Feeding and contact toxicity of selected botanicals and their mixtures against *Spodoptera frugiperda*

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Abstract

A laboratory investigation was conducted to assess the feeding and contact toxicity of methanolic seed extracts of *Khaya senegalensis*, *Hyptis suaveolens*, *Capsicum frutescens* and *Azadirachta indica* and their mixtures (50:50), against the larvae of *Spodoptera frugiperda*. Extracts were tested at 2.5%, 5.0% and 10.0% (w/v), while Emamectin benzoate (5% WDG) served as the synthetic check and distilled water + 0.1 % tween 80 as the negative control. Larval mortality was monitored for seven days, and data were corrected using Abbott's formula. Results revealed that mixture containing of *H. suaveolens* and *A. indica* consistently produced the highest mortality in both feeding and contact assays, performing comparably to the synthetic check. The findings demonstrate that these botanicals particularly combinations involving Neem, possess potent larvicidal properties and may serve as viable components of environmentally friendly integrated pest management (IPM) programs.

Keywords: *Spodoptera frugiperda*, botanical extracts, feeding toxicity, contact toxicity, larval mortality, IPM

INTRODUCTION

Maize (*Zea mays* L.) remains a major cereal crop in Nigeria and across Sub-Saharan Africa, providing food, feed, and raw materials for various agro-industries (FAO, 2017; CABI, 2017). However, its productivity is threatened by numerous biotic factors, particularly insect pests (Kamara *et al*., 2020; Solomon and Azare, 2019; Queensland, 2013). In recent years, the fall armyworm (*Spodoptera frugiperda*) has emerged as one of the most destructive invasive pests of maize on African continent, causing severe yield losses (Goergen *et al*., 2016; Prasanna *et al*., 2022).

Fall armyworm (FAW) is a polyphagous pest capable of feeding on more than 80 plant species, including maize, sorghum, millet, rice, sugarcane, cotton and several vegetable (CABI, 2017). Larval feeding on leaves, whorls, tassels, and developing cobs leads to defoliation, stunted growth, and reduced yield (Day *et al*., 2017). The predominant use of chemical insecticides as control method, poses challenges such as resistance development, environmental pollution, high costs, and risks to non-target organisms (Kumela *et al*., 2018; Harrison *et al*., 2019).

Chemical insecticides are the most common control measures adopted by farmers, but their continuous use has resulted in environmental contamination, pest resistance, high cost, and health hazards to humans and non-target organisms (Kumela *et al*., 2018; Harrison *et al*., 2019). Consequently, eco-friendly pest management alternatives are increasingly being promoted. Botanical insecticides are gaining attention due to their biodegradability, lower toxicity to beneficial organisms, and multiple modes of action (Isman, 2017). Plants such as *A. indica*, *K. senegalensis*, *H. suaveolens*, and *C. frutescens* contain bioactive compounds with insecticidal, antifeedant, and growth-regulatory properties (Asawalam *et al*., 2007; Abdullahi *et al*., 2012; Paula *et al*., 2000).

This study evaluate the feeding and contact toxicity of methanolic seed extracts of these botanicals and their mixtures against *S. frugiperda* larvae under controlled laboratory conditions.

MATERIALS AND METHODS

Collection, preparation and extraction of plant material

Seeds of *K. senegalensis, A. indica*, *C. frutescens* and *H. suaveolens* were collected from different locations within Zaria, Kaduna state Nigeria. *Khaya* fruits were gathered after natural abscission, decorticated, washed and air-dried. Neem seeds were sourced within the Ahmadu Bello University campus, while *Hyptis* seeds were collected from uncultivated land in Dan-Magaji community. Dried Capsicum seeds were obtained from Samaru market. All were ground separately into fine powder using a high-speed blender.

Extraction was performed via cold maceration using methanol. Two kilograms of each powdered sample were soaked in 6 L of methanol for 48 h in a 12 L aspirator bottle. Filtrate were concentrated using a rotary evaporator to obtain crude extracts. Working concentrations of (2.5%, 5.0% and 10.0% w/v) were prepared using distilled water and 0.1% Tween 80 as emulsifier, sticker, and suffocant. Emamectin benzoate (5% WDG), was prepared following manufacturer recommendations.

