

PHYTOCHEMICAL CHARACTERISATION AND DEVELOPMENT OF BOTANICAL BIOPESTICIDES FROM INDIGENOUS PLANTS FOR SUSTAINABLE PEST MANAGEMENT IN DEMONSTRATION FARMS OF POLYTECHNICS IN SOUTH-WEST NIGERIA

LAWAL I. A.¹, OLADAPO J. O.² and OLORUNMAYE I. I.²

¹Department of Science Laboratory Technology, Federal Polytechnic Ede, Osun State, P.M.B 231, Nigeria.

²Department of Electrical Electronic Engineering, Federal Polytechnic Ede, Osun State, P.M.B 231, Nigeria.

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Article Info

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Abstract

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Abstract

*Pest management on polytechnic demonstration farms depends heavily on synthetic insecticides, which are costly, hazardous and increasingly compromised by resistance. This study characterised the phytochemistry of selected indigenous plants and developed and evaluated botanical biopesticides from them for sustainable pest management on demonstration farms of polytechnics in South-West Nigeria. An experimental design combined phytochemical characterisation, formulation, laboratory bioassay and a replicated field trial. Five plants were extracted and characterised, and the most active extracts were formulated and tested against *Spodoptera litura* and *Myzus persicae*. Gas chromatography-mass spectrometry identified azadirachtin, eugenol, piperine, nicotine and rotenone as major active compounds. The optimised formulation (5% *Azadirachta indica* + 3% *Ocimum gratissimum*) achieved 89.6% mortality of *S. litura* and 94.2% of *M. persicae* in the laboratory, with LC_{50} values of 0.82 and 0.58 mg/mL respectively. In the field it reduced pest populations by 78.4% and leaf damage by 82.6%, preserved 85.6% of beneficial insects and gave a yield comparable to synthetic insecticide (2.84 vs. 2.96 t/ha). The cost was ₦33,000 per hectare per season, a saving of 26–45%. Botanical biopesticides from indigenous plants offer an effective, low-cost and sustainable alternative to synthetic insecticides for Nigerian polytechnic demonstration farms.*

Keywords: botanical biopesticides; indigenous plants; phytochemistry; pest management; demonstration farms; Nigeria

Introduction

Insect pests impose heavy losses on crop production, and their management on farms, including the demonstration farms attached to polytechnics, depends overwhelmingly on synthetic insecticides. These chemicals are costly, hazardous to applicators, consumers and the environment, and increasingly compromised by the development of pest resistance, prompting a global search for safer, sustainable alternatives (Ngegba et al., 2022). Research has documented that synthetic pesticide use in Nigerian agriculture is associated with significant health risks to farmers, including

acute poisoning and chronic conditions, as well as environmental contamination of soil and water resources. Studies have estimated that pest-related crop losses in Nigeria range from 20% to 40% of potential yield, with synthetic insecticides representing a significant proportion of production costs for smallholder farmers. The development of resistance to commonly used synthetic insecticides has been documented in multiple pest species in Nigeria, including *Spodoptera* species and aphids, reducing the effectiveness of chemical control and driving farmers to use higher doses or more toxic compounds. Botanical biopesticides, derived from plants, are among the most promising of these alternatives, offering effective pest control through biodegradable, low-toxicity compounds that are less prone to resistance development.

Indigenous plants are a rich source of insecticidal compounds. A substantial literature demonstrates that extracts of many plant species contain phytochemicals, including alkaloids, flavonoids, terpenoids and phenolics, with insecticidal, antifeedant and repellent activity against a range of agricultural pests (Nia et al., 2015; Vázquez-Torres et al., 2024). Research has identified multiple mechanisms of insecticidal action for plant-derived compounds, including neurotoxicity, inhibition of feeding, disruption of moulting and growth, and interference with reproduction. These botanicals are biodegradable, generally of low toxicity to humans and beneficial organisms, and, through their multi-component action, less prone to provoking resistance than single-target synthetics. Studies have demonstrated that plant extracts can act synergistically, with the combination of multiple active compounds producing greater insecticidal activity than individual compounds alone. Nigerian indigenous plants have been extensively documented for their insecticidal properties, with studies identifying numerous species with significant activity against agricultural pests.

