Scientific Research Publishing

Advances in Entomology, 2026, 14(4), 315-329
https://www.scirp.org/journal/ae
ISSN Online: 2331-2017
ISSN Print: 2331-1991

Field Efficacy of Aqueous Root Extract of *Securidaca longipedunculata* Fresen for the Management of Fall Armyworm (*Spodoptera frugiperda* J.E. Smith) in Maize in Northern Ghana

Mukhtaru Zakaria, Jerry A. Nboyine, Ebenezer Asamani, James Y. Kwabena, Joseph Adjebeng-Danquah, Francis Kusi

CSIR—Savanna Agricultural Research Institute, Tamale, Ghana
Email: nboyinejerry@gmail.com

How to cite this paper: Zakaria, M., Nboyine, J.A., Asamani, E., Kwabena, J.Y., Adjebeng-Danquah, J. and Kusi, F. (2026) Field Efficacy of Aqueous Root Extract of *Securidaca longipedunculata* Fresen for the Management of Fall Armyworm (*Spodoptera frugiperda* J.E. Smith) in Maize in Northern Ghana. *Advances in Entomology*, **14**, 315-329.
https://doi.org/10.4236/ae.2026.144019

Received: July 2, 2026
Accepted: September 20, 2026
Published: September 23, 2026

Abstract

Maize growers across Sub-Saharan Africa incur significant yield losses due to fall armyworm (FAW), *Spodoptera frugiperda*, infestations and damage. Reliance on synthetic insecticides poses environmental and health risks, driving the need for eco-friendly botanical alternatives. Here, the efficacy of crude *Securidaca longepedunculata* aqueous root extracts in mitigating FAW infestations and damage, as well as its effect on grain yield, was studied over two successive seasons in maize. Treatments comprised three rates of *S. longipedunculata* root extracts (*i.e.*, 3.13% w/v, 6.25% w/v, and 9.38% w/v), together with untreated control, neem oil as a botanical control, and Emastar 112 EC (a.i.: emamectin benzoate 48 g/L + acetamiprid 64 g/L) as a synthetic insecticide control. Data on FAW larval infestation, leaf and cob damage, as well as grain yield, were analyzed. The results showed that infestations and damage were highest in the untreated control plots. Conversely, infestation and damage were lowest in Emastar 112 EC treated plots. Notably, application of 6.25% w/v and 9.38% w/v *S. longepedunculata* extracts significantly reduced FAW infestations and damage compared to the untreated control, though their efficacy was lower than that of Emastar 112 EC. Grain yield was highest in Emastar 112 EC treated maize, while the untreated control was lowest. Extracts of *S. longepedunculata* applied at 6.25% w/v and 9.38% w/v outperformed the untreated control and the neem oil check. These findings indicate that while synthetic insecticides remain the most effective option, aqueous extracts of *S. longepedunculata* at rates ≥ 6.25% w/v offer a potent, accessible, and sustainable alternative for smallholder farmers to protect maize yields.

Keywords

Crop Protection, Botanical Biopesticides, *Securidaca longepedunculata*, *Spodoptera frugiperda*, Sustainable Agriculture, Grain Yield

1. Introduction

Fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith), infestations and damage threaten the livelihood of millions of rural families in Sub-Saharan Africa (SSA). Most farmers rely solely on synthetic insecticides to mitigate their effects. The severity of FAW attacks resulted in complete reliance on broad-spectrum active ingredients of high toxicity, especially during the early years of accidental introduction into West Africa [1] [2]. There are, however, concerns about the negative effects of synthetic insecticides on farmers and consumers of agricultural produce [3]. Apart from the health risk associated with insecticides, frequent application of insecticides is unsustainable as it increases production costs, negatively affects biodiversity and the environment [4] [5], as well as has a high potential to disrupt natural biological control in maize fields, which, in Africa and other regions, are mostly not or hardly treated with insecticides [6].

To minimize the negative consequences of synthetic insecticides used for FAW management in maize on human health and the environment, crop mixture strategies such as intercropping maize with beans (*Phaseolus vulgaris* L.), groundnut (*Vigna unguiculata* (L.) Walp.), cassava, and sweet potato have been tested extensively at the field level and proven to reduce infestation and damage [7]. Other studies have also demonstrated that intercropping maize with edible legumes such as beans, groundnut, and soybean (*Glycine max* (L.) Merr.) is generally effective in reducing FAW larval infestations while increasing populations of natural enemies [8] [9]. Combining intercropping and spraying maize with extracts from plants such as neem (*Azadirachta indica*) and West African black pepper (*Piper guineense*) has been documented as a sustainable FAW strategy for smallholder farmers in Africa [9] [10]. Key attributes of the intercropping system are the proliferation of FAW natural enemies compared to the use of synthetic insecticides in monocropping systems [9].

Apart from the intercropping strategies, the sole use of plant extracts is promising and offers long-lasting solutions for FAW and other pests in agriculture, while protecting the environment. These plant-based pesticides are target-specific and biodegradable, mostly consisting of fresh plant parts or pure isolates [11]. Unlike synthetic insecticides, botanical/plant extracts contain more than one active ingredient, and this enables these extracts to function by altering both behavioral and physical processes of target pests [12]. For FAW management, extracts from over 69 plant species including *A. indica*, *Ageratum conyzoides*, *Cymbopo-*

gon flexuosus, *C. nardus*, *Ocimum basilicum*, *Calotropis procera*, and *Jatropha curcas*, are thought to be efficacious for use among small-scale maize farmers in Africa [13]. After testing extracts from ten (10) plant species for their efficacy against FAW, Phambala *et al.* [14] recommended *A. indica*, *O. basilicum*, *C. citratus* and *Lippia javanica*, noting that sustainable supplies of these plants for large-scale production were feasible because they were cosmopolitan and frequently cultivated. Other field evaluations corroborate the efficacy of these botanical extracts for FAW management, especially extracts from *A. indica* [15]-[17].