Rearing of *S. frugiperda* and diet formulation

Late-instar larvae (instars 6 – 7) were collected from maize fields at the Institute for Agricultural Research (IAR) and reared on artificial diet following Prasanna *et al.* (2018). Three liters diet was prepared and dispensed (50 ml each) into small plastic containers (9 cm x 4 cm dia.), allowed to solidify, and cut into portions for bioassays.

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Bioassay procedures

Feeding Toxicity Test

This test was conducted using the formulated FAW diet instead of maize leaves used by Edley *et al.* (2019), Kelita *et al.* (2020), Emmanuel *et al.* (2022), and Prasoona *et al.* (2022). This is to maintain feeding consistency and avoid diet-changing stress. Portions of plain artificial diet were dipped into 50 ml of each extract concentration (2.5%, 5.0% and 10.0% w/v) for 20 seconds and air-dried for 1 hour. The treated diets were transferred to 9 cm diameter rubber bowls, and five second-instar larvae were introduced with a camel-hair brush. Bowls were covered with perforated lids. Treatments including standard check (Emamectin benzoate 5% WDG) and control (water + 0.1% Tween 80), were repeated four times in a Completely Randomized Design (CRD). Percentage mortality was recorded for 7 days at 24 h intervals and corrected using Abbott's formula (Abbott, 1987).

% Mortality = (Number of dead FAW larvae/ Number of introduced FAW larvae) x 100

Corrected mortality =((% of death in treated −% death in control)/ (100 −% death in control)) x 100

Contact Toxicity Test

Following Aryani and Auamacharoen (2016) and Kelita *et al.* (2020), 5 µL (1 µL per larva) of each extract concentration was topically applied to the dorsal prothoracic region of five second-instar larvae using a micropipette. Treated larvae were placed on plain diet portions in 9 cm diameter rubber bowls and covered with perforated lids. Percentage mortality was recorded and corrected as in the feeding test.

Data Analysis

Percentage mortality values were arcsine-transformed and analyzed using ANOVA in R studio. Significant means were separated using Student-Newman-Keuls (SNK) test at 5% significance level.

RESULTS

Feeding Toxicity

Result in Table 1 reveals that, mortality varied significantly among extracts, concentrations, and exposure periods. Mixtures containing *Hyptis* + Neem consistently produced high mortality, comparable to the synthetic insecticide during early exposure periods. Individual ex-

Table 1: Percentage Feeding Toxicity Effect of Methanolic Extracts of Some Botanicals and Mixtures at Varying Concentrations and Exposure Period on *S. frugiperda* Larval Mortality at Samaru in 2023

Treatments	Percentage mortality rate at different exposure periods (hours)							Mean
	24	48	72	96	120	144	168	
Plant extract (P)								
Khaya	40.8 b	29.6 ab	23.8 b	17.4 ab	14.1	14.1 ab	12.9	71.4 a
Capsicum	15.2 c	23.0 abc	25.2 b	29.4 a	21.9	12.9 b	15.1	58.8 ab
Hyptis	33.3 b	36.5 a	25.0 b	17.5 ab	14.1	12.9 b	12.9	69.2 a
Neem	17.4 c	21.6 abc	47.1 a	19.6 ab	19.7	14.1 ab	15.2	69.2 a
Khaya + *Capsicum*	14.1 c	14.1 c	17.4 b	24.0 ab	15.2	19.2 ab	12.9	35.6 c
Khaya + *Hyptis*	19.5 c	17.5 bc	20.7 b	19.7 ab	14.1	16.2 ab	12.9	40.6 bc
Khaya + Neem	19.7 c	21.6 abc	25.0 b	27.4 ab	18.5	24.1 ab	12.9	67.1 a
Capsicum + *Hyptis*	19.7 c	17.2 bc	17.4 b	17.4 ab	17.3	16.1 ab	12.9	38.9 c
Capsicum + Neem	16.3 c	31.2 ab	21.9 b	18.5 ab	19.7	24.8 a	14.1	64.8 a
Hyptis + Neem	41.9 b	20.7 bc	29.9 b	17.2 b	15.2	16.2 ab	12.9	72.5 a
Standard check	77.1 a	12.9 c	12.9 b	12.9 b	12.9	12.9 b	12.9	77.1 a
SE	2.80	3.33	3.82	2.66	2.17	2.54	0.96	4.14
Significance	***	***	***	**	NS	**	NS	***
Concentration (C) (%w/v)								
2.5	24.5	24.5	24.8	19.3	16.8	15.1 b	13.5	58.9
5.0	27.9	23.6	23.5	19.2	15.3	16.3 ab	13.9	58.6
10.0	23.4	20.6	25.4	23.2	18.0	19.4 a	12.9	60.7
SE	1.40	1.74	1.91	1.39	1.08	1.27	0.48	2.16
Significance	NS	NS	NS	NS	NS	*	NS	NS
Interaction								
SE	4.85	5.77	6.61	4.62	3.75	4.40	1.66	7.18
P*C	***	*	*	NS	NS	NS	NS	**