Translating this activity into practical pest management requires phytochemical characterisation, formulation and field evaluation. Studies show that identifying the active constituents of a plant, formulating extracts appropriately, and testing them against target pests can yield botanical biopesticides that reduce pest damage and even improve yield, while remaining compatible with beneficial insects (Seni et al., 2025). Research has demonstrated that formulation parameters, including solvent selection, extract concentration, and the addition of adjuvants, significantly affect the efficacy and stability of botanical biopesticides. Studies have shown that effective formulation can improve the shelf-life, rain-fastness and field performance of botanical preparations, making them more practical for farm use. Effective use also depends on evaluating performance under real farm conditions, not only in the laboratory, as field trials account for environmental factors, pest behaviour, and interactions with beneficial organisms (Ngegba et al., 2018). Research has emphasised the need for field evaluation of botanical biopesticides to establish practical value and support adoption by farmers.

Despite abundant evidence of plant insecticidal activity, the development and farm-level evaluation of botanical biopesticides from indigenous South-West Nigerian plants for use on polytechnic demonstration farms remains limited. Much of the evidence stops at laboratory bioassays or addresses stored-product rather than field pests, and few studies progress from phytochemical characterisation through formulation to demonstration-farm evaluation in this

setting (Ngegba et al., 2018). Research on botanical pesticides in Nigeria has focused primarily on laboratory screening of plant extracts, with limited attention to formulation development and field evaluation under local conditions. This study addresses that gap by characterising indigenous plants and developing and evaluating botanical biopesticides for sustainable pest management on demonstration farms.

Statement of the Problem

Pest management on the demonstration farms of South-West polytechnics depends heavily on synthetic insecticides, which are costly, hazardous and increasingly undermined by resistance, even though the region abounds in indigenous plants with proven insecticidal properties. Reliance on synthetics exposes applicators, consumers and the environment to harm and locks farms into an escalating and unsustainable chemical treadmill, while the botanical alternatives that could reduce this dependence remain undeveloped and unproven locally (Ngegba et al., 2022; Nia et al., 2015). The difficulty is that the phytochemistry of promising indigenous plants, effective biopesticide formulations derived from them, and their performance against target pests under demonstration-farm conditions are not established, so farms and educators lack a validated, low-cost botanical option to adopt (Ngegba et al., 2018). This gap perpetuates avoidable cost, hazard and unsustainability.

The specific challenges facing Nigerian polytechnic demonstration farms are situated within a broader context of pest management in Nigerian agriculture. Studies have documented that synthetic pesticide use in Nigeria is often characterised by inappropriate application practices, including over-dosing, use of banned compounds, and inadequate protective equipment, leading to significant health and environmental risks. Research has identified that many Nigerian farmers lack access to affordable and effective alternatives to synthetic pesticides, with botanical options not widely available or validated for local conditions. The demonstration farms attached to polytechnics serve as models for students and surrounding communities, making their adoption of sustainable pest management practices particularly significant. Studies have highlighted the potential for polytechnic farms to serve as demonstration sites for sustainable agricultural technologies, including botanical biopesticides. The development of validated, locally produced botanical biopesticides would enable these farms to model sustainable practice while reducing costs and hazards. These findings underscore the need for phytochemical characterisation, formulation development, and field evaluation of botanical biopesticides from indigenous plants for use on Nigerian polytechnic demonstration farms.

Botanical biopesticides derived from indigenous plants promise effective pest control at low cost while reducing the health and environmental harms of synthetics and slowing resistance, an outcome of clear value for demonstration farms that also model good practice for students and communities (Seni et al., 2025; Vázquez-Torres et al., 2024). Situated in polytechnics, the work builds capacity in phytochemistry, formulation and pest management and has enterprise potential. By characterising plants, developing formulations and evaluating them from laboratory to farm, the study produces a validated, sustainable option and dataset that are immediately actionable. The

beneficiaries are substantial: demonstration farms gain cheaper, safer pest control and a teaching model; students and technicians gain scientific and enterprise capacity; and the environment and food chain benefit from reduced synthetic-pesticide use. This study addresses that gap by characterising indigenous plants and developing and evaluating botanical biopesticides from laboratory to demonstration farm in South-West polytechnics.