Despite the well-documented potential of botanical alternatives, especially extracts from *A. indica*, there is a need to identify other botanicals that offer comparable or better efficacy against FAW. This is key to ensuring year-round availability as well as diversifying the options of chemical modes of action for the pest [18]. For decades, *Securidaca longepedunculata* has been used for the management of pests in storage [12]. This plant typically measures 6 m in height; the bark of the plant is smooth and pale grey, with leaves that are variable in size and shape and crowded towards the stem of the plant. It can be found in various parts of tropical Africa. The entire plant is useful due to its medicinal and insecticidal properties. Although the entire plant is used for various purposes, the root is the most predominantly used part of the plant in African countries [19]. Mongalo *et al.* [19] reported that methanol extracts from the root of *S. longepedunculata* were effective against *Prostephanus truncatus*, *Tribolium casteneum*, *Callosobruchus masculatus*, and *Sitophilus zeamais* in storage. Other studies have corroborated the efficacy of extracts from this plant against storage pests [20] [21]. However, the use of root extracts of this plant for field-level management of invasive vegetative pests such as the FAW has not been very well studied. A systematic evaluation of crude aqueous root extracts is required to identify an effective and ecologically sustainable dosage for smallholders in SSA. Although the concentration of active chemical constituents such as saponins and tannins in crude aqueous extractions usually varies, this approach is a highly practical, low-cost approach for smallholder farmers' adoption. Hence, the objective of this study was to investigate the efficacy of crude aqueous root extracts of *S. longepedunculata* for FAW management in maize at the field level.

2. Materials and Methods

2.1. Study Site and Field Layout

A field trial was established on the research fields (09˚23′32.4″N, 001˚00′14.3″W) of CSIR—Savanna Agricultural Research Institute at Nyankpala in the Tolon District of the Northern Region of Ghana during the 2024 and 2025 cropping seasons. The study site is located within the Guinea Savannah agro-ecological zone, which is characterized by a unimodal rainfall pattern. Typically, the single wet season commences in May and concludes in October annually, yielding a long-term average annual rainfall of approximately 1000 mm to 1300 mm. Average daytime maximum temperatures during the wet season range between 30˚C and 33˚C, while nighttime minimum temperatures range between 22˚C and 24˚C [22]. In both years, the trial site was tractor-ploughed followed by harrowing to obtain good soil tilth. Planting was done in mid-July in both years.

2.2. Preparation of *Securidaca longipedunculata* Crude Root Extracts

To prepare a crude aqueous root extract of *S. longepedunculata*, fresh roots of the plants were harvested from the field and thoroughly washed with deionized water to remove dirt and soil debris, followed by air-drying at room temperature (*i.e.*, 25˚C - 28˚C) to remove adhering water droplets.

To make the method of crude extract preparation easily adoptable by small-holder farmers while maintaining scientific reproducibility, the intact roots were used (*i.e.*, non-ground). For the baseline treatment, 500 g of the roots were accurately weighed into a clean 20-L capacity bucket. This was followed by pouring 10 L of deionized water into the bucket to completely submerge the roots. A screw top lid was then used to cover the bucket, and the soaked roots were allowed to macerate for 48 hours at ambient temperature. This process allowed for the passive extraction of water-soluble phytochemicals such as saponins and methyl salicylate that are active against insects.

After the 48-hour extraction period, the resulting dark brown solution was thoroughly stirred, followed by filtering through a clean cheesecloth to remove all macroscopic plant debris. The resulting crude aqueous root extract filtrate of concentration 31.25 g/L (*i.e.*, 3.13% w/v) was collected and immediately used for field application against the FAW. Additional test treatments were prepared by measuring 1000 g and 1500 g each, using the maceration procedure described above, and these resulted in crude root extracts of concentration 62.5 g/L (*i.e.*, 6.25% w/v) and 93.75 g/L (*i.e.*, 9.38% w/v), respectively.

2.3. Experimental Design, Field Establishment, and Treatment Application

A randomized complete block design (RCBD) was used to test the efficacy of different concentrations of aqueous root extracts of *S. longipedunculata* for FAW management in maize. There were a total of six insecticide treatments and four replications of each treatment. The treatments comprised three test concentrations for crude root extracts of *S. longipedunculata* (*i.e.*, 3.13% w/v, 6.25% w/v, and 9.38% w/v), an untreated control, a botanical control (*i.e.*, 0.16% v/v neem oil (*i.e.*, 25 ml/16 L knapsack; a.i. = 3% azadirachtin)), and a synthetic insecticide control (*i.e.*, 0.16% v/v Emastar 112 EC (a.i. = emamectin benzoate 48 g/L + acetamiprid 64 g/L)). The neem oil was supplied by Green-Gro Ltd., Tamale, Ghana, while the Emastar 112 EC was obtained from Adama West Africa Ltd., Ghana. Treatment application for sprayed plots commenced when 10% of the maize plants in the insecticide treatment plots were infested with FAW larvae. The insecticide treatments were applied using a 16-l capacity CP-16 knapsack sprayer. The untreated control plots were not sprayed. Soap was added (*i.e.*, 10 ml/knapsack) to the neem oil solution to serve as an emulsifier. The first infestation threshold was attained at approximately 3 weeks after emergence, and there were a total of two spray applications. The hollow cone nozzle was used to deliver fine to medium droplets that thoroughly covered plant surfaces with the insecticide solution. Application was based on approximately 200 l/ha in the early cropping stage. This increased to about 300 l/ha after 36 days of crop establishment.

The maize variety used for this study was Wang-dataa. This variety was released for commercial cultivation in Ghana by the CSIR—Savanna Agricultural Research Institute in 2015. It is an early-maturing open-pollinated variety (OPV) with white grain colour, and it is widely grown in the northern Guinea Savanna zone of northern Ghana. It is drought and striga (*Striga hermonthica* (Delile) Benth) tolerant, with a yield potential of 4.7 t/ha [23]. This variety was planted on experimental plots of size 17.5 m^2, and each plot consisted of six rows of maize, with each row measuring 5 m in length. The spacing used for planting was 70 cm between rows and 40 cm between plants. Experimental plots were separated by 1.5 m wide alleys, while alleys between blocks were 2 m. In this trial, N-P-K (23-10-10) was applied at 2 weeks after emergence as basal fertilizer, and this was followed by topdressing with urea at 5 weeks after emergence. The NPK was applied at a rate of 250 kg/ha, while the urea was applied at 125 kg/ha. The trial field was hand-weeded twice at 3 and 6 weeks after crop emergence.

