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Contact toxicity and feeding deterrent activity of *Dennettia tripetala* Bak. and *Jatropha curcas* L. leaf extracts against *Spodoptera frugiperda* J. E. Smith

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Abstract

Background Maize (*Zea mays* L.) is an important annual cereal crop with nutritional benefits, but its production is constrained by activities of insect pests. The fall armyworm (*Spodoptera frugiperda*) is one of the important economic pests that limits the production of maize, causing several damages on maize fields. Synthetic insecticides are commonly used to manage fall armyworm, but they have undesirable side effects on human and the environment. This study aimed to evaluate the contact toxicity and feeding deterrent activities of ethyl acetate and methanol leaf extracts of *Dennettia tripetala* and *Jatropha curcas* against fall armyworm.

Results In the contact toxicity of *Dennettia tripetala* and *Jatropha curcas* extracts, larval mortality increased with an increase in exposure time and concentrations. The extracts possessed significant contact insecticidal effects that ranged between $20.00 \pm 13.94\%$ and $100.00 \pm 0.00\%$. Also, in the feeding deterrent activity test, extracts revealed significant differences ($p < 0.05$) in larva mortality and duration. Larva duration ranged from $56.67 \pm 14.91\%$ to $100.00 \pm 0.00\%$. The larval stages of *S. frugiperda* that were artificially treated with the concentrations of the extract were shorter than those that were exposed to the control treatments. The methanol leaves extracts of *Dennettia tripetala* and *Jatropha curcas* showed no significant difference ($p > 0.05$) in the pupal mortality and pupal weight among the treatments. *Jatropha curcas* ethyl acetate and *Jatropha curcas* methanol extracts had high flavonoid content, and tannin and phenol content was higher in *Dennettia tripetala* ethyl and methanol extracts.

Conclusions From this study, ethyl acetate and methanol leaf extracts (75% and 100% v/v concentrations) are effective as contact and stomach poisons against fall armyworm and suitable replacements for synthetic pesticides.

Keywords Fall armyworm, Tannin, Flavonoid, *Dennettia tripetala*, *Jatropha curcas*, Leaf extracts, Stomach poison

Background

Spodoptera frugiperda J. E. Smith (Lepidoptera: Noctuidae), commonly called fall armyworm (FAW), is one of the devastating insect pests of several crops. It is a polyphagous pest (Baudron et al., 2019), causing damage to economically important cultivated cereal crops such as

maize, rice, sorghum, cotton, and various vegetable crops and eventually impacts food security (Bateman et al., 2018; CABI, 2018; FAO, 2017). Larvae are the damaging stage of FAW; they make different sizes of papery windows in leaves leading to extensive defoliation of plants (Reddy, 2019).

In maize, larvae of FAW destroy fresh leaves, impair growth, and ultimately reduce crop yield. Until 2016, there was no recorded incidence of FAW invasion in West Africa (Bateman et al., 2018). Outbreaks of FAW were reported in January 2016 in southwest Nigeria,

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Ghana, Benin, Sao Tome, and Togo (Bateman et al., 2018). However, FAW is now reported to be present in over 40 countries in tropical and southern Africa, including Madagascar (Bateman et al., 2018). Hence, to meet the demand for maize, it is necessary to tackle the problem of maize yield loss due to FAW (Akhigbe, 2021). Many farmers use synthetic chemical insecticides to mitigate the loss due to FAW infestation. However, synthetic chemical insecticides have unintended detrimental consequences, including residues in food and water (Paragas et al., 2018). The unexpected outcomes of pesticides necessitate the development of alternative effective eco-friendly insecticides.

The use of biopesticides is, by far, more advantageous than their counterparts, chemical pesticides, as they are eco-friendly and host-specific. The use of agrochemicals in the agricultural sector could be replaced with the use of biopesticides (Essiedu et al., 2020).

Dennettia tripetala (Pepper Fruit) is a plant that belongs to the Annonaceae family. It is abundant in the tropical rainforest region of Nigeria (Morah, 2005). It is commonly called ‘pepper fruit’ in English, *mmimi* in Igbo, *nkaika* in Ibibio, *imako* in Urhobo, *ako* in Edo, *opipi* in Idoma, and *igberi* in Yoruba languages of Nigeria (Morah, 2005). *Jatropha curcas* Linn. is commonly known as ‘physic nut,’ a non-food bioenergy plant currently considered an alternative substitute to fossil fuels (Nahar & Ozoires-Hampton, 2011). It is a perennial shrub belonging to the *Euphorbiaceae* family, similar to rubber and cassava trees (Grover et al., 2014; Srinophakun et al., 2011).

This study will therefore provide the feeding and contact toxicity effect of methanol and ethyl acetate extract from *Jatropha curcas* leaves and *Dennettia tripetala* leaves against fall armyworm (*Spodoptera frugiperda*).

Methods

Plant materials

Leaves of *Jatropha curcas* were obtained from Fasola Town, Oyo State, Nigeria, located at latitude 7° 54'N and longitude 3° 46'E, and *Dennettia tripetala* leaves were obtained from the Department of Forest Resources and Wildlife Management, University of Benin, Nigeria, located at latitude 6° 24'N and longitude 5° 37'E.