Aim and Objectives

Aim: To characterise the phytochemistry of selected indigenous plants and develop and evaluate botanical biopesticides from them for sustainable pest management on demonstration farms of polytechnics in South-West Nigeria.

Specific Objectives:

- i. To extract and phytochemically characterise selected indigenous plants with reputed insecticidal activity;
- ii. To formulate botanical biopesticides from the extracts;
- iii. To evaluate the insecticidal efficacy of the formulations against target pests in the laboratory;
- iv. To assess the performance of the formulations against target pests on demonstration farms; and
- v. To establish validated botanical biopesticide formulations and recommendations for sustainable pest management.

Research Questions

1. What are the phytochemical constituents of selected indigenous plants with reputed insecticidal activity?
2. How can the most active extracts be formulated into botanical biopesticides?
3. What is the insecticidal efficacy of the formulations against target pests in the laboratory?

4. What is the performance of the formulations against target pests on demonstration farms?
5. What validated botanical biopesticide formulations and recommendations can be established for sustainable pest management?

Literature Review

The drawbacks of synthetic insecticides have driven sustained interest in botanical alternatives. Reviews establish that reliance on synthetic pesticides imposes costs and hazards to health and the environment and is increasingly undermined by resistance, positioning botanical biopesticides derived from plants as a promising, sustainable alternative (Ngegba et al., 2022). Research has documented that synthetic pesticides can persist in soil and water, accumulate in food chains, and cause acute and chronic health effects in exposed populations. Studies have shown that pest resistance to synthetic insecticides has developed rapidly, with over 500 species of insects and mites having developed resistance to one or more classes of insecticides. This frames the problem the study addresses.

A large literature documents the insecticidal activity of plant extracts and their phytochemistry. Studies show that extracts of diverse plant species contain phytochemicals with insecticidal, antifeedant and repellent activity against agricultural pests, and characterise this activity through bioassay and phytochemical screening (Nia et al., 2015; Vázquez-Torres et al., 2024). Research has identified multiple classes of insecticidal compounds, including alkaloids (e.g., nicotine, piperine), terpenoids (e.g., azadirachtin, pyrethrins), and phenolics (e.g., eugenol, thymol), with diverse mechanisms of action. Studies have demonstrated that the insecticidal activity of plant extracts is often attributable to the synergistic action of multiple compounds, with the complex mixtures of phytochemicals producing greater activity than individual compounds. Nigerian medicinal and aromatic plants have been extensively documented for their insecticidal properties, with studies identifying numerous species with significant activity against agricultural pests. This body of work establishes both the potential of indigenous plants and the methods for characterising them.

A third strand concerns formulation and efficacy against crop pests. Research demonstrates that plant extracts formulated as botanical treatments can reduce pest damage and, in some cases, improve yield while sparing beneficial insects, showing that insecticidal activity can be translated into practical crop protection (Seni et al., 2025). Studies have demonstrated that formulation parameters, including solvent selection (ethanol, methanol, water), extract concentration, and the addition of adjuvants (surfactants, emulsifiers), significantly affect the efficacy, stability and field performance of botanical biopesticides. Research has shown that effective formulation can improve the shelf-life, rain-fastness and adhesion of botanical preparations, making them more

practical for farm use. Studies have reported that botanical formulations can achieve comparable pest control to synthetic insecticides while being safer for beneficial insects and the environment. This literature underpins the study's formulation-and-efficacy focus.

A fourth strand emphasises evaluation beyond the laboratory. Studies note that the effectiveness of botanicals is too rarely tested under real farm conditions, and that field or on-farm evaluation is essential to establish practical value and support adoption, complementing laboratory bioassays (Ngegba et al., 2018). Research has emphasised the need for field evaluation of botanical biopesticides to account for environmental factors, including temperature, humidity, rainfall, and UV radiation, which can affect the stability and efficacy of botanical preparations. Studies have demonstrated that field performance may differ from laboratory results, with some formulations showing reduced efficacy under field conditions due to degradation or wash-off. This grounds the study's progression from laboratory to demonstration-farm evaluation.

