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Assessing The Effectiveness Of Neem Leaf Extract In Controlling Fall Army Worm In Smallholder Maize Gardens In Ikulwe Village, Mayuge District, Uganda

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Abstract

This study assessed the effectiveness of neem (Azadirachta indica) leaf extract in controlling fall army worm (Spodoptera frugiperda) infestations in smallholder maize gardens in Ikulwe Village, Mayuge District, Uganda. The fall army worm (FAW), an invasive pest that first entered sub-Saharan Africa in 2016, had rapidly established itself as the most economically destructive pest of maize in Uganda, causing yield losses estimated at between 20% and 73% depending on infestation severity and management response. The study employed a randomised complete block design (RCBD) with four treatments: neem leaf extract at 100g/L, neem leaf extract at 200g/L, a positive control (lambda-cyhalothrin 5EC), and a negative control (distilled water). Data were collected on larval mortality rate, leaf damage score, and grain yield across three blocks over two growing seasons. Results indicated that neem leaf extract at 200g/L achieved a mean larval mortality rate of 72.4% and a leaf damage score of 2.1 (out of 9), comparable to the chemical control treatment (76.8% mortality, damage score 1.9) and significantly superior to the negative control (18.3% mortality, damage score 6.8). Grain yields in plots treated with 200g/L neem extract (3.12 t/ha) were not significantly different from those in chemical control plots (3.28 t/ha). The study concluded that neem leaf extract at 200g/L constituted an effective, affordable, and environmentally sustainable alternative to synthetic insecticides for FAW management among smallholder maize farmers.

Keywords: Neem Leaf Extract, Azadirachta indica, Fall Army Worm, Spodoptera frugiperda, Maize, Biological Control, Ikulwe Village, Mayuge District, Uganda

1.0 Background of the Study

The fall army worm (FAW), Spodoptera frugiperda (J.E. Smith) (Lepidoptera: Noctuidae), was a highly mobile, polyphagous pest native to the tropical and subtropical regions of the Americas. Following its first detection in West Africa in 2016, FAW spread rapidly across the African continent, reaching Uganda in 2017 and establishing itself as the dominant pest threat to maize production across all major growing regions of the country. The pest's rapid spread was attributable to its exceptional reproductive capacity a single female could lay up to 2,000 eggs across her lifespan its wide host range spanning over 80 plant species, and its demonstrated resistance to multiple classes of synthetic insecticides. In Uganda, FAW had been confirmed in all districts within two years of its initial detection, with prevalence rates in major maize-growing regions including eastern and northern Uganda exceeding 80% of sampled fields(Kazaara et al., 2023).

Maize was Uganda's most widely cultivated food and cash crop, grown by an estimated 3.5 million farm households covering approximately 1.3 million hectares annually (FAOSTAT, 2022). The crop served dual functions as the

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primary dietary staple for a large proportion of the country's rural population and as a critical income source for smallholder households(Turyatemba et al., 2022). FAW's emergence had therefore posed an immediate threat not only to Uganda's food security but also to the livelihoods of millions of smallholder farming families whose income generation capacity was directly tied to maize productivity(Julius & Audrey, 2026b). National-level estimates suggested that FAW had caused yield losses of between 20% and 73% in infested fields, with aggregate annual economic losses to Ugandan agriculture estimated at between USD 85 million and USD 200 million, depending on the assessment methodology applied(Julius & Audrey, 2026a).

The chemical control of FAW with synthetic insecticides represented the most widely adopted management response in Uganda, with lambda-cyhalothrin, chlorpyrifos, and emamectin benzoate among the most commonly used compounds. However, exclusive reliance on chemical control generated multiple concerns: financial inaccessibility for resource-poor smallholder farmers, who typically lacked cash during planting season when FAW management interventions were most critical; environmental contamination of soil, water bodies, and non-target organisms; development of insecticide resistance through repeated exposure; and food safety risks from pesticide residues in harvested grain. These concerns underscored the urgency of identifying effective, affordable, and environmentally sustainable alternatives for FAW management.

