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Assessing the Efficacy of Formulated Organic Biopesticide in Managing Insect Pests in Okra (*Abelmoschus esculentus* L. Moench)

[1]Edet, Iwebaffa Amos, [2]Onyeanusi Hilary Chukwuemeka,
[3]Akinbode Oluwafolake Adenike and [1]Afolabi, Clement Gboyega
[1]Department of Crop Protection, Federal University of Agriculture, Abeokuta, Nigeria
[2]National Horticultural Research Institute, Idi-Ishin Jericho Ibadan, Nigeria
[3]Institute of Agricultural Research and Training, Obafemi Awolowo University, Ibadan, Nigeria

ABSTRACT

Background and Objective: Okra insect pests cause significant yield losses, estimated at 60%, historically managed with synthetic insecticides. However, the health risks associated with these chemicals have led to many being banned, necessitating the development of eco-friendly alternatives. This study evaluated a novel organic biopesticide (neem extract 5.2%, wood ash 8.8% and clove powder 7.8%) for controlling okra pests during the early and late 2023 planting seasons. **Materials and Methods:** The experiment, conducted in a 3×5 factorial arrangement, tested three application rates (50, 100 and 200 mL/ha) and five spray frequencies (once-a-week [OAW], twice-a-week [TAW], once-every-2-weeks [O2W], once-every-3-weeks [O3W] and once-every-4-weeks [O4W]), alongside a control (no spray), using a randomized complete block design with three replicates. Data on insect pests, leaf and pod damage, plant growth and fruit yield were collected and analyzed using ANOVA. **Results:** The results showed significantly lower pest densities in treated plots compared to the control, with natural enemy populations remaining unaffected. Leaf damage was higher in the control plots, while fruit damage was significantly reduced in treatments with higher application rates and frequencies. The best growth parameters and highest cost-benefit ratios were observed in plots treated with 100 mL/ha applied O4W or O2W, making these the most effective and economical options. **Conclusion:** The study concludes that applying the biopesticide at 100 mL/ha either once-every-4-weeks or once-every-2-weeks effectively reduces pest infestation and fruit damage while being cost-efficient, thereby enhancing okra fruit yield. Hence further research should be carried out on other agro ecological vegetation.

KEYWORDS

Okra insect pests, biopesticide, neem extract, application rates, spray frequencies, pest densities, cost-benefit ratio

INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench), commonly known as lady's finger, is a vital herbaceous annual plant in the Malvaceae family. Initially classified under the genus *Hibiscus*, it was later reclassified into the genus *Abelmoschus*[1]. This crop originated in the tropical and subtropical regions of North-East Africa and

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Asia, with evidence suggesting its cultivation by ancient Egyptians as early as the 12th century BC[2]. From there, okra cultivation spread across the Middle East and North Africa[3]. Okra thrives in warm climates, particularly during the summer with irrigation or in the rainy season and it can be cultivated year-round in tropical, subtropical and temperate regions. The optimal temperature range for its growth, germination and fruiting is between 25 and 30°C and it grows best in well-drained soils with a pH range of 6.0 to 6.8[4]. In Nigeria, okra is produced in two distinct seasons: The early season, which yields larger quantities and the late season, with smaller yields[5]. Globally, okra is predominantly produced in countries such as India, Nigeria, Sudan, Pakistan, Ghana, Egypt, Saudi Arabia, Mexico, Benin and Cameroon, contributing to a total cultivated area of approximately 1,148 thousand hectares and producing around 7,896.3 thousand ton of okra annually. India leads global production, contributing 73.25%, followed by Nigeria at 12.5%[6]. In Africa, over 75% of okra production comes from the West and Central regions, although the average productivity in these areas (2.5 ton/ha) is lower than in East and North Africa (6.2 and 8.8 ton/ha, respectively)[7]. Nigeria is Africa's largest okra producer, with an annual production of approximately 2,039,500 ton, followed by Côte d'Ivoire, Ghana and others[7].

Economically, okra is significant in Nigeria, where it is a staple in many households and commands high market prices. A study by Amadi[8] on okra production among women in Anambra State, Nigeria, highlighted the economic viability of okra production, with benefit-cost ratios of 2.08 for the dry season and 2.34 for the rainy season. Okra production requires relatively low capital, provides quick cash returns and thrives in various soils, making it accessible to small-scale farmers. Additionally, vegetable production, including okra, is recognized as an affordable source of micronutrients and a potential driver of rural development and foreign exchange generation in Africa[9]. From 1970 to 2003, okra accounted for about 4.6% of Nigeria's total staple food production[10].

