

# Comparative Toxicological and biochemical Effects of Seed and Leaf extracts of *Azadirachta indica* and *Jatropha curcas* on the Fall armyworm (*Spodoptera frugiperda*) Under Laboratory Conditions

Mayaki Alhaji Cece

[mayaki.cece@fedpolybida.edu.ng](mailto:mayaki.cece@fedpolybida.edu.ng)

Federal Polytechnic

Israel Kayode Olayemi

Federal University of Technology Minna

Muhammadu Tajudeen Salaudeen

Federal University of Technology Minna

Azubuike Christian Ukubuiwe

Federal University of Technology Minna

Ibrahim Maikudi Salihu

Aerospace University Abuja

---

## Research Article

**Keywords:** Fall armyworm, botanical, toxicity, biochemical responses, maize protection

**Posted Date:** September 21st, 2026

**DOI:** <https://doi.org/10.21203/rs.3.rs-10097061/v1>

**License:** © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

**Additional Declarations:** No competing interests reported.

---

# Abstract

The Fall armyworm, an invasive pest first documented in Nigeria in 2016, has caused significant declines in maize productivity across sub-Saharan Africa. This study evaluated the comparative toxicological and biochemical effects of seed and leaf extracts of *Azadirachta indica* (Neem) and *Jatropha curcas* (Physic nut) against Fall armyworm under laboratory conditions. Parameters examined included phytochemical composition, mortality of the larval, lethal concentrations ( $LC_{50}$ ), and the biochemical analysis. Phytochemical screening revealed the presence of phenols, saponins, tannins, steroids, flavonoids, terpenoids, and alkaloids in all extracts. All the botanical extracts significantly increased larval mortality. Probit analysis of larval mortality data yielded  $LC_{50}$  values of 7.95%, 11.18%, 9.38%, and 32.50% for seed extract of *A. indica* (SEAI), seed extract of *J. curcas* (SEJC), leaf extract of *A. indica* (LEAI), and leaf extract of *J. curcas* (LEJC), respectively, after 24 hours of exposure. Biochemical analysis at  $LC_{50}$  concentration revealed significant depletion of teneral reserves and inhibition of enzyme activities in treated larvae relative to controls. Protein, carbohydrate, and lipid contents ranged from 0.60–1.57, 0.53–1.84, and 0.56–1.46 mg/mL, respectively, while aspartate transferase and esterase activities ranged from 53.00–72.34 IU/L and 2.42–3.34 mg naphthol/min per larval, respectively suggesting physiological stress and disruption of metabolic processes. These botanical extracts exhibit multi-target insecticidal properties against Fall armyworm through depletion of energy reserves and inhibition of detoxification enzymes, establishing them as promising eco-friendly biopesticides candidates.

## Introduction

Maize is one of the most important cereal crops cultivated worldwide and serves as a major source of food, feed and industrial raw materials (Erenstein *et al.*, 2022). In Nigeria, maize contributes significantly to food security and household income (Kolapo and Sieber, 2025). However, maize production is threatened by many insects pest, among which the Fall armyworm, is considered one of the most destructive. The young larvae of FAW initially feed in groups on the abaxial surface of young maize leaves and later migrate into the whorl. This feeding behavior produces typical windowing and skeletonization symptoms that decrease the photosynthetically active leaf area and severe infestations may damage the plants growing point, resulting in stunted growth vigor, and substantial yield reduction (Croce *et al.*, 2024). The mature FAW larvae cause significant damage during the reproductive stage of maize by attacking tassels, silks, and developing ears, such feeding activity can adversely affect pollination and fertilization, while ear penetration promotes grain deterioration and predisposes the crop to secondary diseases, ultimately reducing yield and harvest quality (Anjorin *et al.*, 2022). The larvae of FAW have the potential to cause maize yield losses ranging from 8.3–20.6 million metric tonnes per annum in 12 African maize producing countries, valued at US\$2.48b - US\$6.19b (Prasoo et al., 2022). Synthetic pesticides are the predominant approach for managing the FAW in Nigeria and many synthetic pesticides are losing efficacy against the FAW due to pesticide resistance (Li *et al.*, 2025). Additionally, insecticides are prohibitively expensive and contribute to environmental pollution, adversely affecting beneficial flora and fauna in terrestrial and aquatic habitats. Botanical extracts such as *Azadirachta indica* and *Jatropha curcas* have been suggested as viable alternatives to synthetic insecticides for FAW control, being environmentally benign, cost-effective, typically target-specific, and biodegradable (Kumar *et al.*, 2025). Despite the documented insecticidal properties of these botanicals, comparative studies evaluating the toxicological and biochemical effects of their seed and leaf extracts against Fall armyworm are remains limited. Therefore, this study aimed to compare the toxicological and biochemical effects of seed and leaf extracts of *A. indica* and *J. curcas* against FAW under laboratory conditions.

## Materials and methods

**Collection and identification of plant specimens** Seeds and leaves of *Jatropha curcas* (physic nut) and *Azadirachta indica* (neem) were collected from the Biological Garden of Federal Polytechnic Bida, Niger State, Nigeria. Plant specimens were authenticated by a botanist from the Department of Plant Biology, Federal University of Technology Minna. Voucher specimens were deposited in the herbarium of the Department of Animal Biology for future reference. Plant materials were washed with distilled water and air-dried at  $27 \pm 2^\circ\text{C}$  for two weeks until a constant weight was achieved (Bioca junior et al., 2020). **Preparation and extraction of plant materials** Seeds and leaves were separately ground into fine powder using an electric blender (Panasonic MX134) and sieved through a 0.1 mm mesh to standardize particle size. This procedure followed the method described by Phambala et al. (2020) with minor modifications. One hundred grams of each powder was immersed in 1000 mL of distilled water for 72 h with vigorous stirring every six hours (Uyi et al., 2019). The mixture was filtered sequentially through muslin cloth and Whatman No. 1 filter paper (Okafor et al., 2017). Filtrates were concentrated in a rotary vacuum evaporator at  $50^\circ\text{C}$  (Lima et al., 2023), until complete solvent removal, yielding dried crude extracts that were stored at  $4^\circ\text{C}$  until required (Nourou et al., 2022). Stock solutions were prepared and diluted to obtain different concentrations (5%, 7.5% and 10%). **Qualitative phytochemical analysis** Qualitative phytochemical screening was performed according to Ikoyi et al. (2023), to identify alkaloids, tannins, saponins, flavonoids, phenols, cardiac glycosides, steroids, anthraquinones, and terpenoids. Alkaloids were detected using Mayer's reagent; saponins by the persistent froth test; flavonoids by the NaOH colour test; tannins and phenols by the  $\text{FeCl}_3$  colour test; cardiac glycosides by the acetic acid– $\text{H}_2\text{SO}_4$  interface test; steroids and terpenes by the Liebermann–Burchard test; anthraquinones by the benzene–ammonia partition test; and terpenoids by the  $\text{H}_2\text{SO}_4$  colour test.

