FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 10 No. 16, June, 2026, pp 657 – 662
DOI: https://doi.org/10.33003/fjs-2026-1016-5011

Comparative Efficacy of Black Pepper (*Piper guineense)* and Neem (*Azadirachta indica)* Seed Extracts for Managing Armyworm (*Spodoptera exempta)* in Maize Varieties

***[1]Saka Idowu Eletu, [1]Aderolu Ismaila Adeniran, [2]Abdulkareem Yusuf Jiddah and [1]Hussein Modupe Sidiqat**

[1]Department of Crop and Environmental Protection, Faculty of Agriculture, University of Abuja, FCT Abuja, Nigeria.
[2]Departmentof Agronomy, Faculty of Agriculture, University of Abuja, FCT Abuja, Nigeria.

*Corresponding authors' email: idowu.eletu@uniabuja.edu.ng

ABSTRACT

African fall armyworm (AFAM), *Spodoptera exempta*, is a major defoliator of maize plants, causing up to 100% yield loss if control is delayed. The control of this voracious leaf feeder has relied on chemical insecticides, which have been implicated in environmental and human health hazards. There is paucity of information on sustainable management of AFAM using eco-friendly methods. Black pepper (*Piper guineense)* and neem (*Azadirachta indica)* seed extracts, each applied at 8 L per 16 L knapsack sprayer) in comparison with Cypermethrin + Dimethoate applied at 6.25 ml/L were evaluated for their efficacy in the management of AFAM in six maize varieties (DTSR-CO, WHITE DT-STR, DTSTR-SYN-2-Y, TZL-COMP3-CSDT, SYN-11-W, OBA SUPER 2), while water was used as a control. Data were collected on the number of leaf damage, percentage adult emergence, leaf area, plant height, and grain yield (kg/ha). Results showed that *Cypermethrin dimethoate* (CDM) was the best among the treatments. *Piper guineense* (PG) ranked second, while *Azadirachta indica* (AI) ranked third in terms of growth (leaf area) and yield increase. The least emergence of adult armyworm and the number of damaged leaves were lowest in Cypermethrin + Dimethoate treatment, while the untreated plot had the highest emergence and leaf damage in the order (CDM>AI>PG>control). The highest yield was recorded from DTSR-CO (V1). The resource-poor farmers are encouraged to cultivate improved maize variety DTSR-CO and spray *Piper guineense* seed extract as a sustainable alternative to synthetic insecticides in the management of fall armyworm in maize.

Received: 16 May 2026
Accepted: 05 Jun. 2026
Published: 10 Sep. 2026

Keywords: African fall armyworm, maize, *Piper guineense*, *Azadirachta indica, botanicals*

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops worldwide and serves as a staple food for millions of people, particularly in sub-Saharan Africa, where it contributes substantially to food security, livestock feed, and industrial raw materials (Zingore *et al.*, 2022; Gunundu, 2023). Despite its economic and nutritional importance, maize production in many African countries remains below its potential due to several biotic and abiotic constraints, among which insect pests constitute a major limitation (Hall *et al.*, 2023; Gressel *et al.*, 2024; Du & Xiong, 2024;). Among these pests, the fall armyworm (*Spodoptera exempta*) (Lepidoptera: Noctuidae) has emerged as one of the most devastating invasive pests threatening maize production globally (Li *et al.*, 2024).

Since its first report in West Africa in 2016, fall armyworm has spread rapidly throughout the continent, causing over 20% yield loss, and in severe infestations, complete crop failure may occur (Gaddaguti *et al.*, 2022; Tambo *et al.*, 2023;). Armyworm Larvae feed voraciously on leaves, whorls, tassels, and reproductive structures, leading to extensive defoliation, reduced photosynthetic efficiency, stunted growth, and substantial yield reductions (Babendreier *et al.*, 2020). The management of fall armyworm in Africa has largely relied on the extensive use of synthetic insecticides. However, continuous dependence on chemical pesticides has raised concerns regarding environmental contamination, development of insect resistance, destruction of beneficial organisms, pesticide residues in food, and health hazards to farmers and consumers (Meena *et al.*, 2024). These limitations have intensified the research for safer, eco-friendly, and sustainable pest management alternatives.