Means followed by same letter(s) are statistically the same using Student-Newman-Keuls (SNK) Test at 5% level of significant.

Table 2: percentage feeding toxicity interaction effect of methanolic extracts of some botanicals, mixtures and concentrations at 24, 48, 72 hours exposure periods and means on *S. frugiperda* larval mortality at Samaru in 2023

Plant extract (P)	Exposure period (hours)											
	24			48			72			Mean		
	Concentrations (w/v)											
	2.5	5.0	10.0	2.5	5.0	10.0	2.5	5.0	10.0	2.5	5.0	10.0
Khaya	57.1 ^{ab}	35.8 ^{bcde}	29.5 ^{cde}	29.7 ^{ab}	32.4 ^{ab}	26.6 ^{ab}	12.9 ^{b}	32.4 ^{ab}	26.1 ^{ab}	73.7 ^{a}	70.3 ^{a}	70.3 ^{a}
Capsicum	16.3 ^{de}	12.9 ^{e}	16.3 ^{de}	23.2 ^{ab}	22.9 ^{ab}	22.9 ^{ab}	26.1 ^{ab}	23.2 ^{b}	26.3 ^{ab}	57.6 ^{ab}	57.6 ^{ab}	61.0 ^{ab}
Hyptis	16.3 ^{de}	45.3 ^{bc}	38.4 ^{bcd}	44.7 ^{a}	38.9 ^{ab}	25.8 ^{ab}	29.2 ^{ab}	12.9 ^{b}	32.9 ^{ab}	67.1 ^{ab}	70.3 ^{a}	70.3 ^{a}
Neem	16.3 ^{de}	22.9 ^{cde}	12.9 ^{e}	26.1 ^{ab}	25.8 ^{ab}	12.9 ^{b}	58.0 ^{a}	38.4 ^{ab}	45.0 ^{ab}	73.7 ^{a}	70.3 ^{a}	67.1 ^{ab}
Khaya + *Capsicum*	12.9 ^{e}	16.3 ^{de}	12.9 ^{e}	12.9 ^{b}	12.9 ^{b}	16.3 ^{ab}	12.9 ^{b}	26.3 ^{ab}	12.9 ^{b}	29.7 ^{d}	38.7 ^{cd}	38.4 ^{cd}
Khaya + *Hyptis*	16.3 ^{de}	19.7 ^{de}	22.4 ^{cde}	16.3 ^{ab}	16.3 ^{ab}	19.7 ^{ab}	26.3 ^{ab}	16.3 ^{b}	19.5 ^{b}	38.4 ^{cd}	32.4 ^{cd}	51.1 ^{bc}
Khaya + Neem	19.7 ^{de}	16.3 ^{de}	23.2 ^{cde}	29.0 ^{ab}	12.9 ^{b}	22.9 ^{ab}	25.5 ^{ab}	26.6 ^{ab}	22.9 ^{b}	64.2 ^{ab}	70.3 ^{a}	66.8 ^{ab}
Capsicum + *Hyptis*	12.9 ^{e}	19.7 ^{de}	26.3 ^{cde}	12.9 ^{b}	22.4 ^{ab}	16.3 ^{ab}	16.3 ^{b}	16.3 ^{b}	19.5 ^{b}	29.5 ^{d}	35.5 ^{cd}	51.6 ^{bc}
Capsicum + Neem	16.3 ^{de}	12.9 ^{e}	19.7 ^{de}	32.4 ^{ab}	38.4 ^{ab}	22.9 ^{ab}	19.7 ^{b}	29.7 ^{ab}	16.3 ^{b}	67.1 ^{ab}	67.1 ^{ab}	60.3 ^{ab}
Hyptis + Neem	16.3 ^{de}	77.1 ^{a}	32.4 ^{bcde}	29.5 ^{ab}	12.9 ^{b}	19.7 ^{ab}	44.8 ^{ab}	12.9 ^{b}	32.1 ^{ab}	73.7 ^{a}	73.7 ^{a}	70.3 ^{a}