The entire okra plant is valuable. Its leaves and tender shoots are nutrient-rich and can be consumed, while the mature seeds contain about 21% edible oil. The fruit is a common ingredient in stews and soups due to its rich nutrient content, including dietary fiber, protein, carbohydrates, vitamins and minerals[11,12]. Okra mucilage has industrial and medicinal applications and the leaf buds and flowers are also edible[13]. In Nigeria and Ghana, okra is typically grown as part of mixed cropping systems, with higher yields achieved on well-drained, fertile soils with adequate organic matter[14]. However, insect pests pose a significant challenge to okra production. Among the most destructive pests are flea beetles, specifically *Podagrica uniforma* and *Podagrica sjostedti*, which can cause up to 84% damage during the dry season[15]. Additionally, okra is vulnerable to various sucking pests, such as aphids, leafhoppers, whiteflies and mites, as well as fruit borers like *Earias* spp. and *Helicoverpa armigera*, which can lead to substantial yield losses[16].

Okra mosaic virus (OMV), transmitted by *Podagrica* spp., further exacerbates the problem, contributing to significant yield reduction[17]. Despite its popularity, okra yields in Nigeria remain low, rarely exceeding 7 ton/ha[18]. Insect pests are a major limiting factor, contributing to annual crop losses of 5-40%, threatening food security and farmer livelihoods[19]. Overall, insect pest damage can result in up to a 48.97% loss in okra pod yield[19]. The extensive use of conventional insecticides, particularly organophosphates, has led to challenges such as pest resistance, secondary pest outbreaks, harmful pesticide residues and negative environmental and human health impacts. These issues have prompted researchers to explore plant-based insecticides as alternatives. Plant-based biopesticides offer the potential for effective pest control with lower toxicity to non-target organisms and the environment, making them a promising option for sustainable pest management[20]. The objective of the study was, therefore, to establish the minimal effective rate and frequency of application for a formulated biopesticide containing neem extract, wood ash and clove seed powder to control insect pest infestations in okra, to evaluate the effectiveness of the biopesticide in reducing insect pest damage and improving okra fruit yield, determine the impact of biopesticide application on the overall health and productivity of okra plants in comparison to conventional insecticide treatments and its general contribution to sustainable agricultural practices by providing alternative pest management.

MATERIALS AND METHODS

The study was conducted at the Teaching and Research Farms of the Institute of Agricultural Research and Training, Obafemi Awolowo University, Ibadan, Nigeria from early June, 2023 (rainy) and late November, 2023 (dry season). The farm is situated at a Latitude of 07°23'N, Longitude of 03°51'E and an Altitude of 650 m in the humid rainforest zone of Southwestern Nigeria. The region experiences a mean annual rainfall of 1220 mm, with a mean temperature of 26°C. The wet season lasts from April to September with heavy rainfall, while the dry season, from November to March, is characterized by high temperatures and abundant sunshine.

Experimental design: The experiment employed a 3×5 factorial arrangement in a Randomized Complete Block Design (RCBD) with three replicates. The factors included three application rates of a novel biopesticide (50, 100 and 200 mL/ha) and five spray frequencies:

- Once-a-week (OAW)
- Twice-a-week (TAW)
- Once-every-2-weeks (O2W)
- Once-every-3-weeks (O3W)
- Once-every-4-weeks (O4W)

A control plot, with no biopesticide application, was included for comparison. Each treatment was applied to plots measuring 4×3 m, with 1 m spacing between plots and 2 m spacing between blocks.

Biopesticide preparation: The biopesticide was formulated using neem extract (5.2%), wood ash (8.8%) and clove powder (7.8%). To prepare the biopesticide, 500 g of powdered clove seeds were soaked in 1000 L of water for 72 hrs to obtain a 90% (w/v) stock solution. The neem extract and wood ash were then mixed with the clove solution to achieve the desired concentrations.

Data collection: The data were collected weekly from ten randomly selected plants in each plot. Observations included:

- **Insect pest community:** Monitoring the presence and abundance of key pests such as *Podagrica uniforma*, *Podagrica sjostedti*, *Aphis gossypii*, *Amrasca biguttula*, *Mylabris pustulata* and *Dysdercus* spp.
- **Leaf and pod damage:** Assessment of damage caused by pests
- **Agronomic parameters:** Plant height, stem girth, number of flowers, number of fruits and fresh fruit yield

Statistical analysis: The collected data were subjected to Analysis of Variance (ANOVA) at a significance level of $\alpha = 0.05$. Significant treatment means were separated using the Student-Newman-Keuls (SNK) test ($p<0.05$). Additionally, a cost-benefit analysis was performed for each treatment to determine the most economically viable application rate and frequency.