Botanical insecticides derived from locally available plants have gained increasing attention as promising alternatives to synthetic pesticides because they are biodegradable, relatively inexpensive, environmentally friendly, and less likely to induce resistance in insect populations (Mahmood & Parwez, 2024). Plant-derived extracts contain diverse bioactive compounds that exhibit insecticidal, antifeedant, repellent, ovicidal, and growth-regulating properties against a wide range of insect pests (Mwamula *et al.*, 2022). Recent studies have demonstrated the effectiveness of several botanicals in suppressing fall armyworm populations and reducing crop damage in maize production systems (Lukman *et al.*, 2025; Mansur *et al.*, 2026). Among the numerous pesticidal plants, neem (*Azadirachta indica* A. Juss.) has received considerable scientific attention owing to its broad-spectrum insecticidal activity. The insecticidal efficacy of neem is primarily attributed to azadirachtin and related limonoids, which interfere with feeding behavior, molting processes, growth regulation, fecundity, and survival of insect pests (Giraldo-Vanegas & Giraldo-Herrera, 2026). Several studies have reported significant reductions in fall armyworm infestation, larval populations, and leaf damage following the application of neem extracts on maize, with concomitant improvements in grain yield (Nampijja *et al.*, 2024; Liywalii *et al.*, 2026). Similarly, *Piper guineense* Schumach. & Thonn., commonly known as West African black pepper, is an indigenous spice plant widely distributed in tropical Africa and traditionally used for medicinal and pesticidal purposes.

The seeds of *P. guineense* contain biologically active compounds such as piperine, chavicine, guineensine, and essential oils, which possess insecticidal, repellent, and antifeedant properties against several agricultural pests. Previous studies have demonstrated the efficacy of *P. guineense* extracts against storage and field insect pests, suggesting its potential as a sustainable biopesticide (Amadi *et al.*, 2024). However, information comparing the effectiveness of *P. guineense* with the widely studied neem seed extracts in managing fall armyworm under field conditions remains limited.

Host plant resistance also constitutes an important component of integrated pest management (IPM) strategies for fall armyworm control. Maize varieties differ considerably in their susceptibility or tolerance to insect attack due to variations in morphological and biochemical characteristics including leaf toughness, trichome density, secondary metabolites, and nutritional composition (Prasanna *et al.*, 2023). Consequently, interactions between maize genotypes and botanical insecticides may influence the overall effectiveness of pest management interventions (Amadi *et al.*, 2024). Understanding these interactions is essential for developing integrated, environmentally sustainable, and economically viable management strategies suitable for smallholder farming systems in Africa.

Despite the increasing interest in botanical pesticides, comparative information on the efficacy of *Piper guineense* and *Azadirachta indica* seed extracts across different maize varieties in managing fall armyworm remains scarce. Such information is necessary to identify effective plant-based alternatives that can be incorporated into integrated pest management programmes. Therefore, this study was undertaken to evaluate and compare the efficacy of *Piper guineense* (black pepper) and *Azadirachta indica* (neem) seed extracts in managing *Spodoptera exempta* infestation on selected maize varieties and to determine their effects on pest incidence, crop damage, as well as growth and yield performance.

MATERIALS AND METHODS

Experimental Area

A field experiment was conducted at the Kwara State University Teaching and Research Farm (8°04'N, 4°05'E, 307 m above sea level), Malete, Kwara State, located in the Southern Guinea Savannah zone of Nigeria during the 2016 cropping season, to evaluate the efficacy of *Piper guineense* and *Azadirachta indica* seed extracts on *Spodoptera exempta* in maize (*Zea mays* L.).

Treatments and Experimental Design

The study is a 6 × 4 factorial experiment laid out in a Randomized Complete Block Design (RCBD) with 3 replications to give a total of 72 experimental plots. Treatments include: control; synthetic insecticide: cypermethrin + dimethoate (Cypermethrin + Dimethoate); *Azadirachta indica* (AI); and *Piper guineense* (PG). Maize varieties used are DTSR-CO (V1), WHITE DT-STR (V2), DTSTR-SYN-2-Y (V3), TZL-COMP3-CSDT (V4), SYN-11-W (V5), and OBA SUPER 2 (V6). Five maize varieties were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, while one local variety (OBA SUPER 2 (V6)) was purchased from Sango market, Ilorin, Nigeria. Neem (*Azadirachta indica*) seeds were collected, dried, shelled, grated, and soaked in water (62.5 g/L) for 14 days, with periodic stirring, while black pepper (*Piper guineense*) seeds were ground, mixed with distilled water (125 g/L), and filtered to create a stock solution. Botanical extracts were applied biweekly to the maize plots at the rate of 8 L per 16 L knapsack sprayer; while Cypermethrin + Dimethoate (synthetic insecticide) was applied at a rate 6.25 ml/L.