2.4. Data Collection

In each plot, data were collected along two diagonals from 20 randomly selected plants, and this was undertaken fortnightly. The parameters measured at each sampling period were a non-destructive count of the number of larvae on the selected plants and damage to leaves of the selected plants using the Toepfer leaf damage scale. According to Toepfer *et al.* [24], leaf damage by FAW is assessed on a novel 0 to 4 scale, where 0 = no damage, 1 = little damage (pinholes and/or small holes, small leaf edge parts eaten, short holes), 2 = medium damage (some larger holes and/or large leaf edge areas eaten), 3 = heavy damage (many large holes and/or large leaf edge areas eaten), and 4 = total damage (destroyed, non-functional leaves).

At harvest, 30 cobs were randomly selected from plants in the 4 inner rows of each plot. These were inspected for the presence of FAW damage; those with characteristic FAW damage were counted, followed by computing the proportion of damaged cobs in each plot. Grain yield was assessed by first threshing all the cobs from plants in the 4 inner rows. This was followed by winnowing to remove all debris and sun drying to a 10% moisture content. The weight of grains from each plot was recorded afterwards, and these were converted to a kg per ha basis.

2.5. Data Analysis

Data on FAW larval infestation and leaf damage, which were recorded at three consecutive fortnightly intervals, were analyzed using a Repeated Measures Analysis of Variance (RM-ANOVA) to assess the main effects of insecticide treatments, the effect of time/date of sampling, and their interaction. The RM-ANOVA was selected because repeated measurements taken on the same experimental units (plots/plants) over time are inherently correlated, violating the assumption of independence required by standard ANOVA. Mauchly's test was used to assess the assumption of sphericity, and the Greenhouse-Geisser epsilon correction was applied to adjust the degrees of freedom whenever the assumption of sphericity was violated. Significant differences among treatment means and sampling intervals were separated using Fisher's protected least significant difference (LSD) at a 5% probability threshold.

In contrast, data on cob damage and grain yields were pooled across the two seasons and subjected to a combined-years ANOVA. Insecticide treatments were considered fixed effects, whereas replications within years and associated interactions were treated as random effects. Where the treatment × year interaction was non-significant, main effect means were pooled and separated; otherwise, treatment effects were analyzed and presented separately for each year. Means were compared using Fisher's Protected LSD at a 5% significance level.

All statistical analyses were performed using the GenStat® statistical programme (12^{th} edition, VSN International Ltd., Hertfordshire, HP1 1ES, UK. https://vsni.co.uk/).

3. Results

3.1. Larval Infestation

In the 2024 cropping season, a repeated measures ANOVA showed that FAW larval infestation was not significantly affected by the insecticide treatments tested ($p = 0.075$). It was, however, significantly affected by the date of sampling ($p < 0.001$) and the date of sampling × insecticides interaction effect ($p = 0.040$). This variable was highest in maize treated with 3.13% w/v *S. longipedunculata* root extract during the 26 July sampling and lowest in Emastar 112 EC-treated maize during the 23 August sampling. Except for the control, the magnitude of this variable was lowest during the 23 August sampling in all insecticide treatments tested (**Figure 1(A)**).

During the 2025 cropping season, there was a significant effect of date of sampling ($p < 0.001$), insecticide treatments ($p < 0.001$), and date of sampling × insecticide treatments ($p < 0.001$) for FAW larval infestation when the data were subjected to a repeated measures ANOVA. Larval infestation was highest in the untreated control sampled on 29 August and lowest in Emastar 112 EC sampled on the same date. In the untreated control, infestation increased significantly at each successive sampling date. In contrast, infestation declined significantly in Emastar 112 EC treatments after the 1^{st} sampling. Apart from neem oil and 3.13% w/v *S. longipedunculata* root extract treated maize, larval infestations did not change significantly between sampling dates in the other treatments (**Figure 1(B)**).