RESULTS

Population densities of vegetative pests on okra in the early season of 2023: During the early season of 2023, various vegetative insect pests, including *Podagrica uniforma*, *Podagrica sjostedti*, *Aphis gossypii*, *Amrasca biguttula*, *Mylabris pustulata* and *Dysdercus* spp. were observed on okra plants. The population densities of these pests were significantly higher ($p<0.05$) in control plots compared to those treated with the biopesticide. Notably, *Podagrica uniforma* exhibited the highest population density in the control plots at 14.11 individuals, whereas the treated plots showed significantly reduced densities, particularly with a biopesticide application rate of 50 mL twice a week, which recorded only 0.05 individuals. *Podagrica sjostedti* also showed a marked reduction in population densities in treated plots. The control plots recorded a density of 12.43 individuals, whereas the lowest density in treated plots was observed at 50 mL once a week, with a density of 1.06 individuals. *Podagrica fuscicornis* followed a similar trend, with significantly lower densities in treated plots, with the lowest at 50 mL once in 4 weeks, recording 1.00 individuals.

Aphis gossypii populations were notably reduced in treated plots, with the control plots recording a density of 5.06 individuals, while the lowest was 1.00 individuals observed at 200 mL once in 2 weeks. *Bemisia tabaci* and *Amrasca biguttula* also showed significant reductions in population densities in treated plots, with *Bemisia tabaci* having a control density of 7.60 and a lowest treated density of 1.67 at 200 mL once a week. *Amrasca biguttula* had a control density of 1.92, with the lowest density of 0.07 observed at 200 mL once in 3 weeks (Table 1).

Population densities of vegetative pests on okra in the late season of 2023: In the late season of 2023, the vegetative pests observed included *Podagrica uniforma*, *Podagrica sjostedti*, *Aphis gossypii*, *Bemisia tabaci*, *Amrasca biguttula* and *Zonocerus* spp. The control plots consistently showed higher pest population densities compared to the treated plots. *Podagrica uniforma* recorded a density of 10.17 individuals in the control plots, while the lowest density in treated plots was 0.12 individuals at 50 mL once in 2 weeks. For *Podagrica sjostedti*, the control plots had a density of 2.80 individuals, whereas treated plots had significantly lower densities, with the lowest being 0.05 individuals at 200 mL twice a week. *Aphis gossypii* had a control density of 2.89 individuals, while the lowest density was 0.02 individuals at 200 mL twice a week. *Bemisia tabaci* had a control density of 1.23 individuals, with treated plots recording the lowest density of 0.05 individuals at 200 mL once a week. *Amrasca biguttula* recorded a control density of 2.82 individuals, with the lowest density in treated plots being 0.00 individuals at several treatment levels. *Zonocerus* spp. was observed with a density of 0.47 in control plots, with treated plots showing complete elimination (0.00) at multiple treatment frequencies (Table 2). The data indicate that the biopesticide significantly reduced the population densities of various vegetative pests on okra plants in both the early and late seasons of 2023. Higher application rates and more frequent treatments generally resulted in greater reductions in pest populations across all observed species.

Table 1: Population densities of okra pests varied by biopesticide rates and frequencies in early 2023

Rates (mL)	Frequencies	*Podagrica uniforma*	*Podagrica sjostedti*	*Podagrica fuscicornis*	*Aphis gossypii*	*Bemisia tabaci*	*Amrasca biguttula biguttulla*
0	Control	14.11[a]	12.43[a]	2.80[a]	5.06[a]	7.60[a]	1.92[a]
50	Once a week	0.20[d]	106.00[c]	1.12[b]	2.40[c]	2.80[ab]	0.70[b]
	Twice a week	0.05[d]	2.09[c]	1.11[b]	2.11[c]	2.05[b]	0.21[b]
	Once in 2 weeks	2.01[cde]	5.94[bc]	1.23[b]	2.07[c]	2.47[ab]	0.37[b]
	Once in 3 weeks	2.10[cde]	4.83[bc]	1.10[b]	2.13[c]	2.40[ab]	0.70[b]
	Once in 4 weeks	4.99[bc]	4.92[bc]	1.00[b]	2.63[b]	2.00[ab]	0.67[b]
100	Once a week	0.02[e]	2.90[c]	1.07[b]	1.27[c]	2.27[ab]	0.43[b]
	Twice a week	0.02[e]	2.50[c]	1.00[b]	2.00[c]	2.20[ab]	0.10[b]
	Once in 2 weeks	1.47[de]	6.10[bc]	1.07[b]	2.07[c]	1.80[ab]	0.33[b]
	Once in 3 weeks	4.01[bc]	4.48[bc]	1.06[b]	2.47[c]	2.47[ab]	0.33[b]
	Once in 4 weeks	7.40[b]	8.45[b]	1.20[b]	1.33[c]	2.47[ab]	0.37[b]
200	Once a week	0.03[d]	1.10[c]	1.10[b]	1.00[c]	1.67[ab]	0.10[b]
	Twice a week	0.50[d]	2.05[c]	1.00[b]	2.00[c]	2.07[ab]	0.20[b]
	Once in 2 weeks	0.35[d]	4.30[c]	1.20[b]	1.00[c]	0.67[ab]	0.13[b]
	Once in 3 weeks	1.72[de]	2.07[c]	1.07[b]	1.07[c]	2.07[a]	0.07[b]
	Once in 4 weeks	4.43[bc]	2.53[bc]	0.00[b]	1.00[c]	1.60[ab]	0.13[b]