## Rearing of Fall armyworm larvae

Fall armyworm larvae were collected from untreated maize fields using entomological brushes and reared in plastic containers in a controlled growth chamber at  $26 \pm 2^\circ\text{C}$ ,  $75 \pm 5\%$  relative humidity, and a 12:12 h light:dark photoperiod (Prasoon et al., 2022). Pupae were transferred to moist filter-paper-lined Petri dishes and then to mesh-covered emergence cages. Upon adult eclosion, moths were supplied with honey-soaked cotton (Phambala et al., 2020). Fresh maize leaves were supplied for oviposition (Kumar et al., 2019), and eggs were collected daily (Phambala et al., 2020). Hatched larvae were reared to the required instar before use in bioassays. **Toxicological Bioassay** Fresh maize leaf discs (4 cm diameter, from 15–30-day-old plants) were dipped in each of four extract concentrations (5.0%, 7.5%, and 10.0% w/v) for 3 min; control discs were dipped in distilled water. Discs were air-dried on filter paper for 1 h before use. (Phambala et al., 2020). Fall armyworm larvae were food-deprived for 6 h to stimulate feeding, then ten third-instar larvae were introduced per plastic container to minimize cannibalism (Altaf et al., 2022). Containers were covered with muslin cloth secured with rubber bands to allow air circulation (Wahedi et al., 2017). Each treatment, including the control, was replicated three times in a completely randomized design. Larval mortality was recorded at 24, 48, 72 and 96 hours post-treatment. A larval was considered dead if it showed no coordinated movement after gentle probing with a brush (Tchegueni et al., 2023). The lethal concentration of the plant extracts was calculated using the probit analysis.

## Biochemical bioassay at $\text{LC}_{50}$

Maize leaf discs (4 cm diameter) were dipped at the previously determined  $LC_{50}$  concentration of each extract for 3 min, air-dried for 15 min, and offered to 3 h pre-starved third-instar larvae (five per container; three replicates per treatment). Controls received distilled water-treated leaves. After 24 h, dead larvae were removed. Surviving larvae were allowed to feed on untreated maize leaves for 72 h before biochemical analyses (Mukanga et al., 2022).

## Preparation of larval homogenates

Surviving larvae were homogenized in distilled water using a glass tissue grinder on ice. Homogenates were centrifuged at 1500 rpm for 20 min at 4°C to remove cellular and mitochondrial debris (Abdel-Razik and Mahmoud, 2017). Supernatants were stored at – 4°C until analysis.

## Determination of Teneral reserves

### Carbohydrate and lipid content

Carbohydrate content was determined using the anthrone method (absorbance at 625 nm) and lipid content using the vanillin-phosphoric acid method (absorbance at 525 nm). Concentrations were calculated from standard regression equations (Bozdogan et al., 2016).

## Total protein

The concentration of total soluble proteins in the larval samples was estimated following the Biuret method: An aliquot of 0.2 mL of larval homogenate was combined with 5 mL Biuret reagent and incubated for 30 min at 20–25°C for 30 min. Thereafter, absorbance was recorded at 546 nm. Using a spectrophotometer, and protein levels were calculated relative to a protein standard (Wilson and Walker, 2022)

## Determination of Aspartate amino transferase activity

Aspartate aminotransferase (ASAT) activity was determined colorimetrically as described by Abdel-Razik and Mahmoud (2017). Briefly, 0.2 mL of homogenate was added to 1 mL of phosphate buffer (pH 7.4) containing 0.2 mM  $\alpha$ -ketoglutaric acid and 200 mM L-aspartate. After 30 min, 10 mL of 0.4 N NaOH was added and absorbance measured at 520 nm after 5 min. ASAT activity (IU/L) = ( $\Delta OD/min$ )  $\times$  1745.

## Determination of Esterase activity

$\alpha$ - and  $\beta$ -esterase activities were determined using  $\alpha$ -naphthyl acetate and  $\beta$ -naphthyl acetate as substrates, respectively. Naphthol released was quantified spectrophotometrically at 600 nm ( $\alpha$ -esterase) and 555 nm ( $\beta$ -esterase) following addition of diazoblue sodium lauryl sulphate. Activity was expressed as mg naphthol per min per larva (Gaaboub et al., 2012).

## Statistical analysis

Data were subjected to one-way ANOVA. Treatment means were separated using Tukey's HSD test at  $P < 0.05$ . Probit analysis was used to estimate  $LC_{50}$  values.

# Results

## Phytochemical constituents

Results of qualitative phytochemical screening are presented in Table 1. All four extracts contained phenols, flavonoids, tannins, saponins, terpenoids, alkaloids, steroids, and reducing sugars. Glycosides were detected in both seed extracts but were absent in both leaf extracts. Phlobatannins were absent only in LEAI. Phenols, flavonoids, and tannins were highly present ('+++') in SEJC and moderately present ('++') in SEAI, while saponins were moderately present ('++') in LEAI and LEJC.