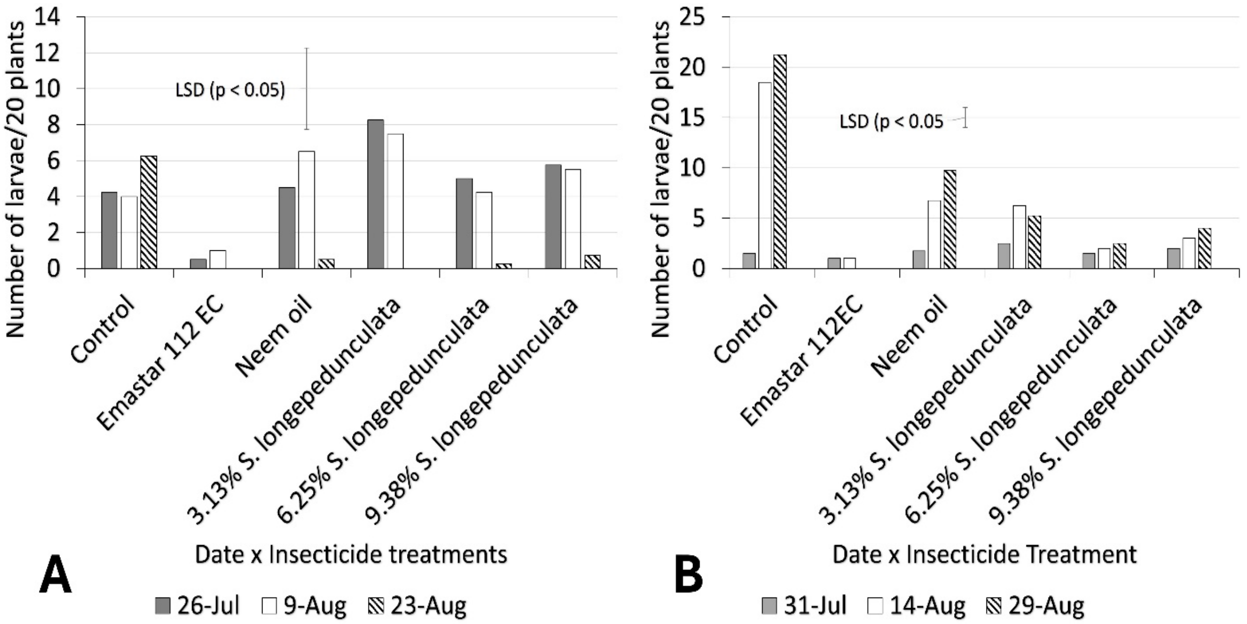

Figure 1. Effect of insecticide treatments on the mean number of fall armyworm larvae per 20 plants at different dates of sampling in maize during the 2024 and 2025 cropping seasons. Note: *S. longipedunculata* = *Securidaca longipedunculata*; LSD = least significant difference at the 5% probability threshold; **A** = 2024 cropping season; **B** = 2025 cropping season.

3.2. Leaf Damage

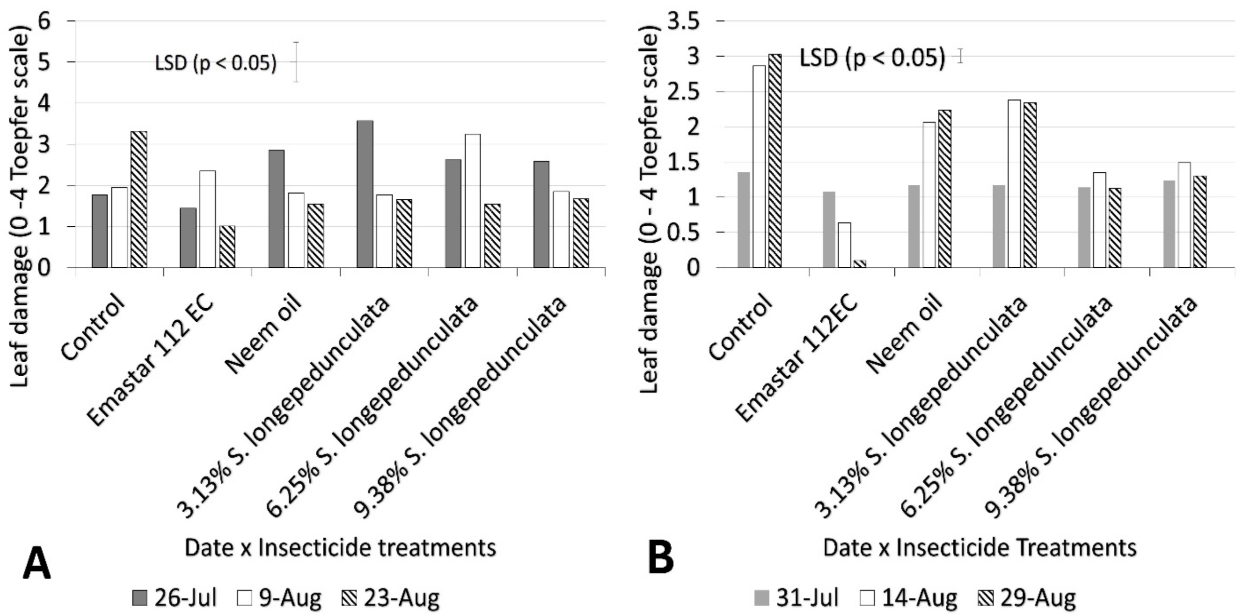

Figure 2. Effect of insecticide treatments on the mean leaf damage by fall armyworm larvae at different dates of sampling during the 2024 and 2025 cropping seasons. Note: *S. longipedunculata* = *Securidaca longipedunculata*; LSD = least significant difference at the 5% probability threshold; **A** = 2024 cropping season; **B** = 2025 cropping season; Toepfer leaf damage scale where: 0 = no damage, 1 = little damage (pinholes and/or small holes, small leaf edge parts eaten, short holes), 2 = medium damage (some larger holes and/or large leaf edge areas eaten), 3 = heavy damage (many large holes and/or large leaf edge areas eaten), and 4 = total damage (destroyed, non-functional leaves).

Crop damage was not significantly affected by the insecticide treatments effect (p = 0.129) when the 2024 cropping season data were subjected to repeated measures ANOVA. It was, however, significantly affected by date of sampling ($p < 0.001$) and date of sampling × insecticides interaction effect ($p = 0.003$). Crop damage was highest in maize treated with 3.13% w/v *S. longipedunculata* root extract that was sampled on 26 July and lowest in those treated with Emastar 112 EC during the 20 August sampling (**Figure 2(A)**).

In the 2025 season, there was a significant date of sampling ($p < 0.001$), insecticide treatments ($p < 0.001$), and date of sampling × insecticide treatments ($p < 0.001$) interaction effect when leaf damage data were subjected to a repeated measures ANOVA. In all insecticide treatments, damage was lowest during the 31 July sampling. This variable increased significantly during subsequent samplings in the untreated control, neem oil, and 3.13% w/v *S. longipedunculata* treated maize. In contrast, leaf damage decreased significantly over time in the Emastar 112 EC-protected maize but did not change significantly in maize protected with *S. longipedunculata* at application rates of 6.25% w/v or 9.38% w/v (**Figure 2(B)**).

3.3. Cob Damage

A combined-years ANOVA for cob damage showed a significant year ($p < 0.001$), insecticide treatments ($p < 0.001$), and year × insecticide treatments ($p < 0.001$) effect. The mean proportion of damaged cobs was highest in the untreated control plots in 2025 and lowest in Emastar 112 EC-protected maize in the same year. FAW damage to cobs was lowest in the Emastar 112 EC treatments in both years. In general, cob damage in the botanical extract treatments was significantly lower than that reported in the untreated control but higher than in Emastar 112 EC-protected maize in both years. Across treatments, the mean proportion of damaged cobs was significantly higher in 2024 (0.53) than in 2025 (0.39) (**Figure 3**).