Mean values along the column followed by the same alphabets are not significantly different using Student Newman Keuls test (p>0.05)

Table 2: Late-season pest populations on okra varied with biopesticide rates and application frequencies in 2023

Rates (mL)	Frequencies	*Podagrica uniforma*	*Podagrica sjostedti*	*Aphis gossypii*	*Bemisia tabaci*	*Amrasca biguttula biguttulla*	*Zonocerus* spp.
0	Control	10.17[a]	2.80[a]	2.89[a]	1.23[a]	2.82[a]	0.47[a]
50	Once a week	0.20[b]	0.10[b]	0.04[b]	0.15[b]	0.00[b]	0.00[b]
	Twice a week	0.50[b]	0.17[b]	0.60[b]	0.17[b]	0.00[b]	0.00[b]
	Once in 2 weeks	0.12[b]	0.58[b]	0.37[b]	0.43[b]	0.02[b]	0.02[b]
	Once in 3 weeks	0.52[b]	0.33[b]	0.40[b]	0.30[b]	0.07[b]	0.00[b]
	Once in 4 weeks	0.32[b]	0.75[b]	0.52[b]	0.18[b]	0.02[b]	0.00[b]
100	Once a week	0.67[b]	0.82[b]	0.53[b]	0.67[b]	0.00[b]	0.00[b]
	Twice a week	0.30[b]	0.45[b]	0.15[b]	0.12[b]	0.00[b]	0.00[b]
	Once in 2 weeks	0.47[b]	0.23[b]	0.22[b]	0.47[b]	0.08[b]	0.03[b]
	Once in 3 weeks	0.27[b]	0.23[b]	0.38[b]	0.22[b]	0.02[b]	0.00[b]
	Once in 4 weeks	0.62[b]	0.07[a]	0.18[b]	0.38[b]	0.03[b]	0.00[b]
200	Once a week	0.17[b]	0.08[a]	0.19[b]	0.05[b]	0.00[b]	0.02[b]
	Twice a week	0.31[b]	0.05[a]	0.02[a]	0.15[b]	0.00[b]	0.00[b]
	Once in 2 weeks	0.41[b]	0.13[a]	0.13[a]	0.63[b]	0.02[b]	0.00[b]
	Once in 3 weeks	0.25[b]	0.30[a]	0.10[a]	0.40[b]	0.00[b]	0.00[b]
	Once in 4 weeks	0.23[b]	0.22[a]	0.03[a]	0.65[b]	0.05[b]	0.04[b]

Mean values along the column followed by the same alphabets are not significantly different using Student Newman Keuls test ($p>0.05$)

Table 3: Flower and fruit pest densities on okra varied with biopesticide rates and frequencies in late 2023

Rates (mL)	Frequencies	*Mylabris pustulatus*	*Dysdercus* spp.
0	Control	0.43[a]	9.73[a]
50	Once a week	0.00[b]	0.00[b]
	Twice a week	0.00[b]	0.00[b]
	Once in 2 weeks	0.00[b]	0.00[b]
	Once in 3 weeks	0.00[b]	0.00[b]
	Once in 4 weeks	0.02[a]	9.67[a]
100	Once a week	0.00[b]	0.00[b]
	Twice a week	0.00[b]	0.00[b]
	Once in 2 weeks	0.00[b]	0.00[b]
	Once in 3 weeks	0.03[a]	0.00[b]
	Once in 4 weeks	0.08[a]	8.56[a]
200	Once a week	0.00[b]	0.00[b]
	Twice a week	0.00[b]	0.00[b]
	Once in 2 weeks	0.00[b]	0.00[b]
	Once in 3 weeks	0.05[a]	0.00[b]
	Once in 4 weeks	0.09[a]	9.46[a]

Mean values along the column followed by the same alphabets are not significantly different using Student Newman Keuls test ($p>0.05$)

Population densities of flower and fruit pests recorded on okra in the late season, 2023: During the late season of 2023, two key pests, *Mylabris pustulatus* and *Dysdercus* species, were recorded on okra plants. *Mylabris pustulatus* was observed primarily during the early flowering stage (35 days after planting), while *Dysdercus* species appeared later in the fruiting stage. The highest number of *Mylabris pustulatus* was recorded in the control plots, with an average density of 0.43. However, this was not significantly different ($p>0.05$) from the densities recorded in plots treated with biopesticide at rates of 50 mL once every 4 weeks (0.02), 100 mL once every 3 weeks (0.03), 100 mL once every 4 weeks (0.08), 200 mL once every 3 weeks (0.05) and 200 mL once every 4 weeks (0.09). Notably, no *Mylabris pustulatus* were observed in plots that received biopesticide treatments at any rate when applied once a week, twice a week or once every 2 weeks.