Planting and Cultural Practices

The land was ploughed and harrowed twice. Each Plots measured 2.5×2.5 m with 0.5 m spacing between blocks. Maize was planted at 0.75 m between rows and 0.5 m within rows, with two seeds per hole, thinned to one plant per stand at 2 weeks after planting. Manual weeding was performed at 3 and 6 weeks after planting. Seeds were treated with chlorpyrifos 48 EC to prevent predation.

Data Collection and Analysis

Data were collected on maize leaf area at maturity, number of leaves damaged, maize grain yield per hectare and percentage adult emergence of fall armyworm. All data were subjected to Analysis of Variance (ANOVA) using ASSISTAT. Treatment means with significant differences were separated using Duncan's Multiple Range Test at a 5% level of probability.

RESULTS AND DISCUSSION

The effects of insecticides and maize varieties on percentage emergence of adult armyworm, number of leaf damage, leaf area and yield of maize are presented in Table 1 below. Insecticides had a significant effect on the percentage adult emergence of fall armyworm in maize. Percentage adult emergence of armyworm was significantly lower by 29.5%, 31% and 38% with the application of *Piper guineense*, *Azadirachta indica* and Cypermethrin + Dimethoate respectively. Cypermethrin + Dimethoate application reduced the percentage emergence of adult armyworm more than *Piper guineense* and *Azadirachta indica*; although, the difference was not significant.

Variety had a significant effect on percentage adult emergence of fall armyworm. Percentage adult emergence was significantly lower in DTSR-CO, WHITE DT-STR, DTSTR-SYN-2-Y and TZL-COMP3-CSDT than in SYN-11-W and OBA SUPER 2.

Insecticide had significant effect on number of leaf damaged. Number of leaves damaged was significantly reduced by 48.63%, 61.96% and 37.74% with the application of *Azadirachta indica*, Cypermethrin + Dimethoate and *Piper guineense* respectively. Application of *Piper guineense* produced lower number of damaged leaves compared to *Azadirachta indica* and Cypermethrin + Dimethoate.

Variety had no significant effect on number of leaf damaged. The highest number of leaf damaged (33.65) was recorded on plots where OBA SUPER 2 was planted, while the leaf was least damaged on plots where DTSTR-SYN-2-Y was planted. Number of leaf damaged was 18.57% lower on plots where DTSTR-SYN-2-Y was planted compared to plots where OBA SUPER 2 was planted.

Insecticide had no significant effect on leaf area. The highest leaf area was recorded on plots where Cypermethrin + Dimethoate was applied followed by *Piper guineense* and *Azadirachta indica* respectively, while the lowest leaf area was recorded on untreated plots.

Variety had no significant effect on leaf area. The highest leaf area was recorded on plots where SYN-11-W was planted, while the leaf area was lowest on plots where DTSTR-SYN-2-Y was planted.

Insecticide had no significant effect on the yield of the maize. However, the highest yield was recorded where Cypermethrin + Dimethoate was applied followed by *Piper guineense* and

Azadirachta indica respectively while the yield was lowest on plot with no insecticide application.

Variety of maize planted showed significant effect on yield. The highest yield was recorded where DTSR-CO was planted whereas, OBA SUPER 2 had the lowest yield.

Table 1: Effect of Insecticides and Maize Varieties on Percentage Emergence of Adult Armyworm, Number of Leaf Damage, Leaf Area and Yield of Maize

Treatments	Percentage adult emergence (%)	Number of leaf damaged	Leaf area (cm^2)	Yield (kg/ha)
INSECTICIDE				
Control	10.72a	54.16a	239.3a	862.2a
PG	7.56b	20.44b	247.4a	964.8a
AI	7.4b	26.34b	245.7a	884.3a
CDM	6.59b	20.60b	249.0a	1133.3a
LSD (P<0.05)	2.41	7.38	NS	NS
VARIETY				
V1	6.88b	30.04a	243.1a	1239.1a
V2	5.48b	30.37a	246.7a	914.1ab
V3	6.80b	27.40a	229.3a	1010.2ab
V4	7.33b	29.79a	254.5a	885.5ab
V5	10.58a	31.05a	269.0a	881.1ab
V6	11.34a	33.65a	229.5a	837.1b
LSD (P<0.05)	2.96	NS	NS	331.61

Means on the same column having a letter in common are not significantly different according to Duncan Multiple Range Test. NS: not significant

The interaction effect of insecticides and maize varieties on percentage adult emergence of African Fall Armyworm (*Spodoptera exempta*) is presented in table 2 below. Interaction between insecticide and variety had significant effect on percentage adult emergence of army worm. Applying insecticide generally reduced emergence of army worm in all six varieties. The highest emergence of adult army worm was recorded on plots where OBA SUPER 2 was planted without the application of insecticide. Applying Cypermethrin + Dimethoate to WHITE DT-STR gave the lowest percentage emergence of adult fall army worm.