Across these strands a consistent gap emerges. Much of the evidence stops at laboratory bioassays or addresses stored-product pests, with limited development and demonstration-farm evaluation of botanical biopesticides from indigenous South-West Nigerian plants (Ngegba et al., 2018). Research on botanical pesticides in Nigeria has focused primarily on laboratory screening of plant extracts, with limited attention to formulation development and field evaluation under local conditions. Moreover, few studies have progressed from phytochemical characterisation through formulation to demonstration-farm evaluation in polytechnic settings. This study addresses that gap by characterising indigenous plants and developing and evaluating botanical biopesticides from laboratory to demonstration farm in South-West polytechnics.

Methods

The study adopted an experimental design combining phytochemical characterisation, formulation and laboratory and field bioassay. Five indigenous plants with reputed insecticidal activity were selected based on ethnobotanical documentation and literature review: *Azadirachta indica* (neem), *Ocimum gratissimum* (scent leaf), *Piper nigrum* (black pepper), *Nicotiana tabacum* (tobacco), and *Tephrosia vogelii* (fish bean). These plants were selected based on documented insecticidal properties in Nigerian traditional agriculture. Plant materials were collected from Osun State, identified by a botanist, and voucher specimens deposited in the herbarium. The plant materials were dried at room temperature, ground to powder, and extracted using ethanol, methanol, and water by maceration (72 hours) and Soxhlet extraction. Solvents were removed using a rotary evaporator, and the crude extracts were stored at 4°C until use.

Phytochemical characterisation was performed through qualitative screening and quantification of major constituent classes by standard colorimetric and spectrophotometric methods, including tests for alkaloids (Dragendorff's reagent), flavonoids (aluminium chloride colorimetric method), terpenoids (Salkowski test), phenolics (Folin-Ciocalteu method), and saponins (foam test). Selected extracts were subjected to gas chromatography-mass spectrometry

(GC-MS) analysis for identification of active compounds, with compounds identified by comparison of mass spectra with the NIST library.

The extracts were formulated into biopesticides at concentrations of 2.5%, 5%, 10%, and 20% (w/v) in water with 0.1% Tween-80 as an emulsifier. The insecticidal efficacy of the formulations was evaluated in the laboratory against reared target pests, including *Spodoptera litura* (tobacco cutworm) and *Myzus persicae* (green peach aphid), using standard bioassays. Leaf disc bioassays were conducted by treating leaf discs with the formulations and introducing ten second-instar larvae (for *S. litura*) or ten adult aphids (for *M. persicae*), with mortality recorded at 24, 48, and 72 hours. Antifeedant activity was assessed by measuring leaf area consumed, and repellent activity was evaluated using choice tests. The LC₅₀ values were determined by probit analysis. Appropriate synthetic (cypermethrin) and untreated controls were included.

The most effective formulations were then evaluated on polytechnic demonstration farms in a replicated field trial. The trial was conducted on a randomized complete block design with four treatments (best botanical formulation, synthetic insecticide, untreated control, and solvent control) and four replications. The test crop was tomato (*Solanum lycopersicum*), a crop commonly grown on demonstration farms and susceptible to the target pests. Treatments were applied weekly using a knapsack sprayer, and data were collected on pest population, crop damage (leaf area damaged and fruit damage), effect on beneficial insects (ladybirds, spiders, and parasitoid wasps), and yield. Pest populations were assessed by counting insects on ten randomly selected plants per plot at weekly intervals. Data were analysed using analysis of variance (ANOVA) with post-hoc Tukey test to compare treatments, and the optimal formulations were identified. All laboratory and field work were conducted under appropriate safety and ethical clearance from the relevant institutional committees.

Results

The study successfully characterised indigenous plants and developed and evaluated botanical biopesticides. The findings are organised below according to the five research questions.

Research Question 1: What are the phytochemical constituents of selected indigenous plants with reputed insecticidal activity?

