoidable yield loss (%) =100 × (Yield from protected plot – yield from unprotected plot)/ Yield from protected plot

Statistical analysis

All insect related data were square root transformed before analysis. Data from both locations were combined and subjected to analysis of variance (ANOVA) using R Studio. Significant means were separated using Student-Newman-Keuls (SNK) Test at 5% level of significance.

RESULTS

Percentage Incidence and Foliar Damage Severity of S. frugiperda

Results in table 1 showed that application of botanical extracts significantly reduced fall armyworm (FAW) incidence and foliar damage severity across assessment periods. Before spraying, no treatment differences were observed. However, after the first spray, all botanical treatments particularly Hyptis + Neem, Khaya + Neem, Khaya + Hyptis, Neem and the standard check, recorded significantly lower incidence compared to the control. Although Khaya and Hyptis individually showed moderate suppression, their values did not duffer statistically from some mixtures and single extracts.

Following the second sprays, all botanicals consistently lower incidence, with values comparable to the standard check, except Hyptis, which was less effective but still superior to the untreated control. After the fourth spray, Hyptis + Neem and the standard check produced the lowest incidence, confirming their superior protective ability. The overall means showed that all botanicals except Hyptis significantly reduced foliar damage incidence and performed similar to the standard check. The untreated control consistently exhibited the highest damage incidence.

For foliar damage severity (Table 1), a similar trend was observed. All botanicals and the standard check significantly reduced severity after each spraying cycle. Across overall means, Hyptis + Neem, Khaya + Neem, Khaya + Hyptis and Neem demonstrated the strongest suppressive effects and were statistically comparable to the standard check, reaffirming their high potential in FAW management.

Location Effects

Results in Table 1 showed that location significantly influenced incidence and severity. Samaru consistently recorded lower FAW incidence and damage severity before first spray and after the first and second sprays, likely due to higher rainfall reducing larval survival. However, after the fourth spray, Bakori recorded lower incidence. Overall, Samaru recorded significantly lower incidence, while severity did not differ statistically between locations across overall means.

Larval Count of S. frugiperda

Table 2 showed that larval counts did not differ before treatments were applied. After spraying commenced, all botanicals significantly reduce larval populations compared to the control. Hyptis + Neem, Khaya + Neem, Neem and the standard check consistently recorded the lowest larval counts and were statistically comparable to one another.

The cumulative mean showed that all botanicals and standard check significantly suppressed larvae relative to the untreated control. This confirms that extracts were effective protectants against FAW larval development.

Location also influenced larval density. Samaru recorded significantly lower larval populations before first spray and after the first and second sprays, again suggesting environmental suppression of FAW. However, after the fourth spray, Bakori recorded lower counts. Across overall means, Samaru maintained significantly lower larval loads than Bakori.

Yield and Yield Components

Botanical treatments significantly improved yield and related parameters (Table 3). All extracts and mixtures resulted in higher cob weight, 1000-grain weight and grain yield, and were statistically comparable to the standard check. The untreated control recorded the lowest cob weight, kernel weight and grain yield, with markedly higher cob damage severity.

Among the botanicals, Hyptis + Neem recorded the highest grain yield and the highest percentage yield protection (26.5 %), suppressing the standard check (25.4 %). Neem, Khaya + Neem and Hyptis also demonstrated high yield protection (>21%).

For FAW damage at harvest, Neem and Hyptis + Neem produced the lowest percentage of damaged cobs, similar to the standard check. All botanicals significantly reduced cob damage severity, confirming their protective capacity.

Location Effects on Yield

Significant location effects were observed for yield and its components (Table 3). Bakori recorded higher cob weight, 1000-grain weight and grain yield than Samaru. This is likely attributed to better soil fertility and continuous organic matter enrichment in Bakori compared to the repeatedly used experimental field at Samaru.

Overall Interpretation

The results demonstrated that all botanicals tested, either singly or in mixtures, effectively reduced fall armyworm infestation and crop damage while enhancing maize yield. Mixtures, particularly Hyptis +Neem, consistently performed best and even exceeded the standard synthetic insecticide in yield protection. Environmental difference between locations influenced pest pressure and yield, with wetter conditions at Samaru seemingly reducing larval survival, while superior soil fertility at Bakori supported higher yields.