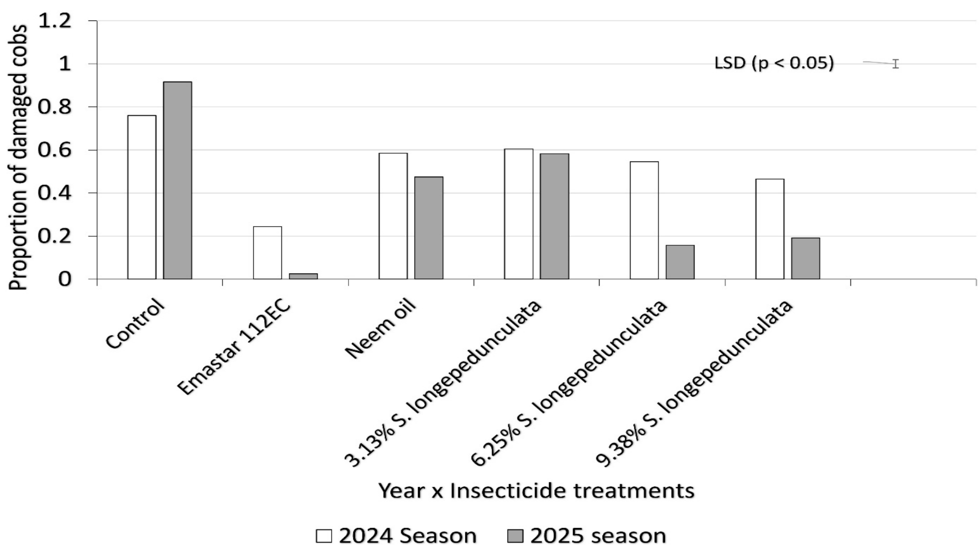

Figure 3. Interaction Effect of Year and Insecticide treatments on the mean proportion of fall armyworm-damaged maize cobs. Note: *S. longipedunculata* = *Securidaca longipedunculata;* LSD = least significant difference at the 5% probability threshold.

3.4. Grain Yield (kg/ha)

Grain yield was not significantly affected by year when data from the two seasons were combined and analyzed ($p = 0.125$). There was also no significant year × insecticide treatments effect ($p = 0.623$) for this variable. Yield was, however, significantly affected by the insecticide treatments tested ($p < 0.001$). The highest yield was recorded in maize treated with Emastar 112 EC, while the lowest was in the untreated control. Yields in maize protected with *S. longipedunculata* applied at 6.25% w/v and 9.38% w/v were significantly higher than those reported in the other insecticide treatments, except Emastar 112 EC (**Figure 4**).

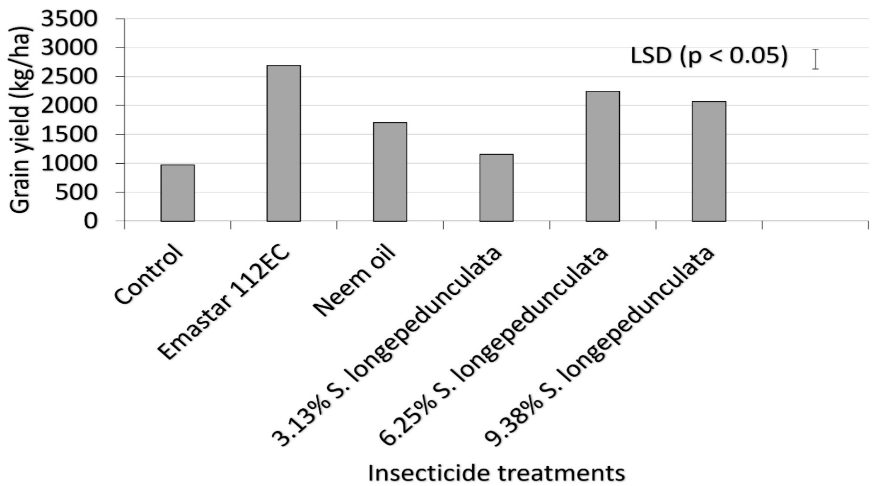

Figure 4. Effect of insecticide treatments on the mean maize grain yield (kg/ha) across combined years. Note: *S. longipedunculata* = *Securidaca longipedunculata;* LSD = least significant difference at the 5% probability threshold.

4. Discussion

Root extracts of *S. longipedunculata* are toxic to Coleopteran storage pests such as *S. zeamais* and *C. maculatus* and have been used to protect stored produce over a nine (9) month duration [20] [25]. These extracts are also active against the aphid, *Schizaphis graminum* Rondani, and have been used to mitigate losses in wheat fields [26] [27]. In this study, aqueous root extract of *S. longepedunculata* was tested for FAW control and found to possess significant insecticidal activity against this pest when applied at rates of 6.25% w/v or higher. At this application rate, it suppressed larval infestation across the two study years, signifying its stability and reliability as a biopesticide. The efficacy of Emastar 112 EC in reducing larval infestation and the relatively higher numbers of larvae in neem oil protected maize compared to the Emastar 112 EC treatment is well documented [2] [16], and hence, the result of this study corroborates those of earlier studies for these pesticides. Unlike neem oil, which effectively mitigates larval infestation, but its treated maize usually has high larval counts per plant [17] [28], the significant reduction achieved for the aqueous *S. longepedunculata* root extracts makes it a compelling alternative to the widely recommended neem oil and Emastar 112 EC for FAW management. Averaging across dates of sampling, insecticide treatments did not significantly affect infestation in 2024, while a significant effect was observed in 2025. Perhaps the high FAW larval infestation pressure in 2025 made the insecticide treatment effect obvious this year.