Neem (Azadirachta indica A. Juss), a tree widely distributed across tropical and subtropical Africa, had long been recognised for its bioinsecticidal properties. The tree's primary bioactive compounds azadirachtin, nimbin, salannin, and related limonoids were concentrated in the seeds but also present in leaves, bark, and roots. These compounds disrupted insect growth, feeding, and reproduction through multiple mechanisms, including anti-feeding activity, growth regulation (juvenile hormone mimicry), and direct mortality at higher concentrations(Suzan & Gracious Kazaara, 2023). Neem was widely available and free of cost in most Ugandan rural communities, where it was planted as a shade tree, boundary marker, and medicinal resource. Its biological safety for humans and mammals made it particularly suitable for integrated pest management (IPM) programmes in food production systems(Kazaara et al., 2024). However, research specifically evaluating neem leaf extract (as opposed to the more concentrated neem seed kernel extract) for FAW control in Ugandan smallholder contexts remained limited, necessitating the present study.

2.0 Problem Statement

The fall army worm had devastated maize yields in Ikulwe Village, Mayuge District, since its first confirmed detection in the area in the 2017 long rains season. Community surveys conducted during the preliminary research phase indicated that between 2018 and 2022, FAW infestations affected an estimated 78% of maize gardens in Ikulwe Village during the first rain season, resulting in average yield losses of between 35% and 55% compared to seasons prior to FAW introduction. Smallholder farmers in the village had responded to FAW with a range of strategies, including manual removal of egg masses and larvae, application of wood ash and soil, intercropping with repellent plants, and purchase of synthetic insecticides. However, the financial costs of synthetic insecticides typically UGX

15,000–25,000 per litre for recommended products, against average household cash incomes of less than UGX 150,000 per month placed chemical control beyond the consistent reach of the majority of smallholder farmers in the village.

Informal farmer knowledge and extension officer recommendations had introduced neem leaf extract as a low-cost, locally available alternative for FAW management in Ikulwe and surrounding communities. Farmers reported that neem leaf extracts applied to maize plants appeared to reduce FAW feeding activity and larval populations, though outcomes were inconsistent and application protocols varied widely. No systematic, rigorously designed experiment had been conducted to quantify the efficacy of neem leaf extract for FAW control in Ikulwe's specific agro-ecological conditions, leaving extension recommendations without a local evidence base and farmers unable to make informed decisions about the appropriate concentration, timing, and frequency of neem extract application. This study was therefore designed to fill this critical evidence gap through a controlled field experiment.

3.0 Main Objective

The main objective of this study was to assess the effectiveness of neem leaf extract in controlling fall army worm in smallholder maize gardens in Ikulwe Village, Mayuge District, Uganda. The specific objectives were: (i) to determine the larval mortality rate of FAW under different neem leaf extract concentrations; (ii) to assess the effect of neem leaf extract treatments on maize leaf damage scores; and (iii) to compare the grain yield of maize under different FAW management treatments including neem leaf extract.

4.0 Literature Review

4.1 Biology and Economic Significance of Fall Army Worm

Spodoptera frugiperda, commonly known as the fall army worm, was a noctuid moth whose larval stage caused the primary agricultural damage. The pest completed its life cycle in approximately 30 days under optimal temperature conditions (28°C), with six larval instars — the last two of which (L5 and L6) were responsible for the majority of plant tissue destruction. Newly hatched larvae fed on leaf tissue, creating characteristic 'window pane' damage patterns, while later instar larvae bored into the maize whorl and ear, causing irreversible damage to developing tissue and grain. FAW preferred maize in the vegetative stage (V2–V8) as its primary host, though infestations continued through silking and grain filling stages.

Research conducted across affected African countries confirmed FAW's devastating economic impact. A study by Day et al. (2017) estimated potential economic losses from FAW across 12 African countries at between USD 2.48 billion and USD 6.19 billion annually in the absence of any control measures. In Uganda specifically, a rapid assessment by the Government of Uganda and FAO (2017) estimated that FAW had already destroyed maize valued at approximately USD 196 million in the first year following its arrival. Subsequent assessments demonstrated that while awareness of FAW had increased among farmers, effective management remained inconsistent, particularly among resource-poor smallholder households with limited access to recommended synthetic insecticides.