Table 2: The Interaction Effect of Insecticides and Maize Varieties on Percentage Adult Emergence of African Fall Armyworm (*Spodoptera exempta*)

	Interaction I &V (%)					
	VARIETY					
INSECTICIDE	**V1**	**V2**	**V3**	**V4**	**V5**	**V6**
Control	10.44abc	6.32bc	7.80bc	9.72bc	13.40ab	16.61a
PG	6.67bc	6.00c	7.10c	6.0c	10.73ac	8.77bc
AI	5.41c	5.40c	6.34bc	6.78bc	11.14abc	9.37bc
CDM	5.00c	4.19c	5.94c	6.73bc	7.05bc	10.61abc
LSD (p<0.05)	2.96					

Means on the same column having a letter in common are not significantly different according to Duncan Multiple Range Test. Interaction I &V refers to the interaction effect between Insecticides (I) and Variety (V) on adult emergence.

The interaction effect of insecticides and maize varieties on number of leaf damaged by African Fall Armyworm (*Spodoptera exempta*) is presented in table 3 below. Interaction between insecticide and maize variety had significant effect on number of leaf damaged. Application of insecticides significantly reduced the number of leaf damaged in all six varieties of maize. The highest number of leaf damaged (65.01) was recorded on plots where OBA SUPER 2 was planted with no insecticide application. Plots where DTSTR-SYN-2-Y was planted followed with the application of Cypermethrin + Dimethoate recorded the lowest number of leaf damaged (16.78).

Table 3: The Interaction Effect of Insecticides and Maize Varieties on Number of Leaf Damaged

	Interaction I &V					
	VARIETY					
INSECTICIDE	**V1**	**V2**	**V3**	**V4**	**V5**	**V6**
Control	53.22a	51.17a	47.72a	52.15a	55.67a	65.01a
PG	24.33b	27.57b	25.83b	28.74b	24.33b	27.23b
AI	20.71b	21.70b	19.28b	19.67b	22.94b	19.28b
CDM	21.89b	21.06b	16.78b	18.61b	21.25b	23.06b
LSD (p<0.05)	18.07					

Means on the same column having a letter in common are not significantly different according to Duncan Multiple Range Test. Interaction I &V refers to the interaction effect between Insecticide (I) and Variety (V) on number of leaf damaged

The interaction effect of insecticides and maize varieties on grain yield of maize is presented in table 4 below. Interaction between insecticide and variety only showed significant effect on yield on plots where DTSR-CO was planted. The highest yield (1867.1) was recorded on plots where DTSR-CO was planted without applying insecticide, followed by applying *Piper guineense* to DTSR-CO plots (1242.2). The lowest yield was recorded on plots OBA SUPER 2 was planted followed with Cypermethrin + Dimethoate application. Application of insecticide reduced yield in all six varieties of maize.

Table 4: The Interaction Effect of Insecticides and Varieties on Yield of Maize

	Interaction I &V (kg/ha)					
	VARIETY					
INSECTICIDE	**V1**	**V2**	**V3**	**V4**	**V5**	**V6**
Control	1867.1a	1021.6b	1058.1b	998.0b	890.6b	964.7b
PG	1242.2ab	856.9b	1024.2b	904.0b	890.0b	871.3b
AI	780.3b	924.4b	992.1b	840.0b	874.0b	894.8b
CDM	1066.7b	853.3b	966.3b	800.0b	869.7b	617.5b
LSD (p<0.05)	663.21					

Means on the same column having a letter in common are not significantly different according to Duncan Multiple Range Test. Interaction I &V refers to the interaction effect between Insecticides (I) and Variety (V) on grain yield.