Preparation of plant extracts

The leaves of *J. curcas* and *D. tripetala* were air-dried for five days and then macerated using a blender (Binatone 1267). The macerated samples were soaked in methanol and ethyl acetate successively for 72 h with periodic shaking and then was filtered to obtain the extract. The extract was then concentrated at the Nigerian Institute of

Science Laboratory Technology (NISLT), Samonda, using a rotary evaporator to obtain a crude extract.

Test insect

The third instar larvae of *Spodoptera frugiperda* maintained on artificial diets at 25 ± 1 °C, and 65–75% relative humidity was obtained from the Insect Rearing Unit of the International Institute of Tropical Agriculture (IITA).

Experimental design and treatment

The contact and feeding toxicity tests were arranged in a completely randomized design (CRD). The plant extracts comprised four types;

- *Jatropha curcas* Methanol
- *Jatropha curcas* Ethyl acetate
- *Dennettia tripetala* Methanol
- *Dennettia tripetala* Ethyl acetate

Each plant extract was made into 100%, 75%, 50%, and 25% concentrations, and the application of each of the extract concentrations was replicated five (5) times. Each replicate had six 3rd instars of *Spodoptera frugiperda* larvae in individual containers. Three controls were also used for the experiment which were water, untreated, and a synthetic standard, Lambda-cyhalothrin 2.5% EC.

Preparation of extract concentration

The plant extract concentrates were diluted with the respective solvents at a concentration of 1 gm/L, and this was termed as the stock solution (100% v/v concentration) as described by Gitahi et al. (2021). The concentrations that were tested are 25% (v/v), 50% (v/v), 75% (v/v), and 100% (v/v). These extract concentrations were prepared as follows: the 25% (v/v) concentration was prepared by diluting 1 ml of the stock solution with 3 ml of solvent to make 4 ml. The 50% (v/v) concentration was prepared by diluting 2 ml of the stock solution with 2 ml of the solvent to make 4 ml, while for the 75% (v/v) concentration, 1 ml of the solvent was added to 3 ml of stock solution to make 4 ml.

Contact assay

The effect of *J. curcas* and *D. tripetala* extracts at various treatments was assessed. One hundred (100) µl of each treatment was added to the abdominal terga of the test insect in each replicate as used in a study by Wheeler and Isman (2001) with limited modification. Mortality was recorded at 24, 48, 72, and 96 h after the insects are exposed to the extracts.

Feeding deterrent Assay

The plant extracts were incorporated into the artificial diet in which cowpea flour and wheat germ were the primary ingredient (Lazari et al., 2000). The diet was prepared by adding the respective extracts at a concentration of 1 gm/L. This was termed the stock solution (100% v/v concentration) as described by Gitahi et al. (2021) with slight modification. The extract concentrations tested were 25% (v/v), 50% (v/v), 75% (v/v), and 100% (v/v). These artificial diets were prepared as follows: the 25% (v/v) concentration was prepared by diluting 1 g of the artificial diet with 3 g of the extract concentration to make up 4 g. Larval duration, larval mortality, pupal mortality, and pupal weight were measured. Larval duration was measured in days and pupal weight a day after pupation.

Quantitative phytochemical screening of plant extracts

Quantitative phytochemical analysis of the methanol and ethyl acetate extract of *J. curcas* and *D. tripetala* was carried out to quantify the alkaloids, tannins, flavonoid, and total phenol content in the extracts. The quantitative phytochemical analysis was conducted at the Department of Chemistry, University of Ibadan.

Total flavonoid content

The procedure to determine the total flavonoid content of the plant extracts was modified from Kavitha et al. (2016). Briefly, 0.5 ml of extract (500 µg/ml), 2 ml of distilled water, and 0.15 ml of sodium nitrite (5% NaNO₂ w/v) were added, and the mixture was allowed to stand for 5 min. To the mixture, 0.15 ml of aluminum chloride (10% AlCl₃) was added and left to stand for 6 min. One milliliter (1 ml) of sodium hydroxide (4%w/v, NaOH) was added. The mixture was made up to the 5 ml mark and incubated at room temperature for 15 min. The absorbance was measured at 510 nm. The procedure was repeated to obtain the blank and calibration curve for the standard flavonoid rutin (5–100 µg/ml).

Total phenolic content

The procedure from Kavitha et al. (2016) was modified to determine the total phenolic content of the plant extract. Two milliliters (2 ml) of Folin–Ciocalteu (1:10) was added to 0.5 ml of the plant extract (500 µg/ml) in a test tube and incubated for 5 min at room temperature (in the dark). Then, 4 ml of sodium carbonate (7.5%, w/v) was added to the mixture. The resultant mixture was incubated in the dark for 30 min at room temperature with intermittent shaking. The absorption was measured at 765 nm. The calibration curve for gallic acid (1–20 µg/ml) and blank was also determined using the same procedure.

Total tannins

Total tannin content was determined using the procedure described by Tambe and Bhambar (2014) with slight modifications. Folin–Ciocalteu (0.25 ml) was added to 3.75 ml of distilled water. Then, 0.05 ml of the extract (500 µg/ml) and 0.5 ml of Na₂CO₃ were added to the solution. The mixture was made up to the 5 ml mark with distilled water. The mixture was well shaken and incubated at room temperature in the dark for 30 min. Absorbance was measured at 700 nm. The calibration curve was obtained for tannic acid (20–100 µg/ml).