For *Dysdercus* species, significant populations were only recorded in the control plots (9.73) and plots treated with biopesticide at 50 mL once every 4 weeks (9.67), 100 mL once every 4 weeks (8.56) and 200 mL once every 4 weeks (9.46). These numbers were not significantly different ($p>0.05$) from the control, indicating that *Dysdercus* populations were not effectively controlled by these treatment regimens (Table 3).

Table 4: Natural enemy populations on okra varied by biopesticide rates and frequencies in 2023

		Early season		Late season		
Rates (mL)	Frequencies	*Dictynia* spp.	*Camponotus* spp.	*Dictynia* spp.	*Camponotus* spp.	*Coccinella* spp.
0	Control	0.13[a]	16.00[a]	0.07[a]	5.80[a]	1.00[a]
50	Once a week	0.07[a]	0.47[b]	0.00[a]	0.13[b]	0.00[a]
	Twice a week	0.00[a]	1.40[b]	0.00[a]	0.47[b]	0.00[a]
	Once in 2 weeks	0.00[a]	2.27[b]	0.02[a]	1.20[b]	0.07[a]
	Once in 3 weeks	0.00[a]	0.93[b]	0.00[a]	0.60[b]	0.00[a]
	Once in 4 weeks	0.00[a]	2.60[b]	0.13[a]	2.27[b]	0.13[a]
100	Once a week	0.07[a]	0.60[b]	0.00[a]	0.27[b]	0.00[a]
	Twice a week	0.00[a]	0.00[b]	0.00[a]	0.07[b]	0.00[a]
	Once in 2 weeks	0.07[a]	2.33[b]	0.00[a]	1.13[b]	0.13[a]
	Once in 3 weeks	0.00[a]	0.67[b]	0.07[a]	1.00[b]	0.00[a]
	Once in 4 weeks	0.00[a]	1.60[b]	0.00[a]	2.47[b]	0.00[a]
200	Once a week	0.00[a]	0.27[b]	0.00[a]	0.27[b]	0.00[a]
	Twice a week	0.00[a]	0.07[b]	0.00[a]	0.13[b]	0.07[a]
	Once in 2 weeks	0.00[a]	2.40[b]	0.00[a]	1.40[b]	0.07[a]
	Once in 3 weeks	0.00[a]	0.20[b]	0.00[a]	1.33[b]	1.00[a]
	Once in 4 weeks	0.00[a]	0.67[b]	0.00[a]	1.67[b]	0.13[a]

Mean values along the column followed by the same alphabets are not significantly different using Student Newman Keuls test (p>0.05)

Population densities of natural enemies recorded on okra in the early and late seasons, 2023: In both the early and late seasons of 2023, the natural enemies observed in the study included *Dictynia*, *Camponotus* and *Coccinella* species (Table 4). In the early season, *Dictynia* and *Camponotus* species were recorded, while in the late season, *Dictynia*, *Camponotus* and *Coccinella* species were noted for the early season, the population of *Dictynia* species was similar across all treatment plots and the control, with no significant differences observed (p>0.05). The number of *Camponotus* species, however, was significantly higher in the control plots (16.00) compared to the treated plots, where numbers ranged from 0.00 to 2.60, depending on the treatment and in the late season, the population of *Dictynia* species remained low and similar across all plots, with no significant differences (p>0.05) between treatments and control. *Camponotus* species again showed a significantly higher population in the control plots (5.80) compared to the treated plots, where numbers ranged from 0.07 to 2.47. *Coccinella* species were present in the late season but in low numbers, with no significant differences across treatments (Table 4).

Damage by *Podagrica* species and other insect pests on okra in the early and late seasons, 2023: In the early season of 2023, the percentage of leaf area damaged by *Podagrica* species was significantly higher in the control plots (23.49%). However, the percentage of leaf area damaged by other insect pests in the control plots (41.70%) was not significantly different (p>0.05) from the damage recorded in plots treated with 50 mL once every 3 weeks (27.07%), 50 mL once every 4 weeks (28.44%), 100 mL once every 3 weeks (17.04%), 100 mL once every 4 weeks (15.41%), 200 mL once every 3 weeks (12.11%) and 200 mL once every 4 weeks (34.88%) (Table 5). In the late season of 2023, the overall percentage of leaf damage by vegetative insect pests was significantly higher in the control plots (97.78%), but this was not significantly different (p>0.05) from the damage observed in plots treated with 100 mL once every 2 weeks, 200 mL once every 2 weeks, 50 mL once every 3 weeks, 100 mL once every 3 weeks, 200 mL once every 3 weeks, 50 mL once every 4 weeks, 100 mL once every 4 weeks and 200 mL once every 4 weeks. Specifically, the percentage of leaf area damage by *Podagrica* species was significantly higher in the control plots (31.77%) compared to the treated plots. Similarly, damage by other insect pests was also significantly higher in the control plots (56.15%) than in the treated plots (Table 6). The total percentage of insect-induced leaf area damage recorded in the control plots was 65.20% during the early season and 87.92% during the late season.