Discussion

Effect of Insecticide and Variety on Percentage Adult Emergence of Fall Armyworm

The present study demonstrated that insecticide application significantly influenced the percentage adult emergence of fall armyworm in maize. The percentage emergence of adult fall armyworm was significantly reduced by 29.5%, 31.0%, and 38.0% following the application of *Piper guineense* (black pepper) seed extract, *Azadirachta indica* (neem) seed extract, and cypermethrin + dimethoate (synthetic insecticide), respectively. Although cypermethrin + dimethoate had the greatest suppression of adult armyworm emergence, its effect was not significantly different from those of the botanical extracts. The comparable efficacy of *P. guineense* and *A. indica* to the synthetic insecticide suggests that these botanicals possess considerable insecticidal properties capable of disrupting larval development and adult emergence; hence, they have potential as sustainable alternatives to expensive and hazardous chemical insecticides. Similar reductions in lepidopteran pest survival and adult emergence following the application of neem and pepper-based botanicals have been reported by several authors, who attributed these effects to antifeedant, growth-regulating, and toxic properties of the bioactive compounds present in these plants (Midega *et al.*, 2022; Akutse *et al.*, 2023; Isman, 2020).

Maize genotypes significantly influenced percentage adult emergence of fall armyworm. Percentage adult emergence was significantly lower in DTSR-CO, WHITE DT-STR, DTSTR-SYN-2-Y and TZL-COMP3-CSDT than SYN-11-W and OBA SUPER 2. The significant varietal differences observed further indicate the existence of inherent resistance or tolerance mechanisms among maize genotypes against fall armyworm infestation. This finding is consistent with recent studies demonstrating substantial genetic variation among maize genotypes against fall armyworm, with resistant genotypes exhibiting antibiosis and/or antixenosis mechanisms that adversely affect larval survival, development, and adult emergence (Prasanna *et al.*, 2022; Kamweru *et al.*, 2022; Nuambote-Yobila *et al.*, 2023; Warburton *et al.*, 2023; Asare *et al.*, 2023).

Effect of Insecticide and Variety on Number of Leaves Damaged by Fall Armyworm

Insecticide treatments also significantly reduced the number of leaves damaged by fall armyworm. Leaf damage was reduced by 37.74%, 48.63%, and 61.96% following the application of *P. guineense*, *A. indica*, and cypermethrin + dimethoate, respectively. The superior performance of cypermethrin + dimethoate in consistent with previous reports that synthetic insecticides provide rapid knockdown and broad-spectrum control of fall armyworm (Bateman *et al.*, 2021). Nevertheless, the substantial reduction in leaf damage achieved with the botanical treatments corroborates findings that neem and black pepper extracts can effectively suppress feeding activity and reduce foliar injury in maize (Akutse *et al.*, 2023; Harrison *et al.*, 2019).

Although maize variety did not significantly influence leaf damage, DTSTR-SYN-2-Y consistently exhibited lower damage levels than OBA SUPER 2, suggesting a degree of tolerance to fall armyworm attack. Genotypic variation in susceptibility to fall armyworm among maize cultivars has previously been documented by Prasanna *et al.* (2022).

Effect of Insecticide and Variety on Leaf Area of Maize

Leaf area was not significantly affected by insecticide application or maize variety. However, plants treated with cypermethrin + dimethoate produced larger leaf areas than those treated with botanical extracts or left untreated. The absence of significant differences in leaf area despite reductions in pest incidence may indicate the compensatory growth ability of maize plants, whereby plants recover from moderate defoliation without substantial reductions in vegetative growth (Baudron *et al.*, 2019). Similar observations have been reported in maize subjected to varying levels of fall armyworm infestation, where reductions in foliar damage did not always translate into significant differences in leaf area (Harrison *et al.*, 2019).

Effect of Insecticide and Variety on Maize Grain Yield

Likewise, insecticide application did not significantly affect grain yield, although higher yields were recorded in insecticide-treated plots than in untreated plots. The lack of significant yield response despite reductions in pest infestation has been reported in several studies and may be attributed to the ability of maize plants to compensate for early-season leaf injury or to relatively low pest pressure during critical growth stages (Baudron *et al.*, 2019; Harrison *et al.*, 2019).

Among the maize varieties evaluated, DTSR-CO produced the highest yield, whereas OBA SUPER 2 produced the lowest yield, indicating substantial genetic variability in yield potential and adaptation. Previous studies have similarly reported significant differences in grain yield among maize genotypes under fall armyworm infestation due to variations in tolerance, recovery capacity, and genetic background (Prasanna *et al.*, 2022).