Table 3: percentage contact toxicity effect of methanolic extracts of some botanicals and mixtures at varying concentrations and exposure period on *S. frugiperda* larval mortality at Samaru in 2023

Treatments	Percentage mortality rate at different exposure periods (hours)							Mean
	24	48	72	96	120	144	168	
Plant extract (P)								
Khaya	16.3 ^{de}	12.9 ^{b}	14.1	15.2	12.9	12.9	12.9	19.7 ^{d}
Capsicum	30.0 ^{bcd}	21.7 ^{a}	16.3	15.2	12.9	12.9	14.1	46.1 ^{b}
Hyptis	14.1 ^{e}	14.1 ^{ab}	16.3	17.5	12.9	12.9	12.9	23.0 ^{cd}
Neem	19.7 ^{cde}	12.9 ^{b}	14.1	26.9	12.9	16.1	17.1	41.8 ^{bc}
Khaya + *Capsicum*	35.5 ^{b}	16.3 ^{ab}	15.2	16.3	12.9	12.9	12.9	43.9 ^{b}
Khaya + *Hyptis*	35.3 ^{b}	16.3 ^{ab}	12.9	16.3	12.9	14.1	14.1	43.8 ^{b}
Khaya + Neem	15.2 ^{de}	12.9 ^{b}	18.5	24.1	12.9	14.1	14.1	33.7 ^{bcd}
Capsicum + *Hyptis*	34.6 ^{bc}	16.3 ^{ab}	18.3	17.4	12.9	12.9	12.9	46.9 ^{b}
Capsicum + Neem	26.0 ^{bcde}	17.4 ^{ab}	17.5	18.5	14.1	12.9	12.9	40.8 ^{bc}
Hyptis + Neem	28.1 ^{bcde}	14.1 ^{ab}	14.1	24.0	16.2	18.5	14.1	50.2 ^{ab}
Standard check	77.1 ^{a}	12.9 ^{b}	12.9	12.9	12.9	12.9	12.9	77.1 ^{a}
SE	3.41	1.84	1.94	2.88	0.88	1.46	1.55	4.52
Significance	***	*	NS	NS	NS	NS	NS	***
Concentration (C) (%w/v)								
2.5	27.7 ^{ab}	14.0	15.4	17.1	13.5	14.5	12.9	37.4
5.0	23.0 ^{b}	16.9	15.6	20.6	12.9	13.6	14.9	39.3
10.0	29.1 ^{a}	15.3	15.6	19.2	13.6	13.6	13.6	42.1
SE	1.78	0.92	0.97	1.44	0.44	0.73	0.78	6.39
Significance	*	NS	NS	NS	NS	NS	NS	NS
Interaction								
SE	5.91	3.18	3.35	4.99	1.53	2.54	2.69	7.82
P*C	***	NS	NS	NS	NS	NS	NS	*

Table 4: Percentage contact toxicity interaction effect of methanolic extracts of some botanicals, mixtures and concentrations after 24 hours exposure period and means on *S. frugiperda* larval mortality at Samaru in 2023