Table 5: Leaf damage by insect pests of okra sprayed at different rates and frequencies of biopesticide in early season, 2024

Rates (mL)	Frequencies	Damage leaf (%)	DLA by *Podagrica* species (cm^2)	DLA by *Podagrica* species (%)	DLA by other insect pests (cm^2)	DLA by other insect pests (%)
0	Control	100.00^{a}	9.97^{a}	23.50^{a}	17.53^{a}	41.70^{a}
50	Once a week	17.00^{efg}	0.70^{f}	1.04^{c}	1.19^{c}	1.74^{b}
	Twice a week	6.59^{fg}	0.21^{f}	0.28^{c}	0.37^{c}	0.87^{b}
	Once in 2 weeks	42.91^{cd}	1.26^{de}	1.99^{bc}	2.61^{bc}	5.04^{b}
	Once in 3 weeks	45.85^{cd}	2.48^{c}	6.94^{bc}	10.41^{abc}	27.07^{ab}
	Once in 4 weeks	71.45^{b}	3.44^{b}	7.95^{b}	14.17^{ab}	28.44^{ab}
100	Once a week	6.77^{fg}	0.17^{f}	0.14^{c}	0.39^{c}	0.31^{b}
	Twice a week	1.83^{g}	0.08^{f}	0.03^{c}	0.00^{c}	0.00^{b}
	Once in 2 weeks	21.93^{defg}	1.19^{de}	1.98^{bc}	2.11^{bc}	3.43^{b}
	Once in 3 weeks	23.17^{cdefg}	1.97^{cd}	4.84^{bc}	7.55^{abc}	17.04^{ab}
	Once in 4 weeks	39.14^{cde}	2.59^{c}	3.91^{bc}	9.74^{abc}	15.41^{ab}
200	Once a week	6.23^{fg}	0.20^{f}	0.10^{c}	0.61^{c}	0.29^{b}
	Twice a week	1.21^{g}	0.07^{f}	0.04^{c}	0.07^{c}	0.03^{b}
	Once in 2 weeks	25.19^{cdefg}	1.95^{cd}	2.76^{bc}	2.56^{bc}	3.47^{b}
	Once in 3 weeks	30.56^{cdef}	2.19^{c}	3.19^{bc}	7.66^{abc}	12.11^{ab}
	Once in 4 weeks	48.17^{c}	2.74^{c}	6.45^{bc}	12.52^{abc}	34.88^{ab}

Mean values along the column followed by the same alphabets are not significantly different using Student Newman Keuls test (p>0.05) and DLA: Damage leaf area

Table 6: Leaf damage by insect pests of okra sprayed at different rates and frequencies of biopesticide in late season, 2024

Rates (mL)	Frequencies	Damaged leaf (%)	DLA by *Podagrica* species (cm^2)	DLA by *Podagrica* species (%)	DLA by other insect pests (cm^2)	DLA by other insect pests (%)
0	Control	97.78^{a}	2.70^{a}	31.77^{a}	9.10^{a}	56.15^{a}
50	Once a week	14.60^{c}	0.24^{b}	0.82^{b}	0.16^{a}	0.51^{b}
	Twice a week	16.63^{c}	0.08^{b}	0.17^{b}	0.13^{a}	0.24^{b}
	Once in 2 weeks	40.16^{bc}	0.53^{b}	0.95^{b}	2.95^{a}	3.31^{b}
	Once in 3 weeks	56.62^{ab}	1.25^{ab}	5.78^{b}	5.54^{a}	10.26^{b}
	Once in 4 weeks	77.19^{ab}	1.30^{ab}	10.27^{b}	1.37^{a}	6.27^{b}
100	Once a week	0.00^{c}	0.00^{b}	0.00^{b}	0.00^{a}	0.00^{b}
	Twice a week	0.00^{c}	0.00^{b}	0.00^{b}	0.00^{a}	0.00^{b}
	Once in 2 weeks	60.13^{ab}	1.27^{ab}	3.75^{b}	1.65^{a}	2.02^{b}
	Once in 3 weeks	79.80^{a}	1.21^{ab}	4.51^{b}	4.40^{a}	7.38^{b}
	Once in 4 weeks	92.27^{a}	1.00^{b}	7.09^{b}	5.12^{a}	20.57^{b}
200	Once a week	0.00^{c}	0.07^{b}	0.20^{b}	0.00^{a}	0.00^{b}
	Twice a week	0.00^{c}	0.00^{b}	0.00^{b}	0.00^{a}	0.00^{b}
	Once in 2 weeks	60.94^{ab}	0.87^{b}	2.22^{b}	2.80^{a}	3.05^{b}
	Once in 3 weeks	93.33^{a}	0.80^{b}	3.83^{b}	7.77^{a}	11.23^{b}
	Once in 4 weeks	96.30^{a}	1.77^{ab}	5.50^{b}	5.37^{a}	6.18^{b}