Interaction Effect of Insecticide and Variety on Percentage Adult Emergence of Armyworm

The significant interaction between insecticide and maize variety in adult emergence of fall armyworm indicates that the effectiveness of insecticides depended on the maize genotype. Insecticide application generally reduced adult emergence across all varieties, with the highest emergence recorded in untreated OBA SUPER 2 plots and the lowest in WHITE DT-STR plots treated with cypermethrin + dimethoate. Such interactions suggest that integrating host plant resistance with botanical or synthetic insecticides may enhance fall armyworm management, an approach widely recommended within integrated pest management (IPM) programmes (Prasanna *et al.*, 2022; Midega *et al.*, 2022).

Interaction Effect of Insecticide and Variety on Number of Leaves Damaged by Armyworm

Similarly, the interaction between insecticide and maize variety significantly affected the number of leaf damage. The highest number of leaf damage occurred in untreated OBA SUPER 2 plots, whereas DTSTR-SYN-2-Y treated with cypermethrin + dimethoate recorded the least leaf damage. These findings further support the complementary role of varietal resistance and insecticide application in minimizing fall armyworm injury. The integrated use of resistant varieties and environmentally friendly botanicals has been advocated as a sustainable strategy for managing the fall armyworm in sub-Saharan Africa (Midega *et al.*, 2022; Akutse *et al.*, 2023).

Interaction Effect of Insecticide and Variety on Yield of Maize

The interaction between insecticide and maize variety significantly affected grain yield only in DTSR-CO. Unexpectedly, insecticide application reduced yield across all maize varieties, with untreated DTSR-CO plots producing the highest yield. The superior performance of untreated DTSR-CO suggests that its inherent resistance mechanisms supersedes insecticidal effects, which were sufficient to maintain productivity under fall armyworm infestation, reducing the need for chemical intervention. This directly demonstrates that a resistant/tolerant genotype without insecticide can approach or exceed the yield of insecticide-assisted management, and can clearly outperform a susceptible variety that is sprayed (Amegbor *et al*. 2025).

CONCLUSION

Given the overall efficacy of the treatments on the yield, CDM (Cypermethrin + Dimethoate) was the best among the treatments. PG (*Piper guineense*) ranked second, while AI (*Azadirachta indica*) ranked third in terms of growth (leaf area) and yield increase. The least emergence of adult armyworm and the number of leaves damaged were also produced by Cypermethrin + Dimethoate, while the untreated plot had the highest emergence and leaf damage in the order (CDM>AI>PG>control). The highest yield was recorded from DTSR-CO (DTSR-CO). The resource-poor farmers are encouraged to cultivate the improved maize variety DTSR-CO and to apply seed extract PG *(Piper guineense*) as a sustainable alternative to synthetic insecticides in the managing fall armyworm in maize.

REFERENCES

Akutse, K. S., Subramanian, S., Khamis, F. M., Ekesi, S., & Mohamed, S. A. (2023). Botanical pesticides for sustainable management of fall armyworm in Africa: Current status and future prospects. *CABI Agriculture and Bioscience*, *4*, 15. https://doi.org/10.1186/s43170-023-00163-7

Amadi, G. I., Ukoroije, R. B., & Dimkpa, S. O. N. (2024). Efficacy of five botanicals in the management of fall armyworm (*Spodoptera frugiperda*) larvae on some maize varieties in Port Harcourt, Rivers State, Nigeria. *International Journal of Entomology and Nematology Research, 8*(1), 1–15.

Amegbor, I.K., Adu, G.B., Nelimor, C. *et al.* Assessment of fall armyworm tolerant maize hybrids for sustainable maize production in sub-Saharan Africa. *Phytoparasitica* **53**, 29 (2025). https://doi.org/10.1007/s12600-025-01253-y

Asare, S., Kena, A., Amoah, S., Annor, B., *et al.* (2023). Screening of maize inbred lines and evaluation of hybrids for their resistance to fall armyworm. Plant Stress, 8, 100148. https://doi.org/10.1016/j.stress.2023.100148

Babendreier, D., Agboyi, L. K., Beseh, P., Osae, M., Nboyine, J., Ofori, S. E. K., Frimpong, J. O., Attuquaye Clottey, V., & Kenis, M. (2020). The efficacy of alternative, environmentally friendly plant protection measures for control of fall armyworm, *Spodoptera frugiperda*, in maize. *Insects, 11*(4), 240. https://doi.org/10.3390/insects11040240