Table 1: *Phytochemical Composition of Plant Extracts*

Phytochemical	<i>A. indica</i>	<i>O. gratissimum</i>	<i>P. nigrum</i>	<i>N. tabacum</i>	<i>T. vogelii</i>
Alkaloids	+++	++	+++	+++	++
Flavonoids	+++	+++	++	++	+++
Terpenoids	+++	++	+	+	++
Phenolics	+++	+++	++	++	++
Saponins	++	+	+	++	+++

Phytochemical	<i>A. indica</i>	<i>O. gratissimum</i>	<i>P. nigrum</i>	<i>N. tabacum</i>	<i>T. vogelii</i>
Total phenolics (mg GAE/g)	156.4	142.6	118.2	124.8	136.2

Note. +++ = strongly present; ++ = moderately present; + = weakly present.

Table 2: GC-MS Identification of Major Active Compounds

Plant	Major Compounds	Retention Time (min)	Relative Abundance (%)
<i>A. indica</i>	Azadirachtin	18.42	28.6
	Nimbin	16.84	12.4
	Salannin	17.62	8.6
<i>O. gratissimum</i>	Eugenol	12.24	42.8
	Thymol	11.86	18.4
	Caryophyllene	14.26	10.2
<i>P. nigrum</i>	Piperine	16.42	38.6
	Limonene	10.84	12.4
	β-Caryophyllene	13.86	8.2
<i>N. tabacum</i>	Nicotine	9.64	52.4
	Nornicotine	8.86	12.8
<i>T. vogelii</i>	Rotenone	20.24	24.6
	Tephrosin	19.42	12.8

Table 1 presents the phytochemical composition of plant extracts. All extracts contained alkaloids, flavonoids, terpenoids, phenolics and saponins, with variations in the strength of detection. *A. indica* and *O. gratissimum* had the highest total phenolic content (156.4 and 142.6 mg GAE/g, respectively). The presence of these phytochemicals is consistent with the literature on plant-derived insecticidal compounds, which has identified these classes of compounds as responsible for insecticidal activity (Ngegba et al., 2022). Table 2 presents the GC-MS identification of major active compounds. Azadirachtin was identified as the major compound in *A. indica* (28.6% relative abundance), consistent with its well-documented insecticidal properties. Eugenol was the major compound in *O. gratissimum* (42.8%), piperine in *P. nigrum* (38.6%), nicotine in *N. tabacum* (52.4%), and rotenone in *T. vogelii* (24.6%). These compounds are all known to possess insecticidal activity through various mechanisms, including neurotoxicity, antifeedant effects, and growth regulation. The identification of these compounds provides a

molecular basis for the insecticidal activity of the extracts and supports the selection of these plants for biopesticide development.

Research Question 2: How can the most active extracts be formulated into botanical biopesticides?

Table 3: Formulation Composition and Characteristics

Formulation	Extract Composition	Concentration	Emulsifier	pH	Stability
F1	<i>A. indica</i> only	5%	Tween-80 (0.1%)	6.8	Stable
F2	<i>O. gratissimum</i> only	5%	Tween-80 (0.1%)	6.4	Stable
F3	<i>A. indica</i> + <i>O. gratissimum</i>	5% + 3%	Tween-80 (0.1%)	6.6	Stable
F4	<i>A. indica</i> + <i>P. nigrum</i>	5% + 3%	Tween-80 (0.1%)	6.8	Stable
F5	<i>O. gratissimum</i> + <i>P. nigrum</i>	5% + 3%	Tween-80 (0.1%)	6.4	Stable

Table 3 presents the formulation composition and characteristics. Five formulations were prepared, with the optimised formulation (F3) comprising 5% *A. indica* extract and 3% *O. gratissimum* extract in water with 0.1% Tween-80 as an emulsifier. All formulations had pH values between 6.4 and 6.8, which is suitable for foliar application and minimizes the risk of phytotoxicity. The formulations were stable at room temperature for at least 30 days, with no visible separation or precipitation. The selection of the combined *A. indica* + *O. gratissimum* formulation was based on the complementary insecticidal mechanisms of azadirachtin (growth regulation and antifeedant) and eugenol (neurotoxicity and repellency), which may produce synergistic effects. The use of Tween-80 as an emulsifier is consistent with the literature on botanical formulation, where surfactants are commonly added to improve the stability and spreading of plant extracts on leaf surfaces.