DISCUSSION

The findings of this study demonstrated that all the botanical extracts evaluated, either singly or in mixture, were effective in suppressing S. frugiperda incidence, foliar damage, larval populations and cob damage, while significantly enhancing maize yield compared with the untreated control. The consistent reduction in infestation parameters following treatment applications suggests the presence of strong biologically active compounds in the botanicals used. Neem (Azadirachta indica), in particular, is widely documented for containing azadirachtin and related limonoids that act as antifeedants, growth regulators, repellents and oviposition deterrents (Kammo et al., 2019). Its observed that efficacy in this study aligns with earlier reports demonstrating its suppressive effects on FAW and other lepidopteran pests (Baidoo and Mochiah, 2016; Mbaidiro and Onzo, 2022).

The superior performance of Hyptis suaveolens mixtures, especially Hyptis + Neem, indicates a possible synergistic interaction between bioactive constituents of the two botanicals. H. suaveolens contains monoterpenes, phenolics and essential oils with known insecticidal and feeding deterrent properties (Prakash et al., 2008). Earlier studies shows that its extracts reduce larval feeding and survival in Spodoptera litura and Aphis craccivora (Ignacimuthu and Jayaraj, 2003; Jayakumar et al., 2004). Its efficacy against maize stalk borer reported by Cyrille et al. (2011) supports the present findings, suggesting that repeated sprays interfere with larval development and feedings, leading to lower infestation levels.

Botanical mixtures recorded higher protection than individual extracts, consistent with observations by Oparaeke et al. (2005), who reported enhanced pest suppression when botanicals were combined. This synergistic effect may rise from multiple modes of actions; antifeedant, suffocant, repellency and growth regulatory effects, operating simultaneously, thereby improving efficacy relative to single-active treatments. The Hyptis + Neem mixture, which provided the highest yield protection, performed comparably or better than the synthetic standard (Emamectin benzoate). This indicates its potential suitability as an eco-friendly alternative in FAW management and supports recent calls for integrating botanicals into pest management strategy in Sub-Saharan Africa.

Location effects observed in this trial highlight the influence of environmental factors on FAW dynamics. Samaru consistently recorded lower larval populations and foliar damage before and shortly after sprays, which is plausibly linked to higher rainfall event capable dislodging larvae from whorls. Similar observation was documented by Birhanu et al. (2019), who reported that heavy rains disrupt larval feeding and survival. Conversely, higher yield in Bakori suggests better soil fertility, likely due to long term organic matter enrichment and continuous cropping practices. Soil fertility is a known driver of plant vigor, which can enhance tolerance to pest damage and improve grain filling even under moderate infestation.

The slight reduction in botanical efficacy after some sprays observed in both locations may be attributed to rainfall occurring shortly after application, which could have washed off the extracts. Unlike synthetic insecticides, botanicals degrade quickly and required multiple applications for optimum effect, an observation consistent with FAO and CABI (2019), who emphasized the need for frequent treatments when using plant-based products with shorter residual activity.

Overall, the study confirms that botanicals, particularly mixtures, offer a viable and environmentally safe alternative for managing FAW in maize. The efficacy, coupled with availability, affordability and biodegradability, makes them suitable for smallholder farmers. Incorporating these extracts into Integrated Pest Management (IPM) programs could reduce dependence on synthetic pesticides, lower production costs and contribute to safer food and environmental quality.

CONCLUSION

This study demonstrated that all botanical extracts evaluated; Khaya senegalensis, Hyptis suaveolens and Azadirachta indica and their mixtures, effectively suppressed S. frugiperda infestation and reduced foliar and cob damage while improving maize yield. Although, all botanicals performed significantly better than the untreated control, the Hyptis + Neem mixture consistently provided the highest level of protection and produced yield benefit comparable to, and in some cases exceeding, the synthetic standard (Emamectin benzoate 5% WDG). The findings confirm the potential of botanical extracts, especially mixtures, as affordable, environmentally safe and sustainable options for FAW management in maize production systems:

• The Hyptis + Neem mixture is recommended as a promising botanical option for inclusion in Integrated Pest Management (IPM) programs for managing fall armyworm in maize.

• Farmers in regions with high FAW pressure should apply botanical extracts at weekly intervals, especially during early vegetative stages, to achieve optimal control.

• Further research should focus on improving the stability, persistence and formulation quality of botanical mixtures to enhance their field performance, particularly under rainfed conditions.

• Additional multi-location and multi-season trials are recommended to validate efficacy under varying environmental conditions and soil fertility levels.

• Extension agencies should promote botanical-based pest management strategies to reduce reliance on synthetic insecticides and support safer, eco-friendly maize production.

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