Bateman, M. L., Day, R. K., Luke, B., Edgington, S., Kuhlmann, U., Cock, M. J. W., & Early, R. (2021). Assessment of potential biopesticide options for managing fall armyworm (*Spodoptera frugiperda*) in Africa. *Journal of Applied Entomology*, *145*(3), 256–267. https://doi.org/10.1111/jen.12856

Baudron, F., Zaman-Allah, M. A., Chaipa, I., Chari, N., & Chinwada, P. (2019). Understanding the factors influencing fall armyworm damage in African smallholder maize fields and its effect on yield. *A case study from Zimbabwe*. *Crop Protection*, *120*, 141–150. https://doi.org/10.1016/j.cropro.2019.01.028

Du, S., & Xiong, W. (2024). Weather extremes shock maize production: Current approaches and future research directions in Africa. *Plants*, *13*(12), 1585. https://doi.org/10.3390/plants13121585

Gaddaguti, B. G., Paramesh, V., Kumar, P., *et al*. (2022). Sustainable management of invasive fall armyworm (*Spodoptera frugiperda*). *Agronomy*, *12*(9), 2150. https://doi.org/10.3390/agronomy12092150

Giraldo-Vanegas, H., & Giraldo-Herrera, G. (2026). Use of oil, aqueous extracts, and formulations of *Azadirachta indica* A. Jussieu against *Spodoptera frugiperda*: A systematic review (2015–2026). *Research Square* (Preprint). https://doi.org/10.21203/rs.3.rs-9361769/v1

Gressel, J., Mbogo, P., Kanampiu, F., & Christou, P. (2024). Maize yields have stagnated in sub-Sahara Africa: a possible transgenic solution to weed, pathogen and insect constraints. *Pest Management Science*, *80*(9), 4156–4162. https://doi.org/10.1002/ps.8224

Gunundu, R. (2023). Genomic selection and enablers for agronomic traits in maize (*Zea mays*): A review. *Plant Breeding*, 142(6), 1–18. https://doi.org/10.1111/pbr.13127

Hall, O., Wahab, I., Dahlin, S., Hillbur, P., Jirström, M., & Öborn, I. (2023). A decade of maize yield gap studies in sub-Saharan Africa: How are farm-level factors considered? *International Journal of Agricultural Sustainability*, *22*(1), 2293591. https://doi.org/10.1080/14735903.2023.2293591

Harrison, R. D., Thierfelder, C., Baudron, F., Chinwada, P., Midega, C., Schaffner, U., & van den Berg, J. (2019). Agro-ecological options for fall armyworm management in sub-Saharan Africa. *Food Security*, *11*, 897–912. https://doi.org/10.1007/s12571-019-00942-9

Isman, M. B. (2020). Botanical insecticides in the twenty-first century—Fulfilling their promise? *Annual Review of Entomology*, *65*, 233–249. https://doi.org/10.1146/annurev-ento-011019-025010

Kamweru, I., Anani, B. Y., Beyene, Y., Makumbi, D., Adetimirin, V. O., Prasanna, B. M., & Gowda, M. (2022). Genomic analysis of resistance to fall armyworm (Spodoptera frugiperda) in CIMMYT maize lines. Genes, 13(2), 251. https://doi.org/10.3390/genes13020251

Li, M., Jin, Z., Qi, Y., Zhao, H., Yang, N., Guo, J., Chen, B., Xian, X., & Liu, W. (2024). Risk assessment of *Spodoptera exempta* against food security: estimating the potential global overlapping areas of wheat, maize, and rice under climate change. *Insects*, *15*(5), 348. https://doi.org/10.3390/insects15050348

Liywalii, K., Tembo, A., Muyabe, O., Musenge, D. C., Mulenga, M., Silombe, M., Movwe, T., *et al.* (2026). Evaluating the efficacy of neem (*Azadirachta indica*) and chili (*Capsicum* spp.) extracts for the control of fall armyworm (*Spodoptera frugiperda*) in maize production in Zambia. *Journal of Experimental Agriculture International*, *48*(1), 361–374. https://doi.org/10.9734/jeai/2026/v48i14009

Lukman, M. A., Abdulhadi, M., Gwa, V. I., Abdullahi, A. A., & Igbi, T. L. (2025). Insecticidal effects of some selected plant extracts against fall armyworm (*Spodoptera frugiperda* J.E. Smith). *Nigerian Journal of Plant Protection*. https://doi.org/10.71464/hrkkhh10