Table 1  
Qualitative phytochemical screening of selected botanical extracts

| Phytochemicals (mg/100g)                                                                                                                                                | SEAI | LEJC | LEAI | SEJC |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------|------|------|
| Phenols                                                                                                                                                                 | ++   | +    | +    | +++  |
| Flavonoids                                                                                                                                                              | ++   | +    | +    | +++  |
| Tannins                                                                                                                                                                 | ++   | +    | +    | +++  |
| Saponins                                                                                                                                                                | +    | ++   | ++   | +    |
| Phlobatanins                                                                                                                                                            | +    | +    | -    | +    |
| Terpenoids                                                                                                                                                              | +    | +    | +    | +    |
| Alkaloids                                                                                                                                                               | +    | +    | +    | +    |
| Glycosides                                                                                                                                                              | +    | -    | -    | +    |
| Steroids                                                                                                                                                                | +    | +    | +    | +    |
| Reducing sugar                                                                                                                                                          | +    | +    | +    | +    |
| (+++)=Highly present,(++)= moderately present,(+)= slightly present,(-)= absent                                                                                         |      |      |      |      |
| key: SEAI = Seed extract of <i>A. indica</i> SEJC = Seed extract of <i>J. Curcas</i> LEAI = Leaf extract of <i>A. indica</i> ; LEJC= Leaf extract of <i>J. Curcas</i> ; |      |      |      |      |

### Percentage Mortality of Fall Armyworm Larvae after Exposure to Different Botanical Extracts at 10% Concentration under Laboratory Conditions

Percentage mortality of FAW larvae after exposure to different botanical extracts at 10%

concentration in the laboratory are detailed in Fig. 1. There was gradual increased in mortality of FAW among the botanical extracts. The results indicated that, there were no significant ( $p > 0.05$ ) differences among the mortality of FAW recorded in SEAI. SEJC and LEAI. The % mortality of FAW ranged from 20% to 56.7% among all the botanical extracts after 24 h treatment while EMMB recorded 96.7% mortality of FAW and untreated control recorded 0.0% mortality of FAW larvae. At 48 h post treatment, there were significant ( $P < 0.05$ ) differences between the mortality of FAW recorded in SEAI and the three botanical extracts (SEJC, LEAI and LEJC). No significant ( $p > 0.05$ ) different between LEAI and SEJC was recorded. Seed extract of *A. indica* recorded the

highest mortality (73.3%) of FAW larvae at 10% concentration while the LEJC recorded the lowest mortality (36.7%) of FAW larvae and EMMB recorded 100% mortality of FAW while untreated control recorded 0.0% mortality. There were significant ( $p < 0.05$ ) differences in % mortality of FAW between SEAI and LEAI, SEJC and LEJC after 72h treatment which recorded 93.3%, 76.7%, 63.3% and 46.7% mortality respectively, while EMMB recorded 100% mortality of FAW and untreated control recorded 3.33% mortality of FAW larvae. At 96 h post treatment, there was no significant ( $p > 0.05$ ) differences of mortality of FAW recorded among SEAI, LEAI, SEJC and EMMB in which each recorded 100% mortality of FAW larvae while LEJC recorded 50% mortality of FAW larvae comparable to untreated control that recorded 3.33% mortality of FAW.

key: SEAI = Seed extract of *A. indica*; SEJC = Seed extract of *J. Curcas*; LEAI = Leaf extract of *A. indica*; LEJC = Leaf extract of *J. Curcas*; EMMB= Emamectrin benzoate, CNTR = Untreated Control

## Lethal concentrations

LC<sub>50</sub> and LC<sub>90</sub> values at 24 h and 48 h are presented in Table 2. After 24 h, SEAI was the most toxic extract, with an LC<sub>50</sub> of 7.95% and LC<sub>90</sub> of 21.59% ( $R^2 = 0.968$ ). SEJC, LEAI, and LEJC recorded LC<sub>50</sub> values of 11.18%, 9.38%, and 32.50%, respectively. After 48 h, LC<sub>50</sub> values decreased across all treatments: SEAI (5.08%), SEJC (9.38%), LEAI (7.14%), and LEJC (18.27%), indicating progressive insecticidal activity over time.

Table 2  
Median  
(LC<sub>50</sub>) and  
upper (LC<sub>90</sub>)  
lethal  
concentration  
of the  
aqueous  
extracts of  
seed and leaf  
of  
*Azadirachta  
indica* and  
*Jatropha  
curcas*  
against Fall  
armyworm

| Treatment | 24hours                 |                  |       |                        | 48hours              |                  |       |                  |
|-----------|-------------------------|------------------|-------|------------------------|----------------------|------------------|-------|------------------|
|           | LC <sub>50</sub><br>(%) | LC <sub>90</sub> | R2    | regression<br>equation | LC <sub>50</sub> (%) | LC <sub>90</sub> | R2    | Regression equa. |
| SEAI      | 7.95                    | 21.59            | 0.968 | 2.9333x+26.667         | 5.08                 | 14.45            | 0.966 | 4.2667x+28.333   |
| SEJC      | 11.18                   | 26.97            | 0.963 | 2.5333x+21.667         | 9.38                 | 28.13            | 0.914 | 2.1333x+30.00    |
| LEAI      | 9.38                    | 28.13            | 0.914 | 2.1333x+30.000         | 7.14                 | 28.57            | 0.891 | 1.8667x+36.667   |
| LEJC      | 32.5                    | 62.5             | 1.000 | 1.333x+6.667           | 18.27                | 41.35            | 0.966 | 1.73333x+18.333  |

Values followed by the same superscript letter within a row are not significantly different at  $p > 0.05$  (Duncan’s Multiple Range Test).

keywords: SEAI = Seed extract of *A. indica* SEJC = Seed extract of *J. Curcas*; LEAI = Leaf extract of *A. indica* LEJC = Leaf extract of *J. Curcas*;