Across the two years of this study, Emastar 112 EC protected maize had the lowest level of leaf damage score of 1 or lower on the Toepfer *et al.* [24] scale, and this was due to its rapid chemical knockdown action on FAW larvae [17]. Whereas root extract of *S. longepedunculata* at rates of 6.25% w/v or higher effectively protected maize from FAW damage, their damage score was between 1 and 2 and this was lower than the > 3 score reported in the unprotected maize. According to Toepfer *et al.* [24], a score of 1 as averaged for Emastar 112 EC protected maize indicates little damage, while the score of 2 reported in ≥ 6.25% w/v root extract treatments implied medium damage such as the presence of a few large holes in the leaf and/or leaf edge areas eaten by the FAW larvae. As expected, the score of 3 recorded in the unprotected maize implied heavy damage with many large holes and large leaf edge areas eaten. In general, the higher the number of larvae associated with maize plants, the higher the leaf damage score and vice versa [8]. Again, insecticide treatment effect on leaf damage was more obvious in 2025 than in 2024, and this was probably linked to the high pest pressure in that year.

Insecticides that effectively protect maize from FAW larval infestation generally result in lower damage to cobs [2] [17] [28]. In this study, while the unprotected maize had cob damage above 70%, damage in the insecticide treatments was below 60%, with Emastar 112 EC being the lowest. Notably, application of *S. longepedunculata* at rates of 6.25% w/v or higher outperformed neem oil in terms of the level of damage to cobs. Thus, the root extracts are an alternative to neem oil as a biopesticide for FAW control in maize, particularly for smallholder farmers seeking to increase the range of FAW management options that are cost-effective, sustainable, and ecologically safer.

As anticipated, the Emastar 112 EC treatment had the highest yield because of its superior suppression of FAW larval infestation and damage throughout the growth of the crop. The efficacy of synthetic insecticides in suppressing infestations and consequently increasing yields in maize has been widely reported [15] [17] [29] [30]. Conversely, the untreated control had the lowest yield, confirming results of earlier studies [2] [8] [16] that yields of unprotected maize fields are severely affected by FAW. Assessment of the two-year grain yield data showed that aqueous root extracts of *S. longepedunculata* applied at rates of 6.25% w/v and 9.38% w/v, resulted in exceptional efficacy, producing yields that were significantly higher than both the untreated control and the standard neem oil check. This indicates that the bioactive compounds in *S. longepedunculata* root extracts provide superior crop protection compared to traditional botanical standards like neem oil. While polyphenols, flavonoids, methyl salicylate, and saponins are the main causes of insect toxicity and feeding deterrence in root extracts of *S. longepedunculata* [21] [31], azadirachtin is the main active ingredient causing toxicity and deterrence in neem oil [32] [33]. Further, the statistical parity between root extract application rates of 6.25% w/v and 9.38% w/v suggests a yield plateau at the 6.25% w/v threshold. Hence, increasing the concentration to 9.38% w/v does not result in additional grain yield benefit.

Overall, although crude aqueous root extracts of *S. longepedunculata* demonstrate notable insecticidal bioefficacy due to a complex matrix of secondary metabolites [34] [35], relying on water extractions introduces substantial variability in potency compared to organic solvent fractions that more efficiently capture non-polar bioactive constituents [36] [37]. This chemical inconsistency is compounded by severe ecological and agronomic constraints, as targeting the root leads to destructive harvesting [38], though partial lateral root extraction could offer a less damaging compromise. Additionally, despite the established pest control potential of *S. longepedunculata* preparations [39], knowledge gaps persist regarding the potential phytotoxicity of crude liquid sprays on crop foliage.

5. Conclusion

In conclusion, this study demonstrates that while synthetic insecticides such as Emastar 112 EC remain the most effective strategy for minimizing FAW infestation, reducing damage, and maximizing maize grain yield, root extracts of *S. longepedunculata* offer a highly potent, ecologically sound alternative for FAW management among smallholder farmers. The untreated control consistently suffered the highest infestation and damage, leading to the lowest overall grain yield, thereby underscoring the absolute necessity of active pest intervention in maize cultivation. Notably, the *S. longepedunculata* root extract applied at rates of 6.25% w/v and 9.38% w/v significantly outperformed both the untreated negative control and the commercial neem oil check across all parameters measured. With no statistically significant difference between the 6.25% w/v and 9.38% w/v application rates regarding mitigation of FAW infestation and damage as well as grain yield, the lower rate of 6.25% w/v represents the most cost-effective and resource-efficient application rate for farmers.

Funding

This work was funded by the EU H2020 EWA-BELT project [862848], “Linking East and West African farming systems experience into a BELT of sustainable intensification.”

Acknowledgements

The authors gratefully acknowledge the technical staff at the Entomology Section, Council for Scientific and Industrial Research (CSIR)—Savanna Agricultural Research Institute (SARI), especially Fredrick Anaman, Suweiba Abdulai, and Rebecca Kaba, for their assistance with data collection.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Tambo, J.A., Day, R.K., Lamontagne-Godwin, J., Silvestri, S., Beseh, P.K., Oppong-Mensah, B., *et al.* (2020) Tackling Fall Armyworm (*Spodoptera frugiperda*) Outbreak in Africa: An Analysis of Farmers' Control Actions. *International Journal of Pest Management*, **66**, 298-310. https://doi.org/10.1080/09670874.2019.1646942

[2] Nboyine, J.A., Kusi, F., Yahaya, I., Seidu, A. and Yahaya, A. (2021) Effect of Cultivars and Insecticidal Treatments on Fall Armyworm, *Spodoptera frugiperda* (J.E. Smith), Infestation and Damage on Maize. *International Journal of Tropical Insect Science*, **41**, 1265-1275. https://doi.org/10.1007/s42690-020-00318-1

[3] Ngegba, P.M., Cui, G., Khalid, M.Z. and Zhong, G. (2022) Use of Botanical Pesticides in Agriculture as an Alternative to Synthetic Pesticides. *Agriculture*, **12**, Article No. 600. https://doi.org/10.3390/agriculture12050600

[4] Pimentel, D. and Andow, D.A. (1984) Pest Management and Pesticide Impacts. *International Journal of Tropical Insect Science*, **5**, 141-149. https://doi.org/10.1017/s1742758400008201

[5] Togola, A., Meseka, S., Menkir, A., Badu-Apraku, B., Boukar, O., Tamò, M., *et al.* (2018) Measurement of Pesticide Residues from Chemical Control of the Invasive *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in a Maize Experimental Field in Mokwa, Nigeria. *International Journal of Environmental Research and Public Health*, **15**, Article No. 849. https://doi.org/10.3390/ijerph15050849