Research Question 3: What is the insecticidal efficacy of the formulations against target pests in the laboratory?

Table 4: Laboratory Insecticidal Efficacy of Formulations Against *S. litura* and *M. persicae*

Formulation	<i>S. litura</i> Mortality (%) at 72h	<i>M. persicae</i> Mortality (%) at 72h	LC ₅₀ (mg/mL) <i>S. litura</i>	LC ₅₀ (mg/mL) <i>M.</i> <i>persicae</i>
F1 (<i>A. indica</i> 5%)	82.4 (2.6)	88.6 (2.8)	1.24	0.86
F2 (<i>O. gratissimum</i> 5%)	76.8 (2.8)	82.4 (3.2)	1.86	1.42

Formulation	<i>S. litura</i> Mortality (%) at 72h	<i>M. persicae</i> Mortality (%) at 72h	LC ₅₀ (mg/mL) <i>S. litura</i>	LC ₅₀ (mg/mL) <i>M. persicae</i>
F3 (<i>A. indica</i> 5% + <i>O. gratissimum</i> 3%)	89.6 (2.4)	94.2 (2.2)	0.82	0.58
F4 (<i>A. indica</i> 5% + <i>P. nigrum</i> 3%)	84.2 (2.6)	88.8 (2.6)	1.06	0.78
F5 (<i>O. gratissimum</i> 5% + <i>P. nigrum</i> 3%)	80.6 (2.8)	86.4 (3.0)	1.42	1.12
Cypermethrin (control)	96.4 (1.8)	98.2 (1.6)	0.12	0.08

Table 5: Antifeedant and Repellent Activity of Best Formulation (F3)

Activity	<i>S. litura</i>	<i>M. persicae</i>
Antifeedant (% leaf area consumed vs. control)	68.4 (3.2)	72.6 (3.4)
Repellent (% repellency at 24h)	62.8 (3.6)	78.4 (3.2)

Table 4 presents the laboratory insecticidal efficacy of formulations. The combined *A. indica* + *O. gratissimum* formulation (F3) achieved the highest mortality against both *S. litura* (89.6%) and *M. persicae* (94.2%) at 72 hours, with the lowest LC₅₀ values (0.82 and 0.58 mg/mL, respectively). The *A. indica* formulation alone (F1) was the second most effective, achieving 82.4% and 88.6% mortality. The combined formulation showed greater efficacy than either single-extract formulation, indicating synergistic or additive effects. The LC₅₀ values for F3 (0.82 mg/mL against *S. litura* and 0.58 mg/mL against *M. persicae*) are comparable to those reported in the literature for botanical extracts against these pests (Nia et al., 2015). The synthetic control (cypermethrin) achieved higher mortality (96.4% and 98.2%) with lower LC₅₀ (0.12 and 0.08 mg/mL), confirming the higher potency of synthetic insecticides. However, the botanical formulations offer advantages in terms of safety and sustainability. Table 5 presents the antifeedant and repellent activity of the best formulation (F3). The formulation showed significant antifeedant activity, reducing leaf area consumed by 68.4% against *S. litura* and 72.6% against *M. persicae*, and repellent activity of 62.8% and 78.4%, respectively. These activities are consistent with the literature on botanical insecticides, which often combine multiple modes of action including toxicity, antifeedant and repellent effects.

Research Question 4: What is the performance of the formulations against target pests on demonstration farms?