# Effect of Sub-lethal Concentrations on Larvae instars Duration of Fall Armyworm

Table 3 demonstrate that exposure to sub-lethal concentrations of the tested botanical extracts delayed larval development, resulting in longer developmental periods across the FAW larval instars. The overall larval duration of FAW was considerably lengthened ( $p < 0.05$ ) on maize leaves treated with SEAI (17.4 days), followed by those reared in treated with LEAI (15.7 days), SEJC (15.4 days), and LEJC (14.7 days) comparable to untreated control (12.9 days). No

significant variations ( $p > 0.05$ ) were observed in the duration of the first larval instar (2.7 days) among the sub-lethal concentrations of all botanical extracts, while a significant difference was noted when compared to the untreated control (2.3 days). The duration of three days (3.0 days)

was seen for the second larval instar of FAW raised on maize leaves treated with SEAI and LEAI, whereas a duration of 2.7 days was noted for SEJC and LEJC. The untreated control exhibited a larval duration of 2.3 days during second larvae instar. The fourth larval instar exhibited a duration of 2.7 days when grown on maize leaves treated with SEAI, while a length of 2.3 days was seen for larvae on maize leaves treated with SEJC, LEAI, and LEJC while untreated control recorded a larval duration of 2.0 days. The SEAI documented a duration of 3.0 days for the fifth larval instar of FAW, whereas a duration of 2.7 days was noted for larvae in LEAI, SEJC, and LEJC. The duration of 3.0 days was seen for the sixth larval instar grown on maize leaves treated with SEAI, whereas a duration of 2.7 days was noted for SEJC and LEAI treatments, and the untreated control larval exhibited a duration of 2.0 days.

Table 3  
Effect of Sub-lethal Concentrations of Different Botanical Extracts on Larval instars Duration of Development of FAW under Laboratory Condition

| Larval instar                                                                                                                                                                                         | Mean duration of larval instars (days) Mean $\pm$ SE |                              |                              |                              |                              |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|
|                                                                                                                                                                                                       | SEAI (1.415%)                                        | SEJC (2.161%)                | LEAI (1.072%)                | LEJC (18.140%)               | CNTR (0.0%)                  |
| 1st                                                                                                                                                                                                   | 2.7 $\pm$ 0.58 <sup>b</sup>                          | 2.7 $\pm$ 0.58 <sup>b</sup>  | 2.7 $\pm$ 0.58 <sup>b</sup>  | 2.7 $\pm$ 0.58 <sup>b</sup>  | 2.3 $\pm$ 0.58 <sup>a</sup>  |
| 2nd                                                                                                                                                                                                   | 3.0 $\pm$ 0.00 <sup>c</sup>                          | 2.7 $\pm$ 0.58 <sup>b</sup>  | 3.0 $\pm$ 0.00 <sup>c</sup>  | 2.7 $\pm$ 0.58 <sup>b</sup>  | 2.3 $\pm$ 0.58 <sup>a</sup>  |
| 3rd                                                                                                                                                                                                   | 3.0 $\pm$ 0.00 <sup>c</sup>                          | 2.3 $\pm$ 0.58 <sup>b</sup>  | 2.3 $\pm$ 0.58 <sup>b</sup>  | 2.0 $\pm$ 0.00 <sup>a</sup>  | 2.0 $\pm$ 0.00 <sup>a</sup>  |
| 4th                                                                                                                                                                                                   | 2.7 $\pm$ 0.58 <sup>c</sup>                          | 2.3 $\pm$ 0.58 <sup>b</sup>  | 2.3 $\pm$ 0.58 <sup>b</sup>  | 2.3 $\pm$ 0.58 <sup>b</sup>  | 2.0 $\pm$ 0.00 <sup>a</sup>  |
| 5th                                                                                                                                                                                                   | 3.0 $\pm$ 0.00 <sup>c</sup>                          | 2.7 $\pm$ 0.58 <sup>b</sup>  | 2.7 $\pm$ 0.58 <sup>b</sup>  | 2.7 $\pm$ 0.58 <sup>b</sup>  | 2.3 $\pm$ 0.58 <sup>a</sup>  |
| 6th                                                                                                                                                                                                   | 3.0 $\pm$ 0.00 <sup>d</sup>                          | 2.7 $\pm$ 0.58 <sup>c</sup>  | 2.7 $\pm$ 0.58 <sup>c</sup>  | 2.3 $\pm$ 0.58 <sup>b</sup>  | 2.0 $\pm$ 0.00 <sup>a</sup>  |
| Total larval duration                                                                                                                                                                                 | 17.4 $\pm$ 1.16 <sup>d</sup>                         | 15.4 $\pm$ 3.00 <sup>c</sup> | 15.7 $\pm$ 2.90 <sup>c</sup> | 14.7 $\pm$ 2.90 <sup>b</sup> | 12.9 $\pm$ 1.74 <sup>a</sup> |
| * Values followed by the same superscript alphabets in a row are not significantly different at P > 0.05. Values are represented in mean $\pm$ standard error of three replicates                     |                                                      |                              |                              |                              |                              |
| key: SEAI = Seed extract of <i>A. indica</i> ; SEJC = Seed extract of <i>J. Curcas</i> ; LEAI = Leaf extract of <i>A. indica</i> ; LEJC = Leaf extract of <i>J. Curcas</i> ; CNTR = Untreated Control |                                                      |                              |                              |                              |                              |

## Biochemical effects at LC<sub>50</sub>

Table 3 presents the effects of LC<sub>50</sub> concentrations of the botanical extracts on the biochemical parameters of FAW, including teneral reserves and enzyme activities. All treated larvae showed significant reductions ( $p < 0.05$ ) in all biochemical parameters relative to controls. Protein ranged from 0.60 to 1.57 mg/mL across treatments versus 1.97 mg/mL in controls; carbohydrate from 0.53 to 1.84 mg/mL versus 1.86 mg/mL; and lipid from 0.56 to 1.46 mg/mL versus 1.48 mg/mL. ASAT activity ranged from 53.00 to 72.34 IU/L versus 76.24 IU/L in controls, and esterase activity from 2.42 to 3.34 mg naphthol/min per larva versus 3.36 in controls. SEAI caused the greatest depletion across all parameters.