Total alkaloids

Total alkaloid content of the plant extract was determined using procedure modified from John et al. (2014). The plant extract (10 mg/ml) was dissolved in methanol, and 5 ml of 2 N HCl was added and filtered. Then, 5 ml of BCG solution and 5 ml of phosphate buffer were added to the mixture. The mixture was shaken, and the complex formed was extracted with 1, 2, 3, and 4 ml chloroform by vigorous shaking. The extracts were collected in a 10-ml volumetric flask and diluted to volume with chloroform. The absorbance of the complex in chloroform was measured at 470 nm.

Preparation of standard curve

Aliquots (0.4, 0.6, 0.8, 1.0, and 1.2 ml) of atropine 100 µg/ml standard solution were transferred to different separatory funnels. Exactly, 5 ml of pH 4.7 phosphate buffers and 5 ml BCG solution were added. The mixture was shaken, and the complex formed was extracted with 1, 2, 3, and 4 ml chloroform by vigorous shaking. The extracts were collected in a 10-ml volumetric flask and diluted to volume with chloroform. The absorbance of the complex in chloroform was measured at 470 nm.

Statistical analysis

Data collected were subjected to analysis of variance (ANOVA) at a 5% level of significance. Means were separated using Tukey's test on the R application software. Data were presented as mean ± standard deviation.

Results

Contact toxicity effect of *D. tripetala* and *J. curcas* ethyl acetate leaf extracts against *S. frugiperda*

Ethyl acetate leaf extract of *D. tripetala*

The mean percentage mortality of *S. frugiperda* larvae to ethyl acetate leaf extract of *D. tripetala* at extract concentration of 25%, 50%, 75%, and 100% is shown in Table 1. At 24 h, the mean percentage mortality ranged from 90.00 ± 14.91 in the 100% extract concentration to 73.33 ± 22.36 in the 25% extract concentration. There was no significant difference ($p > 0.05$) in larvae mortality

Table 1 Contact toxicity of ethyl acetate leaf extracts of *D. tripetala* against *S. frugiperda*

Treatment (% extract)	Mean percent mortality (%) with exposure period (Hours)			
	24 h	48 h	72 h	96 h
25	73.33 ± 22.36 b	80.00 ± 18.26 b	80.00 ± 18.26 b	83.33 ± 13.94 b
50	80.00 ± 13.94 b	80.00 ± 13.94 b	80.00 ± 13.94 b	86.67 ± 16.67 b
75	86.67 ± 13.94 b	93.33 ± 7.45 b	96.67 ± 7.45 b	96.67 ± 7.45 b
100	90.00 ± 14.91 b	96.67 ± 9.13 b	96.67 ± 7.45 b	100.00 ± 0.00 b
H ₂ O	6.67 ± 9.13 a	6.67 ± 9.13 a	6.67 ± 9.13 a	6.67 ± 9.13 a
Untreated	3.33 ± 7.45 a	6.67 ± 9.13 a	6.67 ± 9.13 a	6.67 ± 9.13 a
Lambda-cyhalothrin	100.00 ± 0.00 b	100.00 ± 0.00 b	100.00 ± 0.00 b	100.00 ± 0.00 b

Values are expressed as means ± SD. Statistical comparisons were made within a column, and values followed by the same alphabets along the column are not significantly different using Tukey's test $p < 0.05$

across the extract concentrations and the standard pesticides, Lambda-cyhalothrin. The water and untreated controls had low mortality of 6.67% and 3.33%, respectively, significantly lower than the effects caused by other concentrations. The same trend could be seen at 48, 72, and 96 h as there was also no significant difference ($p > 0.05$) among the extract concentrations and the standard pesticides, Lambda-cyhalothrin. Also, larvae mortality increased with an increase in exposure time from 24 to 96 h (Table 1).

Ethyl acetate leave extract of *J. curcas*

The mean percentage mortality of *S. frugiperda* larvae to ethyl acetate leaf extract of *J. curcas* at extract concentration of 25%, 50%, 75%, and 100% is shown in Table 2.

At 24 h, the mortality ranged from 26.67 ± 9.13 in the 25% extract concentration to 86.67 ± 7.45 in the 100% extract concentration. There was significant difference ($p < 0.05$) in the larvae mortality across the extract concentrations. The larvae mortality at 25% and 50% extract concentration was similar, and the larvae mortality at 100% extract concentration was similar to the standard pesticides, Lambda-cyhalothrin. This same trend could be seen at 48 h.

At 72 h, the larvae mortality ranged from 43.33 ± 9.13 in the 25% extract concentration to 96.67 ± 7.45 in the 100% extract concentration, and larvae mortality increased with an increase in exposure time. There was significant difference ($p < 0.05$) across the extract's concentration. The larvae mortality at 25% and 50% extract concentrations was significantly similar, and the larvae mortality at 75%, 100%, and the standard pesticide used was similar. The water and untreated controls had low mortality of 6.67% and 6.67%, respectively, significantly lower than the effects caused by other concentrations; this same trend at 72 h could also be seen at 96 h (Table 2).