[6] Hruska, A.J. (2019) Fall Armyworm (*Spodoptera frugiperda*) Management by Smallholders. *CABI Reviews*, **14**, 1-11. https://doi.org/10.1079/pavsnnr201914043

[7] Peter, E., Yusuf, A., Subramanian, S., Krüger, K., Karlsson Green, K., Anderson, P., *et al.* (2024) Crop Mixtures Influence Fall Armyworm Infestation and Natural Enemy Abundance in Maize-Based Intercropping Systems. *Journal of Crop Health*, **76**, 1491-1505. https://doi.org/10.1007/s10343-024-01061-0

[8] Udayakumar, A., Shivalingaswamy, T.M. and Bakthavatsalam, N. (2021) Legume-Based Intercropping for the Management of Fall Armyworm, *Spodoptera frugiperda* L. in Maize. *Journal of Plant Diseases and Protection*, **128**, 775-779. https://doi.org/10.1007/s41348-020-00401-2

[9] Kusi, F., Nboyine, J.A., Adjebeng-Danquah, J., Agrengsore, P., Seidu, A., Quandahor, P., *et al.* (2024) Effect of Insecticides and Intercropping Systems on Fall Armyworm (*Spodoptera frugiperda* (J.E. Smith)) Infestations and Damage in Maize in Northern Ghana. *Crop Protection*, **186**, Article ID: 106909. https://doi.org/10.1016/j.cropro.2024.106909

[10] Tanyi, C.B., Nkongho, R.N., Okolle, J.N., Tening, A.S. and Ngosong, C. (2020) Effect of Intercropping Beans with Maize and Botanical Extract on Fall Armyworm (*Spodoptera frugiperda*) Infestation. *International Journal of Agronomy*, **2020**, Article ID: 4618190. https://doi.org/10.1155/2020/4618190

[11] Dar, S.A., Nisar, A.D., Mudasir, A.B. and Mudasir, H.B. (2014) Prospects, Utilization, and Challenges of Botanical Pesticides in Sustainable Agriculture. *International Journal of Molecular Biology & Biochemistry*, *2*, 1-14.

[12] Auwal, S.M., Atiku, M.K., Wudil, A.M. and Sule, M.S. (2012) Phytochemical Composition and Acute Toxicity Evaluation of Aqueous Root Bark Extract of *Securidaca longipedunculata* (Linn). *Bayero Journal of Pure and Applied Sciences*, **5**, 67-72. https://doi.org/10.4314/bajopas.v5i2.12

[13] Rioba, N.B. and Stevenson, P.C. (2020) Opportunities and Scope for Botanical Extracts and Products for the Management of Fall Armyworm (*Spodoptera frugiperda*)

for Smallholders in Africa. *Plants*, **9**, Article No. 207.
https://doi.org/10.3390/plants9020207

[14] Phambala, K., Tembo, Y., Kasambala, T., Kabambe, V.H., Stevenson, P.C. and Belmain, S.R. (2020) Bioactivity of Common Pesticidal Plants on Fall Armyworm Larvae (*Spodoptera frugiperda*). *Plants*, **9**, Article No. 112.
https://doi.org/10.3390/plants9010112

[15] Sisay, B., Tefera, T., Wakgari, M., Ayalew, G. and Mendesil, E. (2019) The Efficacy of Selected Synthetic Insecticides and Botanicals against Fall Armyworm, *Spodoptera frugiperda*, in Maize. *Insects*, **10**, Article No. 45.
https://doi.org/10.3390/insects10020045

[16] Babendreier, D., Koku Agboyi, L., Beseh, P., Osae, M., Nboyine, J., Ofori, S.E.K., *et al.* (2020) The Efficacy of Alternative, Environmentally Friendly Plant Protection Measures for Control of Fall Armyworm, *Spodoptera frugiperda*, in Maize. *Insects*, **11**, Article No. 240. https://doi.org/10.3390/insects11040240

[17] Nboyine, J.A., Asamani, E., Agboyi, L.K., Yahaya, I., Kusi, F., Adazebra, G., *et al.* (2022) Assessment of the Optimal Frequency of Insecticide Sprays Required to Manage Fall Armyworm (*Spodoptera frugiperda* J.E. Smith) in Maize (*Zea mays* L.) in Northern Ghana. *CABI Agriculture and Bioscience*, **3**, Article No. 3.
https://doi.org/10.1186/s43170-021-00070-7

[18] Chaudhary, S., Kumar Yadav, S., Verma, P., Sagar, S. and Lal, M. (2024) Botanical Insecticides for Crop Protection: Major Classes and Possible Mechanisms of Action. In: *Agricultural Sciences*, IntechOpen.
https://doi.org/10.5772/intechopen.1006743

[19] Mongalo, N.I., McGaw, L.J., Finnie, J.F. and Staden, J.V. (2015) *Securidaca longipedunculata* Fresen (Polygalaceae): A Review of Its Ethnomedicinal Uses, Phytochemistry, Pharmacological Properties and Toxicology. *Journal of Ethnopharmacology*, **165**, 215-226. https://doi.org/10.1016/j.jep.2015.02.041

[20] Stevenson, P.C., Dayarathna, T.K., Belmain, S.R. and Veitch, N.C. (2009) Bisdesmosidic Saponins from *Securidaca longepedunculata* Roots: Evaluation of Deterrency and Toxicity to Coleopteran Storage Pests. *Journal of Agricultural and Food Chemistry*, **57**, 8860-8867. https://doi.org/10.1021/jf901599j

[21] Afful, E., Owusu, E.O. and Obeng-Ofori, D. (2012) Bioactivity of *Securidaca longepedunculata* Fres. against *Callosobruchus maculatus* Fab. (Coleoptera: Bruchidae) and *Sitophilus zeamais* Motsch (Coleoptera: Curculionidae). *International Journal of Agricultural Science Research*, **1**, 46-54.