Table 3  
Biochemical effect of LC50 of aqueous extract of selected botanical extract against FAW

| Parameter              | Value obtained in treated with LC <sub>50</sub> of botanical extracts |               |               |               |               |
|------------------------|-----------------------------------------------------------------------|---------------|---------------|---------------|---------------|
|                        | SEAI                                                                  | SEJC          | LEAI          | LEJC          | CONTROL       |
| Protein (mg/ml)        | 0.60 ± 0.22a                                                          | 0.80 ± 0.22b  | 1.57 ± 0.12d  | 1.24 ± 0.14c  | 1.97 ± 0.10e  |
| Carbonhydrate (mg/ml)  | 0.53 ± 0.29a                                                          | 0.73 ± 0.29c  | 1.32 ± 0.09b  | 1.84 ± 0.13d  | 1.86 ± 0.09d  |
| Lipid (mg/ml)          | 0.56 ± 0.05a                                                          | 1.18 ± 0.09b  | 0.86 ± 0.05d  | 1.46 ± 0.09c  | 1.48 ± 0.09e  |
| Aspartate tranf.(IU/L) | 53.00 ± 1.41a                                                         | 63.00 ± 1.41b | 65.34 ± 0.93c | 72.34 ± 0.43d | 76.24 ± 0.06e |
| Esterases (IU/L)       | 2.42 ± 1.04a                                                          | 3.11 ± 0.08c  | 2.57 ± 0.04b  | 3.34 ± 0.08d  | 3.36 ± 0.09d  |

Value followed by the same superscript in a row are not significantly different at  $p > 0.05$

## Discussion

The phytochemical profiles of *A. indica* and *J. curcas* extracts documented here are broadly consistent with previous reports. The detection of alkaloids, flavonoids, saponins, and terpenoids in *A. indica* aligns with findings by Kharmal (2021). The absence of glycosides in both leaf extracts contrasts with Jose et al. (2023), who detected glycosides in neem leaf extracts; this discrepancy likely reflects differences in extraction solvent and methodology. The phytochemical profile of *J. curcas* seed extracts, including phenols, flavonoids, and steroids, corroborates the findings of Buduwara et al. (2023).

Botanical extracts (*A. indica* and *J. curcas*) utilized in this study demonstrate considerable potential as natural substitutes for synthetic owing to their bioactive compounds with insecticidal efficacy (Ali et al., 2025). The selection of these botanical species was guided by their proven insecticidal efficacy against FAW, their widespread availability, affordability, and their environmental impact (Filonemo et al., 2020; Degaga and Degaga, 2024). In this study, botanical extracts has showed different level of efficacy against third larvae instar of FAW. The extracts of SEAI, LEAI and SEJC consistently resulted in high larvae mortality which is similar with those of Sisay et al. (2019) who reported high larvae mortality of FAW using the seeds extract of *A. indica* and *J. curcas*. The efficacy of the therapy on the seeds and leaves of *A. indica* regarding FAW may stem from the capacity of Azadirachtin to suffocate the FAW, resulting in mortality, alongside its several modes of action, functioning as a repellent, antifeedant, insect growth regulator, and attractant (Mukanga et al., 2022). There was a substantial difference in the efficacy of SEAI and SEJC after 72 h of treatment. In this study, SEAI shown superior efficacy compared to SEJC. Conversely, Ahmed (2023) observed that there was no significant difference in the efficiency of the seed extract of *J. curcas* and *A. indica* at 72 h post-treatment application on FAW larvae. The mismatch, may be ascribed to variations in concentration, temperature, or relative humidity. At 96 h post-treatment, SEAI, LEAI, and SEJC achieved 100% mortality of FAW comparable to the efficacy of EMMB. This aligns with prior research (Degaga and Degaga, 2024). The aqueous extract of *J. curcas* leaves in this investigation exhibited limited insecticidal activity against FAW at 24 to 72 h post-treatment, which may be ascribed to the concentration levels utilized. The high efficacy of *A. indica* and *J. curcas* can be attributed to their phytochemical contents. The high mortality of FAW recorded in *A. indica* may be attributed to high concentrations of phenol and tannins. Phenolic

compounds have strong antioxidant properties, which can disrupt the metabolism of insect. Wang *et al.* (2018) demonstrates the relationship between phenolic contents and antioxidant activity in various plant species have shown that, higher phenolic content are linked to increased antioxidant activity. Emamectin benzoate 5% utilized as a reference in this study, shown substantial efficacy against FAW, with mortality rates between 96.7% and 100%. These findings is similar with those of Ali *et al.* (2025), who reported a mortality rate of 53.5% to 100% for FAW. The control experiment demonstrated 0.0% mortality of FAW at 24, 48, and 72 h post-treatment, confirming that the observed mortality in the treated trial was exclusively attributable to the toxic effects of the botanical extracts. All botanical extracts exhibited notable efficacy in managing FAW, with mortality rates demonstrating a clear dependence on both concentration and exposure duration; higher extract concentrations and prolonged exposure times resulted in significantly increased larval mortality.

The  $LC_{50}$  of 7.95% for SEAI indicates it is the most potent extract. This value exceeds the 263.02 ppm reported for shallot leaf (*Allium ascalonicum*) extract against Fall armyworm (Putri and Aini, 2021), but is considerably lower than the 1 479 ppm recorded for *Annona mukosa* seed extract against *Helicoverpa armigera* (Souza *et al.*, 2017). These differences likely reflect variations in extraction solvent polarity, plant species, and target insect susceptibility.