Contact toxicity effect of methanol leaf extract of *D. tripetala* and *J. curcas* against *S. frugiperda*
Methanol leaf extract of *D. tripetala*

The mean percentage mortality of *S. frugiperda* larvae to methanol leaf extract of *D. tripetala* at extract concentration of 25%, 50%, 75%, and 100% is shown in Table 3. Data were presented as mean ± standard deviation.

At 24 h, the mortality ranged from 20.00 ± 13.94 in the 25% extract concentration to 63.33 ± 18.26 in the 100% extract concentration. There was significant difference ($p < 0.05$) in the larvae mortality across the extract

Table 2 Contact toxicity of ethyl acetate leaf extracts of *J. curcas* against *S. frugiperda*

Treatment (% extract)	Mean percent mortality (%) with exposure period (Hours)			
	24 h	48 h	72 h	96 h
25	26.67 ± 9.13 b	26.67 ± 9.13 b	43.33 ± 9.13 b	43.33 ± 9.13 b
50	36.67 ± 13.94 b	43.33 ± 9.13 b	43.33 ± 9.13 b	53.33 ± 13.94 b
75	73.33 ± 9.13 c	76.67 ± 9.13 c	80.00 ± 13.94 c	93.33 ± 9.13 c
100	86.67 ± 7.45 cd	93.33 ± 9.13 cd	96.67 ± 7.45 c	100.00 ± 0.00 c
H ₂ O	3.33 ± 7.45 a	6.67 ± 9.13 a	6.67 ± 9.13 a	10.00 ± 9.13 a
Untreated	3.33 ± 7.45 a	3.33 ± 7.45 a	6.67 ± 14.91 a	10.00 ± 14.91 a
Lambda-cyhalothrin	100.00 ± 0.00 d	100.00 ± 0.00 d	100.00 ± 0.00 c	100.00 ± 0.00 c

Values are expressed as means ± SD. Statistical comparisons were made within a column, and values followed by the same alphabets along the column are not significantly different using Tukey's test $p < 0.05$

Table 3 Contact toxicity of methanol leaf extracts of *D. tripetala* against *S. frugiperda*

Treatment (% extract)	Mean percent mortality (%) with exposure period (Hours)			
	24 h	48 h	72 h	96 h
25	20.00±13.94 ab	26.67±9.13 b	26.67±9.13 b	26.67±9.13 b
50	26.67±9.13 bc	30.00±7.45 b	30.00±7.45 b	30.00±7.45 b
75	46.67±7.45 cd	50.00±11.79 c	53.33±13.94 c	56.67±9.13 c
100	63.33±18.26 d	70.00±13.94 d	73.33±14.91 d	76.67±9.13 d
H ₂ O	6.67±9.13 ab	6.67±9.13 a	6.67±9.13 a	6.67±9.13 a
Untreated	3.33±7.45 a	3.33±7.45 a	3.33±7.45 a	6.67±9.13 a
Lambda-cyhalothrin	100.00±0.00 e	100.00±0.00 e	100.00±0.00 e	100.00±0.00 e

Values are expressed as means ± SD. Statistical comparisons were made within a column, and values followed by the same alphabets along the column are not significantly different using Tukey's test $p < 0.05$

concentrations. The larvae mortality at 25% and 50% extract concentration was similar. There was significant difference ($p < 0.05$) between the 100% extract concentration and the standard pesticides, Lambda-cyhalothrin. This same trend could be seen at 48 h.

At 72 h, the larvae mortality ranged from 53.33 ± 13.94 in the 25% extract concentration to 90.00 ± 5.83 in the 100% extract concentration. There was significant difference ($p < 0.05$) across the extract's concentration. The larvae mortality at 25% and 50% extract concentrations was similar. There was no significant difference ($p > 0.05$) observed in the larvae mortality at 75%, 100%, and the standard pesticide used. The water and untreated controls had low mortality of 6.67% and 6.67%, respectively, lower than the effects caused by other concentrations; this same trend at 72 h could also be seen at 96 h. The percentage mortality remained constant from 48 to 92 h of extract exposure across the extract's concentrations (Table 3).

Methanol leaf extract of *J. curcas*

The mean percentage mortality of *S. frugiperda* larvae to methanol leaf extract of *J. curcas* at extract concentration of 25%, 50%, 75%, and 100% is shown in Table 4.

At 24 h, the mortality ranged from 43.33 ± 9.13 in the 25% extract concentration to 76.67 ± 14.91 in the 100% extract concentration. There was significant difference ($p < 0.05$) in the larvae mortality across the extract concentrations. The larvae mortality at 25% and 50% extract concentration was similar. There was significant difference ($p < 0.05$) between the 100% extract concentration and the standard pesticides, Lambda-cyhalothrin. This same trend could be seen at 48 h.

At 72 h, the larvae mortality ranged from 53.33 ± 13.94 in the 25% extract concentration to 90.00 ± 14.91 in the 100% extract concentration. There was significant difference ($p < 0.05$) across the extract's concentration. The larvae mortality at 25% and 50% extract concentrations were similar. Significant difference ($p < 0.05$) was observed in the larvae mortality at 75%, 100%, and the standard pesticide used. The water and untreated controls had low mortality of 6.67% and 3.33%, respectively, lower than the effects caused by other concentrations; this same trend can be seen at 72 h. The percentage mortality remained constant or had little increase from 48 to 92 h of extract exposure across the extract's concentrations (Table 4).