4.2 Neem as a Bioinsecticide

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Neem (Azadirachta indica) had been extensively studied as a source of natural insecticides for over four decades. The primary bioactive compound, azadirachtin — a complex limonoid concentrated at 2,500–3,000 ppm in neem seed kernels and 50–200 ppm in neem leaves — demonstrated multiple modes of action against target insects. It inhibited ecdysone-mediated moulting processes, preventing larvae from completing developmental transitions; disrupted feeding behaviour through anti-feedant activity; reduced fecundity through reproductive hormone interference; and caused direct mortality at higher concentrations through digestive system disruption. The multi-site mode of action of neem-based pesticides was identified as a significant advantage over synthetic insecticides, as it made the development of resistance far more difficult than for single-site-mode compounds.

Research on neem-based products for FAW control specifically demonstrated promising efficacy outcomes. A study by Sisay et al. (2019) in Ethiopia found that neem seed kernel extract (NSKE) at a 5% concentration achieved 68.3% larval mortality in FAW under field conditions, while a Kenyan study by Nabwile et al. (2020) documented 71.2% mortality with NSKE at 200g/L applied twice weekly. However, research specifically evaluating neem leaf extract (which was more readily available to farmers than seed kernel extract) for FAW control under Ugandan conditions remained sparse, leaving an evidence gap that the present study sought to address. Ekesi et al. (2016) noted that neem leaf extract, while lower in azadirachtin concentration than NSKE, offered practical advantages in terms of ease of preparation and year-round availability in most African farming communities, potentially making it a more sustainable component of smallholder IPM programmes.

5.0 Methodology

5.1 Research Design

The study employed a Randomized Complete Block Design (RCBD) with four treatments replicated across three blocks, for a total of 12 experimental plots. The RCBD was selected to control for soil fertility and micro-climatic heterogeneity within the experimental field in Ikulwe Village, which was situated on gently sloping terrain with moderate variation in soil organic matter content. Each experimental plot measured 5m × 6m (30 m²), with a 1m buffer strip between adjacent plots to minimise spray drift between treatments. The experiment was conducted over two consecutive growing seasons (Season 1: March–June 2023; Season 2: August–November 2023) to account for seasonal variability in FAW pressure, temperature, and rainfall patterns.

5.2 Materials and Treatments

Four treatments were evaluated: T1 neem leaf extract at 100g of fresh neem leaves per litre of water (100g/L); T2 neem leaf extract at 200g of fresh neem leaves per litre of water (200g/L); T3 positive control using lambda-cyhalothrin 5EC insecticide at the recommended rate of 30mL/15L (0.2%); and T4 — negative control using distilled water only. Neem leaf extract was prepared by crushing freshly harvested neem leaves using a manual blender, soaking the crushed material in water at the specified concentration for 24 hours, and filtering through a double layer of muslin cloth to remove plant material. The extract was applied to maize plants using a hand-operated knapsack sprayer, with applications directed into the maize whorl the primary FAW feeding and oviposition site three times per week

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commencing at plant emergence (V1 stage) and continuing until grain filling (R2 stage). The maize variety used was NARO Hybrid Maize 212 (NARO 212), a drought-tolerant variety widely cultivated by Ikulwe Village farmers.

5.3 Data Collection

Three primary data variables were measured at defined intervals throughout each growing season. Larval mortality rates were assessed by counting live and dead FAW larvae within the whorl and on leaf surfaces of 10 randomly selected plants per plot at weekly intervals, computing percentage mortality as (dead larvae / total larvae) × 100. Leaf damage scores were assessed using the standard 1–9 leaf damage scoring scale developed by Davis et al. (1992), where 1 indicated no visible damage and 9 indicated severe damage to the leaf canopy. Scores were recorded for 10 randomly selected plants per plot at 2-week intervals. Grain yield was measured at harvest by weighing all cobs harvested from the central 4m × 4m of each plot, converting to tonnes per hectare and adjusting to a standard moisture content of 12.5%.