Table 6: *Field Performance of Botanical Biopesticide on Demonstration Farm*

Parameter	Botanical Biopesticide (F3)	Synthetic Insecticide	Untreated Control
Pest population reduction (%)	78.4 (4.2)	84.6 (3.8)	0
Leaf damage reduction (%)	82.6 (3.8)	88.4 (3.2)	0
Fruit damage reduction (%)	76.8 (4.4)	84.2 (3.6)	0
Beneficial insect survival (%)	85.6 (3.2)	42.4 (4.8)	100
Yield (t/ha)	2.84 (0.18)	2.96 (0.16)	1.42 (0.12)
Yield increase over control (%)	100.0	108.5	0

Table 6 presents the field performance of the botanical biopesticide on the demonstration farm. The botanical formulation reduced pest populations by 78.4% compared to the untreated control, which was slightly lower than the synthetic insecticide (84.6%). Leaf damage reduction was 82.6% for the botanical formulation versus 88.4% for the synthetic, and fruit damage reduction was 76.8% versus 84.2%. The most significant difference was in beneficial insect survival: the botanical formulation preserved 85.6% of beneficial insects compared to only 42.4% for the synthetic insecticide. This is consistent with the literature on botanical biopesticides, which are generally less harmful to non-target organisms than broad-spectrum synthetic insecticides. Yield was comparable between the botanical formulation (2.84 t/ha) and the synthetic (2.96 t/ha), with both significantly higher than the untreated control (1.42 t/ha). The botanical formulation achieved 100% yield increase over the control, while the synthetic achieved 108.5%. These findings demonstrate that the botanical biopesticide can provide effective pest control and comparable yield to synthetic insecticides, while being safer for beneficial insects and the environment. The field results are consistent with the literature on botanical biopesticides, which has demonstrated effective pest control under field conditions in various crops (Seni et al., 2025).

Research Question 5: What validated botanical biopesticide formulations and recommendations can be established for sustainable pest management?

Table 7: *Expert Validation Results (N = 5 experts)*

Criterion	Mean (SD)	Interpretation
Efficacy (pest control performance)	3.80 (0.45)	Very high
Safety (low toxicity to humans and beneficials)	3.60 (0.55)	High
Sustainability (environmental benefits)	3.80 (0.45)	Very high

Criterion	Mean (SD)	Interpretation
Cost-effectiveness (relative to synthetics)	3.60 (0.55)	High
Feasibility (production and application)	3.60 (0.55)	High
Overall mean	3.68	High

Note. Four-point scale: 1 = Poor, 4 = Excellent.

Table 8: Replicable Production and Application Framework

Phase	Activities	Estimated Cost (₦)	Timeline
1. Plant Collection	Collect and dry plant materials	50,000	2 weeks
2. Extraction	Extract with ethanol using maceration or Soxhlet	120,000	2 weeks
3. Formulation	Mix extracts, add emulsifier, bottle	80,000	1 week
4. Quality Control	Test pH, stability, and efficacy	30,000	1 week
5. Application	Spray on crops at weekly intervals	50,000/season	Ongoing
Total Production Cost		330,000	
Cost per Litre		₦550	
Cost per Hectare per Season		₦33,000	

Table 7 presents the expert validation results. Experts rated the formulation highly across all criteria, with an overall mean of 3.68. Efficacy (3.80) and sustainability (3.80) received the highest ratings, confirming the effectiveness and environmental benefits of the botanical biopesticide. Safety (3.60), cost-effectiveness (3.60) and feasibility (3.60) were also highly rated. Table 8 presents the replicable production and application framework. The framework comprises five phases: (1) Plant Collection – collecting and drying plant materials; (2) Extraction – extracting with ethanol using maceration or Soxhlet; (3) Formulation – mixing extracts, adding emulsifier and bottling; (4) Quality Control – testing pH, stability and efficacy; and (5) Application – spraying on crops at weekly intervals. The total production cost per litre is ₦550, and the cost per hectare per season is ₦33,000. This compares favourably with synthetic insecticides, which cost approximately ₦45,000–60,000 per hectare per season, representing a cost saving of 26–45%. The validated formulation and implementation framework provide a practical, affordable and sustainable option for pest management on Nigerian polytechnic demonstration farms.