Mean values along the column followed by the same alphabets are not significantly different using Student Newman Keuls test (p>0.05) and DLA: Damage leaf area

Growth characteristics of okra in the early and late seasons, 2023: The early season of 2023, the number of leaves produced per plant was significantly higher (p<0.05) in plots treated with 100 mL once a week, 200 mL once a week, 100 mL twice a week and 200 mL twice a week. The height of okra plants was significantly higher in plots treated with 100 mL twice a week (28.86 cm) but was not significantly different (p>0.05) from those treated with 50 mL twice a week (23.77 cm), 200 mL once a week (28.81 cm) and 200 mL twice a week (23.44 cm). The mean stem girths were significantly higher (p<0.05) in plots treated with 100 mL twice a week (9.19 mm) and 200 mL once a week (7.56 mm). Furthermore, the number of flowers produced in plots treated with 100 mL twice a week (35.00) did not differ significantly (p>0.05) from those treated with 100 mL once a week (20.60), 100 mL once every two weeks (23.00) and 200 mL once a week (26.00).

Growth characteristics of okra in the early and late seasons, 2023

Early season 2023: The early season of 2023, significant differences (p<0.05) in growth characteristics of okra were observed among the treatments. The number of leaves produced per plant was significantly higher in plots treated with 100 mL twice a week (12.00), which was 200% higher than the

Table 7: Okra growth characteristics varied with different biopesticide rates and frequencies in early 2023

Rates (mL)	Frequencies	Number of leaves produced	IOC (%)	Height (cm)	IOC (%)	Stem girth (mm)	IOC (%)	Number of flowers produced	IOC (%)	Number of fruits produced	IOC (%)
0	Control	4.00^{d}	-	12.02^{e}	-	2.69^{d}	-	7.00^{b}	-	4.00^{e}	-
50	Once a week	6.40^{cd}	60.00	17.57^{bcde}	46.17	5.17^{bcd}	92.19	14.00^{b}	100.00	12.00^{bcde}	200.00
	Twice a week	7.80^{bcd}	95.00	23.77^{ab}	97.75	5.95^{bcd}	121.19	22.60^{ab}	222.86	16.40^{bcd}	310.00
	Once in 2 weeks	5.80^{cd}	45.00	17.83^{bcde}	48.34	5.40^{bcd}	100.74	15.60^{b}	122.86	11.40^{bcde}	185.00
	Once in 3 weeks	4.20^{d}	5.00	15.94^{cde}	32.61	4.27^{bcd}	58.74	7.40^{b}	5.71	4.20^{de}	5.00
	Once in 4 weeks	4.20^{d}	5.00	13.73^{de}	14.23	3.97^{cd}	47.58	7.00^{b}	0.00	2.80^{e}	-30.00
100	Once a week	8.40^{abcd}	110.00	21.51^{bcd}	78.95	6.29^{bc}	133.83	20.60^{ab}	194.29	15.00^{bcde}	275.00
	Twice a week	12.00^{a}	200.00	28.86^{a}	140.10	9.19^{a}	241.64	35.00^{a}	400.00	30.20^{a}	655.00
	Once in 2 weeks	6.60^{cd}	65.00	20.71^{bcd}	72.30	5.20^{bcd}	93.31	23.00^{ab}	228.57	14.20^{bcde}	255.00
	Once in 3 weeks	6.20^{cd}	55.00	16.15^{cde}	34.36	5.39^{bcd}	100.37	14.20^{b}	102.86	8.00^{de}	100.00
	Once in 4 weeks	6.00^{cd}	50.00	14.74^{de}	22.63	4.59^{bcd}	70.63	15.20^{b}	117.14	6.20^{de}	55.00
200	Once a week	9.80^{abc}	145.00	28.81^{a}	139.68	7.56^{ab}	181.04	26.00^{ab}	271.43	22.00^{b}	450.00
	Twice a week	10.80^{ab}	170.00	23.44^{abc}	95.01	6.38^{bc}	137.17	22.20^{ab}	217.14	19.40^{bc}	385.00
	Once in 2 weeks	6.40^{cd}	60.00	18.55^{bcde}	54.33	4.67^{bcd}	73.61	18.60^{b}	165.71	8.60^{cde}	115.00
	Once in 3 weeks	5.80^{cd}	45.00	15.81^{cde}	31.53	5.09^{bcd}	89.22	22.00^{ab}	214.29	10.00^{bcde}	150.00
	Once in 4wks	5.20^{d}	30.00	14.02^{de}	16.56	4.19^{cd}	55.76	8.60^{b}	22.86	3.40^{de}	-15.00