5.4 Data Analysis

Data were analysed using SPSS version 25 and Genstat software (17th edition). Analysis of variance (ANOVA) was performed to test for statistically significant differences among treatment means for all three response variables. Where ANOVA indicated significant differences, Tukey's Honest Significant Difference (HSD) test was used for post-hoc pairwise comparison of treatment means. Percentage mortality data were arcsine-transformed before analysis to meet the normality assumption of ANOVA. All statistical tests were performed at a 5% significance level ($\alpha=0.05$).

6.0 Results

6.1 Larval Mortality Rates

Table 1: Mean Fall Army Worm Larval Mortality Rates by Treatment and Season

Treatment	**Season 1 Mortality (%)**	**Season 2 Mortality (%)**	**Combined Mean (%)**	**Std. Error**	**Significance**
T1: Neem Extract 100g/L	58.2	61.4	59.8a	1.87	Significant
T2: Neem Extract 200g/L	70.8	74.1	72.4b	1.64	Significant
T3: Lambda-cyhalothrin (Control+)	74.2	79.5	76.8b	1.52	Significant
T4: Distilled Water (Control–)	16.9	19.7	18.3c	0.94	—

Note: Means followed by the same letter are not significantly different at $p \leq 0.05$ (Tukey's HSD). $F(3,8)=287.4$, $p<0.001$.

Source: Primary Data, 2025

Table 1 presents the mean larval mortality rates achieved by each treatment across the two growing seasons. The analysis of variance revealed highly significant differences among treatments ($F(3,8)=287.4$, $p<0.001$). The chemical

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control (T3: lambda-cyhalothrin) achieved the highest combined mean larval mortality of 76.8%, followed closely by neem leaf extract at 200g/L (T2) with a mean mortality of 72.4%. Critically, the Tukey's HSD post-hoc test revealed no statistically significant difference between T2 and T3 ($p>0.05$), confirming that neem leaf extract at 200g/L provided FAW larval control that was statistically equivalent to the recommended synthetic insecticide. Neem leaf extract at 100g/L (T1) achieved a significantly lower but still substantial mortality rate of 59.8%, which was statistically distinct from both T2 and T3. The negative control (T4) achieved a mean larval mortality of only 18.3%, representing background mortality attributable to natural causes rather than treatment effects. Both neem extract treatments demonstrated improved efficacy in Season 2 compared to Season 1, potentially reflecting improved application technique as farmers and research assistants gained experience with extract preparation and application protocols.

6.2 Leaf Damage Scores

Table 2: Mean Leaf Damage Scores by Treatment and Season (Scale: 1–9)

Treatment	Season 1 Score	Season 2 Score	Combined Mean	Std. Error
T1: Neem Extract 100g/L	3.2	2.8	3.0a	0.19
T2: Neem Extract 200g/L	2.2	2.0	2.1b	0.12
T3: Lambda-cyhalothrin (Control+)	2.0	1.8	1.9b	0.11
T4: Distilled Water (Control–)	6.9	6.7	6.8c	0.22

Note: Lower scores indicate less leaf damage. Means followed by the same letter are not significantly different at $p\leq0.05$. $F(3,8)=412.6$, $p<0.001$.

Source: Primary Data, 2025

Table 13 presents the mean leaf damage scores recorded across the two growing seasons. ANOVA indicated highly significant treatment effects on leaf damage ($F(3,8)=412.6$, $p<0.001$). The chemical control (T3) achieved the lowest mean damage score (1.9), consistent with its highest larval mortality rate, while neem extract at 200g/L (T2) recorded a mean damage score of 2.1 not significantly different from T3 ($p>0.05$), confirming visual equivalence in plant protection outcomes between the two treatments. Neem extract at 100g/L (T1) achieved a mean damage score of 3.0, representing moderate leaf damage and a statistically significant difference from T2 and T3. The negative control plots recorded severe leaf damage (mean score=6.8), characteristic of unmanaged FAW infestations. These findings reinforced the conclusion that neem leaf extract at 200g/L provided plant protection outcomes equivalent to synthetic insecticide, which had important implications for farmers seeking effective yet affordable and environmentally safe FAW management options.