Table 4 Contact toxicity effect of methanol leaf extracts of *J. curcas* against *S. frugiperda*

Treatment (% extract)	Mean percent mortality (%) with exposure period (Hours)			
	24 h	48 h	72 h	96 h
25	43.33±9.13 b	53.33±13.94 b	53.33±13.94 b	53.33±13.94 b
50	53.33±13.94 b	60.00±19.00 b	60.00±19.00 bc	60.00±19.00 bc
75	60.00±9.13 bc	76.67±14.91 bc	83.33±16.67 cd	83.33±16.67 cd
100	76.67±14.91 c	86.67±13.94 c	90.00±14.91 d	90.00±14.91 d
H ₂ O	3.33±7.45 a	3.33±7.45 a	6.67±9.13 a	6.67±9.13 a
untreated	3.33±7.45 a	3.33±7.45 a	6.67±9.13 a	6.67±7.45 a
Lambda-cyhalothrin	100.00±0.00 d	100.00±0.00 d	100.00±0.00 d	100.00±0.00 d

Values are expressed as means ± SD. Statistical comparisons were made within a column, and values followed by the same alphabets along the column are not significantly different using Tukey's test $p < 0.05$

Feeding deterrent activity of ethyl acetate leave extract of *D. tripetala* and *J. curcas* against *S. frugiperda*

Ethyl acetate leaf extract of *D. tripetala*

The feeding deterrent effect of ethyl acetate leaf extract of *D. tripetala* at extract concentration of 25%, 50%, 75%, and 100% is shown in Table 5.

The larvae duration (days) ranged from 11.47 ± 1.04 in the 100% extract concentration to 13.33 ± 1.65 in the 50% extract concentration. The water and untreated diet control had the standard larvae duration days of between 17 to 20 days.

There was no significant difference ($p > 0.05$) in the larvae mortality across the extract concentrations. The larvae mortality (%) ranged from 80.00 ± 13.94 in the 50% extract concentration to 93.33 ± 14.91 in the 100% extract concentration; there was no larvae mortality in the water and untreated diet control. The pupal mortality (%) ranged from 16.67 ± 0.00 in the 25% extract concentration to 33.33 ± 0.00 in the 100% extract concentration; there was no significant difference ($p > 0.05$) in the pupal mortality across the extract concentrations. Also, the pupal weight (Grams) ranged from 0.21 ± 0.01 in the 75% extract concentration to 0.24 ± 0.01 in the 25% extract concentration; there was no significant difference ($p > 0.05$) in the pupal weight across the extract

concentrations and the water and untreated controls (Table 5).

Ethyl acetate leaf extract of *J. curcas*

The feeding deterrent effect of ethyl acetate leaf extract of *J. curcas* at extract concentration of 25%, 50%, 75%, and 100% is shown in Table 6.

The larvae duration (days) ranged from 11.39 ± 0.44 in the 75% extract concentration to 14.74 ± 2.20 in the 25% extract concentration. The water and untreated diet control had the standard larvae duration days of between 17 to 20 days.

There was no significant difference ($p > 0.05$) in the larvae mortality at extract concentrations of 50%, 75%, 100%, and the standard pesticide, Lambda-cyhalothrin. The larvae mortality (%) ranged from 60.00 ± 27.84 in the 25% extract concentration to 100.00 ± 0.00 in the 100% extract concentration. There was no significant difference ($p > 0.05$) in the pupal mortality across the extract concentrations. Also, the pupal weight (grams) ranged from 0.23 ± 0.02 in the 25% extract concentration to 0.24 ± 0.04 in the 50% and 75% extract concentration; there was no significant difference ($p > 0.05$) in the pupal weight across the extract concentrations and the water and untreated controls (Table 6).

Table 5 Feeding deterrent activity of ethyl acetate leaf extract of *D. tripetala* against *S. frugiperda*

Treatment (% extract)	Larval duration (Days)	Larval mortality (%)	Pupal mortality (%)	Pupal weight (Grams)
25	12.40 ± 1.28 ab	83.33 ± 23.57 b	16.67 ± 0.00 ab	0.24 ± 0.01 a
50	13.33 ± 1.65 b	80.00 ± 13.94 b	20.83 ± 8.33 b	0.23 ± 0.01 a
75	12.40 ± 1.28 ab	83.33 ± 16.67 b	22.22 ± 19.25 b	0.21 ± 0.01 a
100	11.47 ± 1.04 ab	93.33 ± 14.91 b	33.33 ± 0.00 b	0.22 ± 0.02 a
H ₂ O	18.33 ± 0.41 c	0.00 ± 0.00 a	0.00 ± 0.00 a	0.26 ± 0.02 a
Untreated	17.67 ± 0.00 c	0.00 ± 0.00 a	0.00 ± 0.00 a	0.25 ± 0.03 a
Lambda-cyhalothrin	11.00 ± 0.00 a	100.00 ± 0.00 b	–	–

Values are expressed as means $\pm$ SD. Statistical comparisons were made within a column, and values followed by the same alphabets along the column are not significantly different using Tukey's test $p < 0.05$

Table 6 Feeding deterrent activity of ethyl acetate leaf extract of *J. curcas* against *S. frugiperda*