All botanical extracts extended the duration of the FAW larvae instar and this may be due to the high concentrations of bioactive compounds in botanicals such as Phenol, tannins, saponin and terpenoids which can alter normal growth. Pavana *et al.* (2023) reported that, the lower growth rate is due to the principal compounds present in the botanicals, which interferes with the growth by disrupting the normal functions of the endocrine system and decreased the efficiency of converting food into biomass in turn reducing the growth rate. The results of this study indicate that the larval instar development of FAW can greatly differ according on plant type. The total larval duration (17.4 days) recorded in the SEAI significantly differs from other botanicals and the untreated control, likely due to the presence of *Azadirachtin* in the seed extract of *A. indica*, which may function as a molting inhibitor, hindering the larvae's capacity to shed their exoskeleton and impeding their progression to subsequent developmental stages. Chaudhary *et al.* (2017) found that neem extract disrupts the hormonal equilibrium essential for effective molting, particularly by suppressing ecdysone activity, hence prolonging the larval phases and preventing their development into adulthood. The results of this study is similar with those of Bezerra *et al.* (2019), who reported a larval duration of 18 days when FAW larvae were reared on maize leaves treated with *Machaerium opacum* leaf extract. However, they contrast with the findings of Martinez *et al.* (2017), which indicated a larval duration of 19.38 days for FAW larvae reared on maize plants treated with *Argemone ochroleuca*. The discrepancies may stem from changes in plant species utilized for FAW management, the solvents employed, or concentration of the extracts. Zavala-Sánchez *et al.* (2019) reported that, the exposure of larval of FAW to chloroform extract of the leaves of *Senna crotalarioides* extends the duration of the larval stage of FAW to 23.7 days. Significant depletion of proteins, carbohydrates, and lipids indicates that botanical extracts disrupt nutrient metabolism and energy homeostasis in Fall armyworm larvae. Protein depletion would directly impair larval growth, consistent with evidence that plant secondary metabolites particularly tannins and saponins interact with dietary proteins and digestive enzymes to reduce bioavailability (Pandey *et al.*, 2022). Carbohydrate depletion reflects disrupted energy metabolism, consistent with the findings of Huang *et al.* (2020), who demonstrated that phenolic compounds inhibit key glycolytic enzymes in lepidopteran larvae. Lipid depletion is also significant, as lipids serve as the primary energy reserve during food deprivation and are essential for metamorphosis. Kamaraj *et al.* (2021), reported analogous lipid depletion in *Spodoptera litura* treated with phenolic-rich plant extracts, suggesting a conserved mechanism of action across noctuid species. The inhibition of enzyme activities provides

additional mechanistic evidence. Reduced ASAT activity indicates dysfunction in amino acid metabolism and damage to fat body tissues, which serve a liver-like function in insects. Changes in ASAT are established biomarkers of metabolic disruption and cellular damage, as noted by Nathan et al. (2020). Although the reduction in esterase activity was modest in absolute terms, it carries toxicological significance: Esterases are key detoxification enzymes responsible for hydrolyzing ester bonds in xenobiotics. Their inhibition would compromise the insect's detoxification capacity, resulting in accumulation of toxic compounds and eventual death—a mechanism previously demonstrated by Ramalho et al. (2023) for botanical esterase inhibitors in lepidopteran pests.

## Conclusion

The seed and leaf extracts of *A. indica* and *J. curcas* demonstrated multi-target insecticidal properties against *S. frugiperda* larvae through depletion of energy reserves and inhibition of detoxification enzymes. SEAI was the most toxic extract, followed by LEAI, SEJC, and LEJC. These extracts represent promising eco-friendly biopesticide candidates suitable for integration into fall armyworm management programmes. Field evaluation and formulation development are recommended to advance their practical application.

## Declarations

**Ethics approval and consent to participate** Not applicable

**Consent for publication** All the authors agreed that the submitted work has not been published previously, that the work is not under consideration for publication elsewhere and that all authors agreed to the publication of this work

**Data availability and materials** All data supporting the findings of this study are available within the paper

**Conflict of interest** All the authors has agreed that, there is no conflict of interest,

**Funding** No financial assistance was received from individual or organization

**Authors contributions.** Cece, M. A: collection of the data,, writing the first draft, Olayemi, I. K: Conceptualized the idea, methodology, validation, Salaudeen, M. T: Supervision, writing original draft, writing review, Ukubuiwe, A. C: writing review and editing, Salihi, I. M: Conduct data analysis and revised second draft.

**Acknowledgements** The authors wish to acknowledge the management of the Department of Animal Biology, Federal University of Technology, Minna, Nigeria for providing laboratory space where the experiment of FAW was conducted.

## References

1. Abdel-Razik MA, Mahmoud SA (2017) Toxicological and biochemical effects of jojoba, *Simmondsia chinensis* extract on cotton leafworm. *Spodoptera littoralis* J Plant Prot Pathol 8(6):233–239.  
<https://doi.org/10.21608/jppp.2017.49660>
2. Ahmed S (2023) Screening of Management options and efficacy evaluations against Fall Armyworm (J.E. Smith) (Lepidoptera: Noctuidae) on maize in Assosa, Ethiopia. *J Entomol Ornithol* 1(1):000101