6.3 Grain Yield

Table 3: Maize Grain Yield by Treatment (tonnes per hectare at 12.5% moisture)

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Treatment	**Season 1 Yield (t/ha)**	**Season 2 Yield (t/ha)**	**Mean Yield (t/ha)**	**Yield Advantage over Control– (%)**
T1: Neem Extract 100g/L	2.68	2.84	2.76a	64.3
T2: Neem Extract 200g/L	3.06	3.18	3.12b	85.7
T3: Lambda-cyhalothrin (Control+)	3.22	3.34	3.28b	95.2
T4: Distilled Water (Control–)	1.64	1.72	1.68c	—

Note: Means followed by the same letter are not significantly different at $p \leq 0.05$. $F(3,8)=198.3$, $p<0.001$.

Source: Primary Data, 2025

Table 3 presents the maize grain yield data collected at harvest across the two growing seasons. ANOVA revealed highly significant treatment effects on grain yield ($F(3,8)=198.3$, $p<0.001$). The chemical control treatment (T3) recorded the highest mean yield at 3.28 t/ha, representing a 95.2% yield advantage over the unmanaged negative control (1.68 t/ha). Crucially, neem leaf extract at 200g/L (T2) recorded a mean yield of 3.12 t/ha statistically equivalent to T3 ($p>0.05$, Tukey's HSD) and represented an 85.7% yield advantage over the negative control. These yield outcomes confirmed that the crop protection provided by 200g/L neem leaf extract translated into meaningful grain yield improvements, comparable to those achieved by the recommended synthetic insecticide. Neem extract at 100g/L (T1) achieved an intermediate yield of 2.76 t/ha statistically different from both T2 and T3, and from T4 representing a 64.3% yield advantage over the unmanaged control. These findings collectively established that neem leaf extract at 200g/L represented an effective management option that could significantly reduce the catastrophic yield losses associated with unmanaged FAW infestations.

7.0 Conclusions

The study concluded that neem leaf extract at 200g/L was effective in controlling fall army worm infestations in smallholder maize gardens in Ikulwe Village, Mayuge District, Uganda. The treatment achieved mean larval mortality rates, leaf damage scores, and grain yields that were statistically equivalent to the recommended synthetic insecticide (lambda-cyhalothrin 5EC), confirming its efficacy as an alternative pest management option. Neem leaf extract at 100g/L also demonstrated significant FAW control, though at a lower level than the 200g/L concentration, suggesting a dose-response relationship in the extract's bioinsecticidal activity.

The study further concluded that neem leaf extract offered significant practical advantages over synthetic insecticides for smallholder farmers in Ikulwe Village and comparable communities across Uganda. Its primary raw material fresh neem leaves was freely available, requiring no financial outlay. Extract preparation required only basic equipment (containers, a blender or mortar, and muslin cloth) accessible to most smallholder farming households. The extract's demonstrated safety for humans and non-target organisms made it particularly suitable for use in food production systems and by farmers with limited access to personal protective equipment. These advantages positioned neem leaf

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extract at 200g/L as a highly viable component of integrated pest management strategies for FAW among resource-constrained smallholder maize farmers.

8.0 Recommendations

Based on the findings, it was recommended that the Mayuge District Agricultural Office, in partnership with the National Agricultural Research Organisation (NARO) and national extension services, should promote neem leaf extract at 200g/L as a primary FAW management recommendation for smallholder maize farmers in Ikulwe Village and across the district, supported by extension training on correct preparation and application methods. NARO should conduct further research to investigate the efficacy and cost-effectiveness of neem leaf extract in combination with other IPM components including push-pull intercropping, biological control agents, and conservation agriculture practices to develop comprehensive FAW management packages suitable for different farming contexts. The optimal application frequency and timing within the maize crop growth cycle should be investigated in further trials to maximise the cost-effectiveness of neem extract applications. Development partners supporting Uganda's maize sector should consider funding the establishment of community-based neem extract preparation centres in high-FAW-pressure areas to facilitate consistent, high-quality extract preparation among farmer groups with limited individual capacity.

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