Treatment (% extract)	Larval duration (Days)	Larval mortality (%)	Pupal mortality (%)	Pupal weight (Grams)
25	14.74 ± 2.20 b	60.00 ± 27.89 b	16.67 ± 13.61 a	0.23 ± 0.02 a
50	12.13 ± 1.30 a	93.33 ± 14.91 c	16.67 ± 13.61 a	0.24 ± 0.04 a
75	11.39 ± 0.44 a	96.67 ± 7.45 c	16.67 ± 13.61 a	0.24 ± 0.04 a
100	11.53 ± 0.84 a	100.00 ± 0.00 c	–	–
H ₂ O	18.07 ± 0.36 c	6.67 ± 9.13 a	6.67 ± 9.13 a	0.25 ± 0.02 a
untreated	18.33 ± 0.47 c	3.33 ± 7.45 a	3.33 ± 7.45 a	0.26 ± 0.06 a
Lambda-cyhalothrin	11.00 ± 0.00 a	100.00 ± 0.00 c	–	–

Values are expressed as means $\pm$ SD. Statistical comparisons were made within a column, and values followed by the same alphabets along the column are not significantly different using Tukey's test $p < 0.05$

Feeding deterrent activity of methanol leave extracts of *D. tripetala* and *J. curcas* against *S. frugiperda*

Methanol leaf extract of *D. tripetala*

The feeding deterrent effect of methanol leaf extract of *D. tripetala* at extract concentration of 25%, 50%, 75%, and 100% is shown in Table 7. The larvae duration (days) ranged from 11.39 ± 0.78 in the 75% extract concentration to 14.74 ± 1.74 in the 25% extract concentration. The water and untreated diet control had the standard larvae duration days of between 17 to 20 days.

There was significant difference ($p < 0.05$) in the larvae mortality across the extract concentrations. The larvae mortality (%) ranged from 60.00 ± 18.26 in the 25% extract concentration to 100.00 ± 0.00 in the 100% extract concentration. There was no significant difference ($p > 0.05$) in the pupal mortality across the extract concentrations. Also, the pupal weight (grams) ranged from 0.23 ± 0.02 in the 25% extract concentration to 0.24 ± 0.04 in the 50% and 75% extract concentration; there was no significant difference ($p > 0.05$) in the pupal weight across the extract concentrations and the water and untreated controls (Table 7).

Methanol leaf extract of *J. curcas*

The feeding deterrent effect of methanol leaf extract of *J. curcas* at extract concentration of 25%, 50%, 75%, and 100% is shown in Table 8.

The larvae duration (days) ranged from 11.33 ± 0.24 in the 75% extract concentration to 15.60 ± 1.61 in the 25% extract concentration. There was significant difference ($p < 0.05$) in the larval duration across the extract concentrations. The water and untreated diet control had the standard larvae duration days of between 17 to 20 days.

There was significant difference ($p < 0.05$) in the larvae mortality across the extract concentrations. The larvae mortality (%) ranged from 56.67 ± 14.91 in the 50% extract concentration to 100.00 ± 0.00 in the 75% and 100% extract concentration. There was no significant difference ($p > 0.05$) in the pupal mortality across the extract concentrations and the controls. Also, there was no significant difference ($p > 0.05$) in the pupal weight across the extract concentrations and the water and untreated controls (Table 8).

Quantitative phytochemical analysis of *D. tripetala* and *J. curcas* ethyl acetate and methanol leaf extracts

The quantitative phytochemical analysis of ethyl acetate and methanol leaf extract of *D. tripetala* and *J. curcas* was conducted to quantify the flavonoid, total phenol content, total alkaloid content, and total tannin contents of the extracts.

Table 7 Feeding deterrent activity of methanol leaf extract of *D. tripetala* against *S. frugiperda*

Treatment (% extract)	Larval duration (Days)	Larval mortality (%)	Pupal mortality (%)	Pupal weight (Grams)
25	14.74 ± 1.74 b	60.00 ± 18.26 b	16.67 ± 7.45 a	0.23 ± 0.02 a
50	12.13 ± 1.09 a	93.33 ± 14.91 c	16.67 ± 7.45 a	0.24 ± 0.04 a
75	11.39 ± 0.78 a	96.67 ± 7.45 c	16.67 ± 7.45 a	0.24 ± 0.04 a
100	11.53 ± 1.34 a	100.00 ± 0.00 c	–	–
H ₂ O	18.07 ± 0.82 c	6.67 ± 5.84 a	6.67 ± 4.50 a	0.27 ± 0.02 a
untreated	18.33 ± 0.47 c	3.33 ± 7.45 a	3.33 ± 7.45 a	0.27 ± 0.02 a
Lambda-cyhalothrin	11.00 ± 0.00 a	100.00 ± 0.00 c	–	–

Values are expressed as means $\pm$ SD. Statistical comparisons were made within a column, and values followed by the same alphabets along the column are not significantly different using Tukey's test $p < 0.05$

Table 8 Feeding deterrent activity of methanol leaf extract of *J. curcas* against *S. frugiperda*