3. Ali MA, Abd-Elgalil DMS, Bakry MMS, Mohamed GS (2025) Evaluation of the potential toxicity of plant extracts, pathogenic fungi, and chemical pesticides for the management of *Spodoptera frugiperda*. J Plant Dis Prot 132:103
4. Altaf N, Arshad M, Majeed MZ, Ullah MI, Latif H, Zeeshan M (2022) Comparative effectiveness of chlorantraniliprole and neem leaf extract against Fall armyworm. *Spodoptera frugiperda* Sarhad J Agric 38(3):833–840. <https://doi.org/10.17582/journal.sja.38.3.833.840>
5. Bezerra EF, Santos RG, Menezes SCA, Almeida SCA, Jesus GF, Rocha CE, Araujo SM (2019) Toxicity of *Machaerium opacum* (Fabaceae) leaf extracts against Fall Armyworm (*Spodoptera frugiperda* (JE Smith) (Lepidoptera Noctuidae). J Agricultural Sci 11:292–301
6. Boica Junior AL, Rodrigues NEL, Janini JC, Bottega DB, Sousa VQ, Silva AGD (2020) Association of peanut cultivars and aqueous neem extract in the feeding and development of *Spodoptera frugiperda* Entomo Brasiliis 13:e909. <https://doi.org/10.12741/embrasilis.v13.e909>
7. Bozdogan H, Erbey M, Aksoy HA (2016) Total amount of protein, lipid and carbohydrate in some adult Curculionidae (Coleoptera). J Entomol Zool Stud 4(5):242–248
8. Buduwara JH, Naphtali RS, Adiet T, Sami R, Tafem ML, Tadouno MF (2023) Qualitative phytochemical screening and larvicidal efficacy of *Jatropha curcas* extracts on mosquito larvae. J Appl Life Sci Int 26(6):98–105. <https://doi.org/10.9734/jalsi/2023/v26i6619>
9. Chaudhary S, Kanwar RK, Sehgal A, Cahill DM, Barrow CJ, Sehgal R, Kanwar JR (2017) Progress on *Azadirachta indica* based biopesticides in replacing synthetic toxic pesticides. Front Plant Sci 8:226969
10. Dagaga AH, Degaga EG (2024) Natural enemies of the Fall Armyworm and comparing Neem aqueous extracts with its larvae, Gurage Zone, Central Ethiopia. *Heliyon*, 10 (11),e32083
11. Filomeno CA, Barbosa L, Teixeira R, Pinheiro AL, Farias ES, Ferreira JS & Picanco
12. .M. (2020) Chemical diversity of essential oils of Myrtaceae species and their insecticidal activity against *Rhyzopertha dominica*. Crop Prot, 137, 105309
13. Gaaboub I, El-Kady HA, El-Khayat EF, El-Shewy AM (2012) Biochemical and histological effect of some plant extracts, insecticide and bioinsecticide against *Spodoptera littoralis* (Boisd.). *Bio-Pesticides Tech.*:21–32
14. Huang L, Zhang M, Wang H (2020) Effects of plant secondary metabolites on insect nutrient metabolism and growth. Insects 11(4):234. <https://doi.org/10.3390/insects11040234>
15. Ikoyi WTA, Ashien UU, Bobzom BS, Wilson IA, Akpabio UA, Obi ACR (2023) ).Efficacy of *Jatropha curcas* leaf extract on some isolates associated with surgical wounds. J Adv Microbiol 23(8):1–10. <https://doi.org/10.9734/jamb/2023/v23i8823>
16. Jose KR, Vijayakumar K, Sujith S, Vergis J, Deepa PM, George A (2023) Phytochemical analysis of aqueous extract of *Azadirachta indica* leaves. Pharma Innov J 12(10):1505–1511
17. Kamaraj C, Santhoshkumar T, Vetterchand M, Rajasekaran M (2021) Insecticidal and biochemical effects of plant phenolics against *Spodoptera litura* (Lepidoptera:Noctuidae). Phytoparasitica 49:117–130. <https://doi.org/10.1007/s12600-020-00849-4>
18. Kharmal S (2021) Qualitative and quantitative phytochemical screening of *Azadirachta indica* Juss. plant parts. Int J Appl Sci Biotechnol 9(2):122–127. <https://doi.org/10.3126/ijasbt.v9i2.37759>
19. Kumar DM, Nimbalkar A, Kamble V, Kumar MVS (2019) In-vitro screening of *Barleria accuminata* for antifeedant activity against Fall armyworm (*Spodoptera frugiperda*). J Biol Chem Res 36(1):128–130

20. Lima AF, Ribeiro LP, Lira SP, Carvalho GA, Vendramim JD (2023) Growth inhibitory activities and feeding deterrence of Solanaceae-based derivatives on Fall armyworm. *Agriculture* 13:420. <https://doi.org/10.3390/agriculture13020420>
21. Martinez AM, Aguado-Pedraza AJ, Vinuela E, Rodríguez- Enríquez, Lobit CL P., Ómez
22. Pineda S (2017) Effects of ethanolic extracts of *Argemone ochroleuca* (Papaveraceae) on the food consumption and development of *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Fla Entomol* 100:339–345
23. Mukanga M, Machuku O, Chipabika G, Matimelo M, Mumba K, Mabote ND (2022) Bio-efficacy of crude aqueous leaf extracts against Fall armyworm (*Spodoptera frugiperda*) and maize ear rots in Zambia. *Adv Biol Res* 3(1):38–49
24. Nathan SS, Chung PG, Murugan K (2020) Effects of botanical insecticides on enzyme systems of lepidopteran pests. *J Appl Entomol* 144(5):345–356
25. Nourou KNA, Alain H, Bertrand MS, Patrice NDJ (2022) Evaluation of the insecticidal potential of *Jatropha curcas* seed extracts on pests of okra in the field. *East Afr Sch J Agric Life Sci* 5(9):157–166
26. Okafor SN, Chibueze GC, Obonga WO, Ezeokonkwo MA, Muogbo CC (2017) Aqueous methanol extract of the root bark of *Zanthoxylum zanthoxyloides* provides a natural remedy for dental caries and toothache. *World J Pharm Res* 6(7):336–349
27. Osman HH (2012) Toxicological, biological and biochemical impact of two plant extracts against *Spodoptera littoralis* (Boisd.). *Egypt J. Agric. Res.* 2012; 90(4):1497–1512
28. Pandey A, Sharma P, Mishra R (2022) Influence of plant secondary metabolites on insect digestive enzymes. *J Insect Sci* 22(1):12. <https://doi.org/10.1093/jisesa/ieab093>
29. Pavana JK, Sharanabasappa SD, Mallikarjuna HB, Kalleshwaraswamy CM, Basavaraj NT, Mota-Sanche D (2023) Sublethal effects of botanicals on the growth and development of Fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae). *Curr Sci* 125(1):52–58
30. Phambala K, Tembo Y, Kabambe VH, Stevenson PC, Belmain SR (2020) Bioactivity of common pesticidal plants on Fall armyworm larvae (*Spodoptera frugiperda*). *Plants* 9(1):112. <https://doi.org/10.3390/plants9010112>
31. Putri DA, Aini PN (2021) Ethanolic extract of shallot leaves (*Allium ascalonicum* L.) as botanical pesticide to control Fall armyworm (*Spodoptera frugiperda*). *J Biotechnol Nat Sci* 2 1(2):100–104
32. Prasoon KR, Jaba J, Srinivasan G, Nagarajan K (2022) Rearing of *Spodoptera frugiperda* on artificial diet under laboratory conditions. *Indian J Entomol* 84(1):123–127
33. Ramalho FS, Nguyen TH, Oliveira DR (2023) Effects of botanical extracts on insect metabolic and detoxification processes. *Pest Manag Sci* 79(4):1201–1212. <https://doi.org/10.1002/ps.7297>
34. Sisay B, Tefera T, Wakgari M, Ayalew G, Mendesil E (2019) The efficacy of selected synthetic insecticides and botanicals against Fall armyworm, *Spodoptera frugiperda*, in maize. *Insects*. 2019; 10(2):45. <https://doi.org/10.3390/insects10020045>
35. Souza CM, Baldin ELL, Ribeiro LP (2017) Lethal and growth inhibitory activities of neotropical Annonaceae-derived extracts against *Helicoverpa armigera*. *J Pest Sci* 90:449–459. <https://doi.org/10.1007/s10340-016-0763-2>
36. Tchegueni M, Agboka K, Tchabi A, Kolani L, Tchao M, Touno AK (2023) Insecticidal effect of *Jatropha curcas* L. oil on *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae). *Asian J Agric Horti Res* 10(3):9–18. <https://doi.org/10.9734/ajohr/2023/ v10i3207>