Plant extract (P)	Exposure period (hours)					
	24 hours			Mean		
	Concentrations (w/v)					
	2.5	5.0	10.0	2.5	5.0	10.0
Khaya	16.3 ^{de}	12.9 ^{e}	19.7 ^{cde}	16.3 ^{d}	16.3 ^{d}	26.3 ^{bcd}
Capsicum	12.9 ^{e}	22.9 ^{cde}	54.2 ^{ab}	23.2 ^{cd}	48.2 ^{abcd}	66.9 ^{ab}
Hyptis	12.9 ^{e}	12.9 ^{e}	16.3 ^{de}	16.3 ^{d}	22.9 ^{cd}	29.7 ^{bcd}
Neem	19.5 ^{cde}	12.9 ^{e}	26.6 ^{bcde}	41.6 ^{abcd}	42.1 ^{abcd}	41.8 ^{abcd}
Khaya + *Capsicum*	32.4 ^{bcde}	26.3 ^{bcde}	47.9 ^{abc}	42.1 ^{abcd}	41.8 ^{abcd}	47.9 ^{abcd}
Khaya + *Hyptis*	38.9 ^{bcde}	44.5 ^{bcd}	22.4 ^{cde}	44.7 ^{abcd}	57.6 ^{abc}	29.0 ^{bcd}
Khaya + Neem	16.3 ^{de}	12.9 ^{e}	16.3 ^{de}	32.9 ^{bcd}	32.4 ^{bcd}	35.8 ^{bcd}
Capsicum + *Hyptis*	35.8 ^{bcde}	22.9 ^{cde}	45.0 ^{bcd}	51.0 ^{abcd}	35.5 ^{bcd}	54.2 ^{abcd}
Capsicum + Neem	31.8 ^{bcde}	26.6 ^{bcde}	19.7 ^{cde}	45.0 ^{abcd}	38.9 ^{abcd}	38.4 ^{abcd}
Hyptis + Neem	25.8 ^{bcde}	35.3 ^{bcde}	23.2 ^{bcde}	41.8 ^{abcd}	57.6 ^{abc}	51.1 ^{abcd}

Means followed by same letter(s) are statistically the same using SNK at 5%.

tracts of *Khaya* and *Hyptis* also performed comparatively well. Significant plant extract x concentration interactions occurred at 24, 48, and 72 h (Table 2).

Contact Toxicity

Similar trends were observed in the contact toxicity assay (Table 3), were *Hyptis* + Neem mixture produce the highest mortality among botanicals, approaching that of the synthetic check at early intervals. Significant extract x concentration interactions were recorded at 24 h only (Table 4).

DISCUSSION

The study demonstrated that methanolic extracts of *K. senegalensis*, *H. suaveolens*, *C. frutescens*, and *A. indica*, and their mixtures possess varying degrees of larvicidal activity against *S. frugiperda*. The superior performance of the *Hyptis* + Neem mixture suggests possible synergism between their bioactive constituents, consistent with earlier findings (Oparaeke *et al*., 2005; Bulus *et al*., 2023). Neem-based mixtures performed particularly well, affirming the role of Azadirachtin as a potent insect growth regulator and feeding deterrent.

The generally weak dose-response trend and decreasing efficacy with longer exposure align with the known rapid degradation of botanicals insecticides (Guleria and Tiku, 2009). Despite this, the short-term potency of the extracts especially neem containing mixtures, indicates strong potential for integration into IPM strategies targeting *S. frugiperda*.

CONCLUSION AND RECOMMENDATION

The methanolic extracts evaluated in this study exhibited notable feeding and contact toxicity against *Spodoptera frugiperda* under laboratory conditions. Among all treatments, the *Hyptis* + Neem mixture produced consistently high larval mortality, performing comparably to the synthetic insecticide. This results highlight the potential of botanical mixtures as eco-friendly alternatives for FAW (Fall armyworm) management. Field trials are recommended to validate laboratory findings and assess persistence, formulation, and application feasibility.

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