Treatment (% extract)	Larval duration (Days)	Larval mortality (%)	Pupal mortality (%)	Pupal weight (Grams)
25	15.60 ± 1.61 c	73.33 ± 25.28 b	0.00 ± 0.00 a	0.23 ± 0.02 a
50	13.20 ± 1.46 b	56.67 ± 14.91 b	6.67 ± 9.13 a	0.23 ± 0.02 a
75	11.33 ± 0.24 a	100.00 ± 0.00 c	–	–
100	11.54 ± 0.30 ab	100.00 ± 0.00 c	–	–
H ₂ O	18.20 ± 0.56 d	3.33 ± 7.45 a	3.33 ± 7.45 a	0.25 ± 0.01 a
untreated	18.60 ± 0.37 d	3.33 ± 7.45 a	3.33 ± 7.45 a	0.25 ± 0.01 a
Lambda-cyhalothrin	11.00 ± 0.00 a	100.00 ± 5.27 c	–	–

Values are expressed as means $\pm$ SD. Statistical comparisons were made within a column, and values followed by the same alphabets along the column are not significantly different using Tukey's test $p < 0.05$

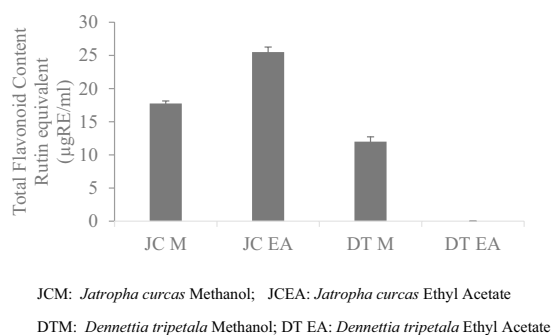


Fig. 1 Total flavonoid content in leaf extracts

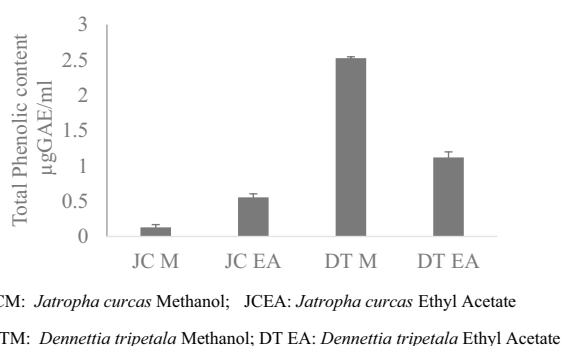


Fig. 2 Total phenolic content in leaf extracts

Total flavonoid content

Total flavonoid content of the extract was evaluated using rutin as a reference compound. The calibration curve of rutin was obtained at 510 nm. The ethyl acetate leaf extract of *J. curcas* had the highest flavonoid content of 25.5 µg RE/ml, followed by the methanol leaf extract of *J. curcas* of 17.75 µgRE/ml. Flavonoid was absent in the ethyl acetate leaf extract of *D. tripetala* (Fig. 1).

Total phenolic content

Total phenolic content of the extract was evaluated using gallic acid as a reference standard. The leaf extracts of *D. tripetala* had high total phenol content compared to the leaf extracts of *J. curcas*. The methanol leaf extract of *D. tripetala* had the highest TPC of 2.5 µgGAE/ml, while the methanol leaf extract of *J. curcas* had the lowest TPC of 0.13 µgGAE/ml (Fig. 2).

Total alkaloid content

Total alkaloid content of the extract was evaluated using atropine as a reference standard. The ethyl acetate leaf extract of *J. curcas* had the highest total alkaloid content of 8.28 µg atropine equivalent/ml, while the methanol leaf extract of *J. curcas* had the lowest alkaloid content (Fig. 3).

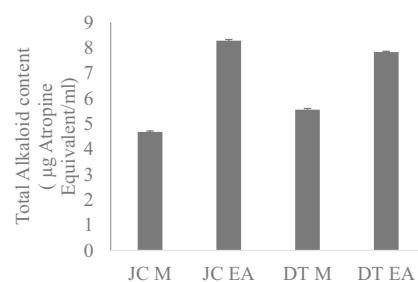


Fig. 3 Total alkaloid content in leaf extracts

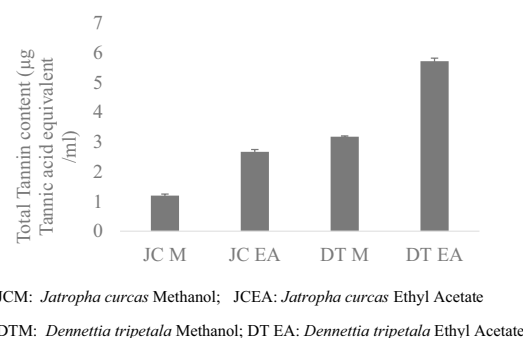


Fig. 4 Total tannin content in leaf extracts

Total tannin content

Total tannin content of the extract was evaluated using tannic acid as a reference standard. The leaf extracts of *D. tripetala* had higher tannin content than those of *J. curcas*. The ethyl acetate leaf extract of *D. tripetala* had the highest tannin content of 5.72 µg tannic acid equivalent / ml, while the methanol leaf extract had the lowest tannin content (Fig. 4).

Discussion

In this study, the feeding and contact toxicity effects of ethyl acetate and methanol leaf extracts of *D. tripetala* and *J. curcas* against *S. frugiperda* were evaluated.