37. Uyi O, Amolo IG, Adetimehin AD (2019) Insecticidal activities of the leaf extract of the invasive alien plant *Chromolaena odorata* (Asteraceae) against *Macrotermes* species (termites). *Nig J Entomol* 35:145–153
38. Wahedi JA, Elkanah OS, Danba EP, Zakariya R, Ishuwa MN (2017) Vincent VM. Effect of plant oil treatments against *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae) on stored maize. *GSC Biol Pharm Sci* 1(2):1–6
39. Wang Y (2018) Correlation analysis of phenolic contents and antioxidation in yellow and black seeded *brassica napus*. *Molecules* 223(7):1815
40. Wilson K, Walker J (2020) Principles and Techniques of Biocheistry and Techniques of Biochemistry and Molecular Biology, 9th edn. Cambridge University Press
41. Zavala-Sánchez MA, Rodríguez-Chávez JL, Figueroa-Brito R, Quintana-López CM, Bah MM, Campos-Guillén J, Bustos-Martínez JA, Zamora-Avella D, Ramos-López MA (2019) Bioactivity of 1-octacosanol from *Senna crotalarioides* (Fabaceae: Caesalpinioideae) to control *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Fla Entomol* 102(4):731–737

## Figures

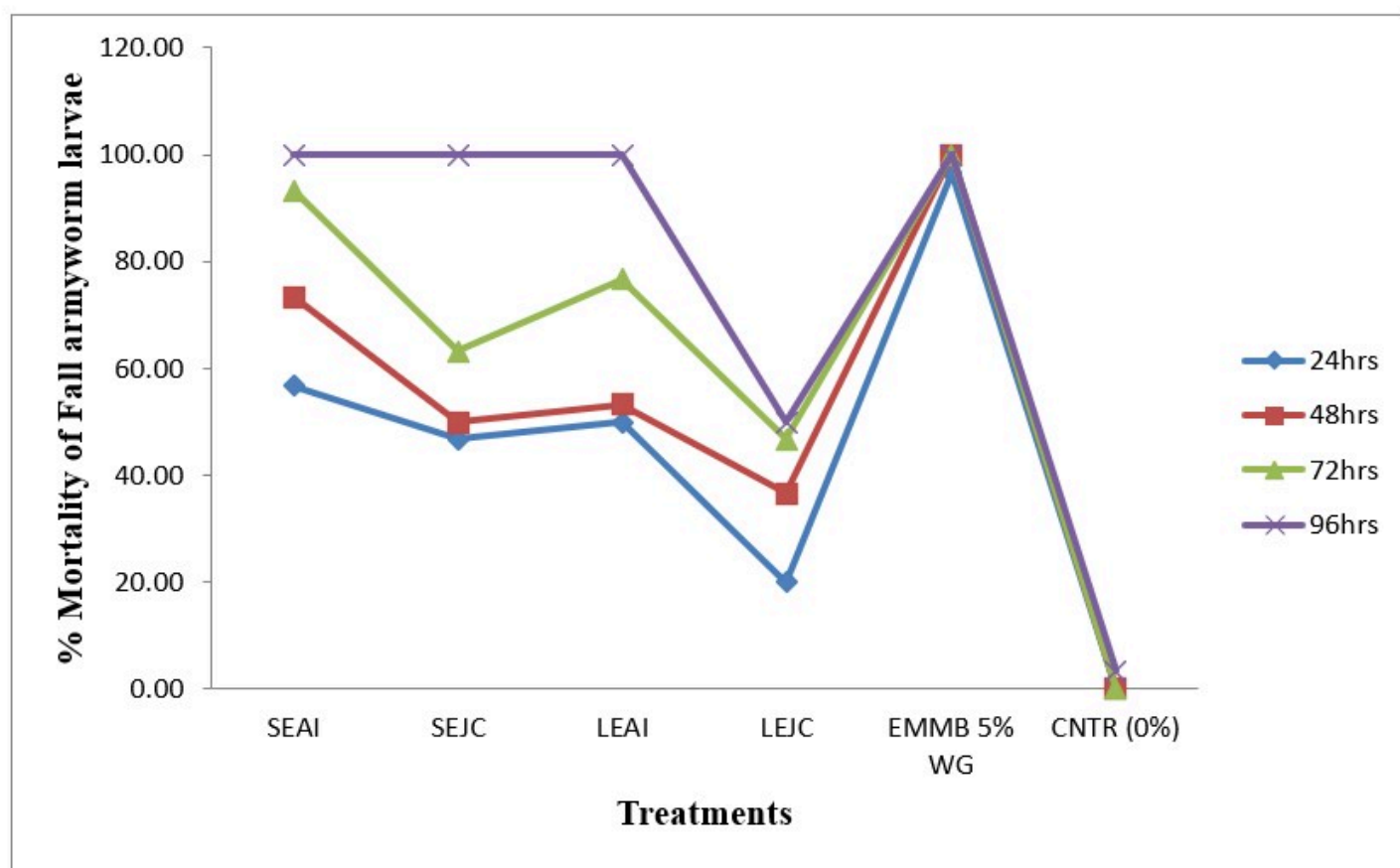


Figure 1

**Percentage Mortality of Fall Armyworm Larvae after Exposure to Different Botanical Extracts at 10 % Concentration under Laboratory conditions.**

key: SEAI = Seed extract of *A. indica*; SEJC = Seed extract of *J. Curcas*; LEAI = Leaf extract of *A. indica*; LEJC = Leaf extract of *J. Curcas*; EMMB= Emamectrin benzoate, CNTR = Untreated Control