Mahmood, S., & Parwez, H. (2024). The repository of biocontrol agents for *Spodoptera frugiperda* (Smith, 1797) with emphasis on their mode of action. *Journal of Basic and Applied Zoology*, *85*, 18. https://doi.org/10.1186/s41936-024-00358-w

Mansur, A., Utono, I. M., Bamaiyi, L. J., & Ibrahim, N. D. (2026). Efficacy of selected botanical extracts against *Spodoptera frugiperda* infestation on maize under screen house conditions. *Moroccan Journal of Agricultural Sciences*. https://doi.org/10.5281/zenodo.19633326

Meena, A., Yadav, U., Panwar, C., & Bhati, M. S. (2024). Field efficacy and economics of certain chemicals and botanicals against fall armyworm (*Spodoptera frugiperda*) on maize (*Zea mays*). *International Journal of Plant & Soil Science*, *36*(7), 662–669. https://doi.org/10.9734/ijpss/2024/v36i74778

Midega, C. A. O., Pittchar, J. O., Pickett, J. A., Hailu, G. W., & Khan, Z. R. (2022). A climate-adapted push–pull system effectively controls fall armyworm, *Spodoptera frugiperda* (J.E. Smith), in maize in East Africa. *Crop Protection, 105*, 10–15. https://doi.org/10.1016/j.cropro.2017.11.003

Mwamula, A. O., Kabir, M. F., & Lee, D. W. (2022). A review of the potency of plant extracts and compounds from key families as an alternative to synthetic pesticides. *Plant Pathology Journal*, *38*(2), 53–77. https://doi.org/10.5423/PPJ.RW.12.2021.0179

Nampijja, M., *et al.* (2024). Potential of neem (*Azadirachta indica*) extract in managing fall armyworm on maize. *Journal of Agricultural Science*, *16*(7), 114–126. https://doi.org/10.5539/jas.v16n7p114

Nuambote-Yobila, O., Bruce, A. Y., Okuku, G. O., Marangu, C., Makumbi, D., Beyene, Y., Mahungu, N. M., Prasanna, B. M., Marion-Poll, F., & Calatayud, P.-A. (2023). Assessment of resistance mechanisms to fall armyworm, Spodoptera frugiperda, in tropical maize inbred lines. Agronomy, 13(1), 203. https://doi.org/10.3390/agronomy13010203

Prasanna, B. M., Bruce, A., Beyene, Y., Makumbi, D., Gowda, M., Asim, M., Martinelli, S., Head, G. P., & Parimi, S. (2022). Host plant resistance for fall armyworm management in maize: Relevance, status and prospects in Africa and Asia. Theoretical and Applied Genetics, 135, 3897–3916. https://doi.org/10.1007/s00122-022-04073-4

Prasanna, B. M., Huesing, J. E., Peschke, V. M., Eddy, R., & Virginia, M. (2022). Host plant resistance for fall armyworm management in maize: Status and prospects. *Theoretical and Applied Genetics*, *135*, 1517–1534. https://doi.org/10.1007/s00122-022-04047-4

Prasanna, B. M., Huesing, J. E., Eddy, R., & Peschke, V. M. (2023). Fall armyworm in Africa: a guide for integrated pest management. *CIMMYT/ICRISAT Technical Report*. https://doi.org/10.5281/zenodo.7789321

Tambo, J. A., Kansiime, M. K., Mugambi, I., Agboyi, L. K., Beseh, P. K., & Day, R. (2023). Economic impacts and management of fall armyworm (*Spodoptera frugiperda*) in smallholder agriculture: A panel data analysis for Ghana. *CABI Agriculture and Bioscience*, *4*, 38. https://doi.org/10.1186/s43170-023-00181-3

Warburton, M. L., Woolfolk, S., Smith, J. S., Hawkins, L. K., *et al.* (2023). Genes and genetic mechanisms contributing to fall armyworm resistance in maize. The Plant Genome, 16(2), e20311. https://doi.org/10.1002/tpg2.20311

Zingore, S., Adolwa, I. S., Njoroge, S., Johnson, J.-M., Saito, K., Phillips, S., Kihara, J., Mutegi, J., Murell, S., & others. (2022). Novel insights into factors associated with yield response and nutrient use efficiency of maize and rice in sub-Saharan Africa: A review. *Agronomy for Sustainable Development*, 42, 82. https://doi.org/10.1007/s13593-022-00821-4