In the contact toxicity test, the two plant species displayed contact toxicity properties against *S. frugiperda* larvae. Mortality of fall armyworm (FAW) larvae increased with an increase in the concentration of *J. curcas* and *D. tripetala* leaf extracts and also with an increase in time of exposure from 24 to 96 h. This agrees with the report of Kovendan et al. (2011) that the larvicidal efficacy of *J. curcas* leaf methanol extracts against a dipteran, *Culex quinquefasciatus*, occurred 24 h after treatment. The larval mortality was generally high in the

ethyl acetate leaf extract of *D. tripetala* at all exposure times. The 100% ethyl acetate leaf extract of *D. tripetala* had the same mortality effect as the pesticide standard, Lambda-cyhalothrin 2.5% EC against *S. frugiperda*, and could be an effective biopesticide against *S. frugiperda*.

The contact toxicity effect of the ethyl acetate leaf extracts of *J. curcas* could be seen at 75% extract concentration across the exposure time. The larval mortality was generally low at the 25% and 50% ethyl acetate leaf extracts of *J. curcas*.

The methanol leaf extract of *D. tripetala* had low mortality at 25%, 50%, and 75% at each exposure time, and also the 100% methanol leaf extract of *D. tripetala* had low larval mortality compared to the 100% ethyl acetate leaf extract of *D. tripetala* and *J. curcas*; this shows that the methanol leaf extract of *D. tripetala* was less potent than the ethyl acetate leaf extract of *D. tripetala* and *J. curcas*.

The methanol leaf extracts of *J. curcas* had low mortality in the 25% and 50% extract concentrations across the exposure periods. The 75% and 100% methanol leaf extracts of *J. curcas* showed an increase in larval mortality with an increase in exposure time. The 100% methanol leaf extracts of *J. curcas* at 72 h and 96 h exposure period had similar mortalities with the standard pesticide, Lambda-cyhalothrin.

The effects of the treatments at different extract concentration levels on *S. frugiperda* were notably different from each other. The bioactivities of ethyl acetate and methanol leaf extracts of *D. tripetala* and *J. curcas* were directly proportional to the extract concentrations. The higher the plant extract concentration, the more potent the extract.

In the feeding deterrent activity of ethyl acetate leaf extract of *D. tripetala* and *J. curcas* against *S. frugiperda*, the extracts revealed a significant difference in the larva duration and larva mortality in relation to the water and untreated artificial diet controls. There was a shortening in the larval stages of *S. frugiperda* fed with artificial treated with the extract's concentrations (25%, 50%, 75%, and 100%) compared with the control treatments (water and untreated). In contrast, in the feeding deterrent activity of methanol leaf extracts of *D. tripetala* and *J. curcas* against *S. frugiperda*, the extracts also revealed a significant difference ($p < 0.05$) in the larva duration and larva mortality in relation to the water and untreated artificial diet controls, and the methanol leaf extracts of *D. tripetala* and *J. curcas* showed no significant difference ($p > 0.05$) in the pupal mortality and pupal weight among the treatments; this agrees with the study of Ribeiro et al. (2012) that there was no significant difference in the effect of methanolic extracts of *Jatropha curcas* on *Spodoptera frugiperda* pupal weight.

Hence, methanol and ethyl acetate extracts of *J. curcas* and *D. tripetala* at 75% and 100% extract concentration could easily replace Lambda-cyhalothrin and achieve control of FAW just like the synthetic chemical.

J. curcas ethyl acetate and *J. curcas* methanol extracts had high flavonoid content, which is known to prevent larvae growth and cause high mortality, according to Lina et al. (2023). The *J. curcas* ethyl acetate and *J. curcas* methanol extracts performed best in larval mortality, which could be a result of the high flavonoid content present.

Tannin content was higher in *D. tripetala* ethyl acetate and methanol extracts compared to the quantities detected in *J. curcas*. Karamanoli et al. (2011) reported that tannin binds to insect salivary proteins and digestive enzymes. Hence, tannins are toxic to insects.

Conclusions

From the study, the ethyl acetate and methanol leaf extracts (75% and 100% v/v concentrations) are effective as contact and stomach poisons against fall armyworm, and suitable replacements for synthetic pesticides. In the contact toxicity test, the 75% and 100% methanol and ethyl acetate leaf extracts of *J. curcas* showed an increase in larval mortality with an increase in exposure time; the extracts performed best in larval mortality. The 75% and 100% *D. tripetala* ethyl acetate and methanol extracts performed best in the feeding deterrent activity as they shortened the larval duration and increased the pupal mortality of *S. frugiperda*.

Farmers should reduce their use of synthetic pesticides due to the residues they leave on crop produce and the decimation of beneficial organisms. Biopesticides are an effective and environmentally friendly option for pest management. However, like any pest control method, they require careful consideration and proper use to achieve the best results.

Abbreviations

FAW	Fall armyworm
FAO	Food and Agricultural Organization
CABI	Centre for Agriculture and Bioscience International
NISLT	Nigerian Institute of Science Laboratory Technology
IITA	International Institute of Tropical Agriculture
CRD	Completely randomized design
EC	Emulsifiable concentrates
ANOVA	Analysis of variance

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Author contributions

OI performed the experiment and drafted the manuscript. OA supervised the research. All authors read and approved the manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the study are available from the corresponding author upon reasonable request.

Declarations

Competing interests

The authors declare that they have no competing interests.

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