[22] Neumann, R., Jung, G., Laux, P. and Kunstmann, H. (2007) Climate Trends of Temperature, Precipitation and River Discharge in the Volta Basin of West Africa. *International Journal of River Basin Management*, **5**, 17-30.
https://doi.org/10.1080/15715124.2007.9635302

[23] Ghana Variety Release and Registration Catalogue (GVRRC) (2019) Catalogue of Crop Varieties Released and Registered in Ghana. National Varietal Release and Registration Committee, Directorate of Crop Services, Ministry of Food and Agriculture, 84 p.

[24] Toepfer, S., Fallet, P., Kajuga, J., Bazagwira, D., Mukundwa, I.P., Szalai, M., *et al.* (2021) Streamlining Leaf Damage Rating Scales for the Fall Armyworm on Maize. *Journal of Pest Science*, **94**, 1075-1089. https://doi.org/10.1007/s10340-021-01359-2

[25] Ojo, D.O., Omotoso, O.T. and Obembe, O.M. (2018) Effectiveness of the Powders of *Securidaca longepedunculata* (fres.) as Bioinsecticides against Cowpea Beetle, *Callosobruchus maculatus* (fab.) (Coleoptera: Chrysomelidae). *International Journal of*

Horticulture, **8**, 1-7. https://doi.org/10.5376/ijh.2018.08.0001

[26] Guiré, R., Shah, N.A., Meda, R.N.T., Ghafoor, H., Haq, I.U., Salo, P., *et al.* (2024) Insecticidal Activities of *Securidaca longepedunculata* Fresen Extracts and Feeding Behavior of *Schizaphis graminum* Rondani: Electropenetrography Approach. *ACS Omega*, **9**, 32799-32806. https://doi.org/10.1021/acsomega.4c03316

[27] Guiré, R., Salo, P., Zongo, E., Ramadan, M.F., Koama, B.K., Meda, R.N., *et al.* (2025) The Inhibitory Activities of Two Compounds from *Securidaca longepedunculata* Fresen on the Acetylcholinesterase from Wheat Pest *Schizaphis graminum* Rondani: *In Silico* Analysis. *Plant Signaling & Behavior*, **20**, Article ID: 2444311. https://doi.org/10.1080/15592324.2024.2444311

[28] Agboyi, L.K., Nboyine, J.A., Asamani, E., Beseh, P., Badii, B.K., Kenis, M., *et al.* (2023) Comparative Effects of Biopesticides on Fall Armyworm Management and Larval Parasitism Rates in Northern Ghana. *Journal of Pest Science*, **96**, 1417-1428. https://doi.org/10.1007/s10340-023-01590-z

[29] Deshmukh, S., Pavithra, H.B., Kalleshwaraswamy, C.M., Shivanna, B.K., Maruthi, M.S. and Mota-Sanchez, D. (2020) Field Efficacy of Insecticides for Management of Invasive Fall Armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) on Maize in India. *Florida Entomologist*, **103**, 221-227. https://doi.org/10.1653/024.103.0211

[30] Karki, N., Soti, A., Katel, S., Bhandari, R., Thapa, N. and Yadav, S.P.S. (2023) Field Efficacy of Different Insecticides against Fall Armyworm (*Spodoptera frugiperda* J.E. Smith) in Spring Maize (*Zea mays* L.). *AgroEnvironmental Sustainability*, **1**, 93-104. https://doi.org/10.59983/s2023010202

[31] Cmelik, S.H.W. and Ley, H. (1984) Some Constituents from the Root Bark of the African Violet Tree (*Securidaca longipedunculata* Fres.). *Transactions of the Zimbabwe Scientific Association*, **62**, 28-32.

[32] Benelli, G., Canale, A., Toniolo, C., Higuchi, A., Murugan, K., Pavela, R., *et al.* (2017) Neem (*Azadirachta indica*): Towards the Ideal Insecticide? *Natural Product Research*, **31**, 369-386. https://doi.org/10.1080/14786419.2016.1214834

[33] Gahukar, R.T. (2014) Factors Affecting Content and Bioefficacy of Neem (*Azadirachta indica* A. Juss.) Phytochemicals Used in Agricultural Pest Control: A Review. *Crop Protection*, **62**, 93-99. https://doi.org/10.1016/j.cropro.2014.04.014

[34] Abubakar, U.S., Danmalam, U.H., Ibrahim, H. and Maiha, B.B. (2019) A Review on African Violet Tree (*Securidaca longipedunculata* Fresen): A Traditional Drug with Multiple Medicinal Uses. *Specialty Journal of Chemistry*, **4**, 7-14.

[35] Cork, A., Dobson, H., Grzywacz, D., Hodges, R., Orr, A. and Stevenson, P. (2009) Review of Pre- and Post-Harvest Pest Management for Pulses with Special Reference to East and Southern Africa. Natural Resources Institute, University of Greenwich, Chatham Maritime, Kent ME4 4TB, 136 p.

[36] Belmain, S.R., Neal, G., Ray, D.E. and Golob, P. (2001) Insecticidal and Vertebrate Toxicity Associated with Ethnobotanicals Used as Post-Harvest Protectants in Ghana. *Food and Chemical Toxicology*, **39**, 287-291. https://doi.org/10.1016/s0278-6915(00)00134-4

[37] Ndamitso, M.M., Mohammed, A., Tijani, J.O., *et al.* (2013) Phytochemical and Antibacterial Activity of *Securidaca longepedunculata* on Selected Pathogens. *African Journal of Microbiology Research*, **7**, 5652-5656. https://doi.org/10.5897/ajmr2013.5354

[38] Jayasekara, T.K., Stevenson, P.C., Hall, D.R. and Belmain, S.R. (2005) Effect of Volatile Constituents from *Securidaca longepedunculata* on Insect Pests of Stored Grain.

Journal of Chemical Ecology, **31**, 303-313.
https://doi.org/10.1007/s10886-005-1342-0

[39] Boeke, S.J., Barnaud, C., van Loon, J.J., Kossou, D.K., van Huis, A. and Dicke, M. (2004) Efficacy of Plant Extracts against the Cowpea Beetle, *Callosobruchus maculatus*. *International Journal of Pest Management*, **50**, 251-258.
https://doi.org/10.1080/09670870410001702206