Discussion

The central finding of this study is the demonstration that a botanical biopesticide formulated from indigenous Nigerian plants (*A. indica* and *O. gratissimum*) can effectively control target pests on demonstration farms, achieving 78.4% pest population reduction and 100% yield increase over the untreated control, while preserving beneficial insects (85.6% survival) and providing cost savings of 26–45% compared to synthetic insecticides. These findings are consistent with the literature on botanical biopesticides, which has demonstrated effective pest control with plant-derived formulations in various crops (Ngegba et al., 2022; Seni et al., 2025). The identification of azadirachtin, eugenol, and piperine as major active compounds is consistent with the literature, which has documented these compounds as having significant insecticidal, antifeedant, and repellent activities. The synergistic effect observed with the combined *A. indica* + *O. gratissimum* formulation (F3) is consistent with the literature on botanical insecticides, which has demonstrated that combinations of plant extracts can produce greater activity than individual extracts due to complementary modes of action.

The laboratory bioassay results showed that the combined formulation achieved 89.6% mortality against *S. litura* and 94.2% against *M. persicae* at 72 hours, with LC_{50} values of 0.82 and 0.58 mg/mL, respectively. These values are comparable to those reported in the literature for botanical extracts against these pests. The antifeedant (68.4% and 72.6% reduction in leaf area consumed) and repellent (62.8% and 78.4% repellency) activities observed are consistent with the multi-modal action of botanical insecticides, which often combine toxicity with behavioural effects. The field evaluation showed that the botanical formulation reduced pest populations by 78.4% and leaf damage by 82.6%, with yield comparable to the synthetic insecticide (2.84 vs. 2.96 t/ha). These findings are consistent with the literature on botanical biopesticides, which has demonstrated effective pest control under field conditions with yields comparable to synthetic treatments. The most significant advantage of the botanical formulation was its preservation of beneficial insects (85.6% survival compared to 42.4% for the synthetic), which is consistent with the literature on the selectivity of botanical insecticides. The cost analysis showed that the botanical biopesticide costs ₦33,000 per hectare per season compared to ₦45,000–60,000 for synthetic insecticides, representing a cost saving of 26–45%. This cost advantage, combined with the safety and environmental benefits, makes the botanical biopesticide an attractive option for demonstration farms. The expert validation (overall mean 3.68) confirmed the efficacy, safety, sustainability, cost-effectiveness and feasibility of the formulation. The implementation framework developed in this study provides a practical roadmap for producing and applying the botanical biopesticide on demonstration farms. The five-phase framework, from plant collection to application, is designed to be adaptable to different farm contexts and resource levels. The emphasis on local production using indigenous plants ensures sustainability and reduces dependence on external inputs. Overall, the findings confirm that botanical biopesticides from indigenous plants offer an effective, low-cost and sustainable alternative to synthetic insecticides for pest management on Nigerian polytechnic demonstration farms.

Conclusion

This study characterised the phytochemistry of selected indigenous plants and developed and evaluated botanical biopesticides from them for sustainable pest management on demonstration farms of polytechnics in South-West Nigeria. Five indigenous plants were extracted and phytochemically characterised, with GC-MS identifying azadirachtin, eugenol, piperine, nicotine, and rotenone as major active compounds. The optimised formulation (5% *A. indica* + 3% *O. gratissimum*) achieved 89.6% mortality against *S. litura* and 94.2% against *M. persicae* in the laboratory, with LC_{50} values of 0.82 and 0.58 mg/mL, respectively. Field evaluation showed 78.4% pest population reduction, 82.6% leaf damage reduction, 85.6% beneficial insect survival, and yield comparable to synthetic insecticide (2.84 vs. 2.96 t/ha). The botanical biopesticide costs ₦33,000 per hectare per season, representing a cost saving of 26–45% compared to synthetic insecticides. The study provides a validated botanical biopesticide formulation and a replicable production and application framework. The principal implication is that botanical biopesticides from indigenous plants offer an effective, low-cost and sustainable alternative to synthetic insecticides for pest management on Nigerian polytechnic demonstration farms, and that the formulation and framework developed in this study provide the tools and guidance required to support wider adoption. Future research should extend this work in several directions: evaluating the formulation against a broader range of pests and crops; investigating the long-term stability and shelf-life of the formulation; assessing the economic viability at commercial scale; conducting multi-season field trials to evaluate consistent performance; and exploring the potential for commercialisation and enterprise development.

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Conflict of Interest

The authors declare that there are no competing financial interests or personal relationships that could have influenced the work reported in this study.

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