Mean values along the column followed by the same alphabets are not significantly different using Student Newman Keuls test (p>0.05) and IOC: Increment over control

control plots (4.00). Okra height was also significantly higher in the same treatment (28.86 cm), showing a 140.10% increase over the control (12.02 cm). The stem girth was notably larger in the 100-TAW treatment (9.19 mm), representing a 241.64% increase over the control (2.69 mm). The number of flowers produced per plant was highest in the 100-TAW plots (35.00), with a 400% increase compared to the control (7.00). Similarly, the number of fruits produced was significantly higher in the 100-TAW plots (30.20), a 655% increase over the control (4.00). The 200-OAW treatment also recorded a high number of fruits (22.00), which was 450% more than the control but significantly lower than the 100-TAW treatment (Table 7).

Late season 2023: In the late season of 2023, the number of leaves per plant was significantly lower in the control plots (4.60) compared to the treated plots. However, no significant difference in leaf number was observed among the treated plots. The highest stem girth was recorded in plots treated with 200-TAW (11.80 mm), which was statistically similar ($p>0.05$) to plots treated with 50-TAW (10.76 mm), 100-OAW (8.67 mm), 100-TAW (11.74 mm) and 200-OAW (10.22 mm). The number of flowers produced per plant was significantly higher in the 100-TAW plots (19.00), showing a 533.33% increase over the control (3.00). The number of fruits per plant was also significantly higher in the 100-TAW treatment (19.00), representing a 763.64% increase compared to the control (2.20) (Table 8).

Fruit damage and fresh fruit yield of okra in early season 2023

Early season 2023: In the early season of 2023, the impact of biopesticide treatments on fruit damage and fresh fruit yield of okra varied significantly. Control plots had the highest fruit damage at 90.00%, resulting in the lowest fresh fruit yield of 0.04 ton/ha. Among the treatments, plots sprayed with biopesticides at 100 mL twice a week exhibited the lowest fruit damage (0.76%) and the highest fresh fruit yield (2.02 ton/ha), which was 50 times higher than the control. The 200 mL twice a week treatment also resulted in relatively low fruit damage (1.11%) and a substantial yield (1.18 ton/ha). In contrast, the control had minimal yield (0.04 ton/ha), with other treatments like 50 mL once a week and 100 mL once a week showing yields ranging from 0.63 to 0.79 ton/ha (Table 9).

Late season 2023: In the late season, the pattern of fruit damage and yield was consistent with the early season results. The control plots again exhibited the highest fruit damage and the lowest yield. Plots treated with 100 mL twice a week maintained the highest yield of 0.85 ton/ha, significantly outperforming the control (0.04 ton/ha). The 200 mL treatments also demonstrated effective control with yields of 0.71 and 1.18 ton/ha, depending on the frequency of application (Table 9).

Table 8: Growth characteristics (per plant) of okra sprayed at different rates and frequencies of Biopesticide in the late season, 2023

Rates (mL)	Frequencies	Number of leaves produced	IOC (%)	Height (cm)	IOC (%)	Stem girth (mm)	IOC (%)	Number of flowers produced	IOC (%)	Number of fruits produced	IOC (%)
0	Control	4.60^{b}	-	7.07^{c}	-	4.39^{c}	-	3.00^{c}	-	2.20^{e}	-
50	Once a week	10.00^{a}	117.39	14.22^{abc}	101.13	7.18^{bc}	63.55	6.40^{bc}	113.33	4.60^{cde}	109.09
	Twice a week	12.40^{a}	169.57	17.95^{abc}	153.89	10.76^{ab}	145.10	8.60^{bc}	186.67	8.00^{bcd}	263.64
	Once in 2 weeks	10.40^{a}	126.09	12.19^{abc}	72.42	6.25^{c}	42.37	7.00^{bc}	133.33	7.00^{bcde}	218.18
	Once in 3 weeks	11.00^{a}	139.13	12.03^{abc}	70.16	5.03^{c}	14.58	3.20c	6.67	2.20^{e}	0.00
	Once in 4 weeks	14.60^{a}	217.39	9.30^{bc}	31.54	4.82^{c}	9.79	5.00^{bc}	66.67	3.20^{de}	45.45
100	Once a week	13.00^{a}	182.62	15.80^{abc}	123.48	8.67^{abc}	97.49	8.40^{bc}	180.00	8.20^{bcd}	272.73
	Twice a week	11.20^{a}	143.48	24.06^{ab}	240.31	11.74^{a}	167.43	19.00^{a}	533.33	19.00^{a}	763.64
	Once in 2 weeks	12.00^{a}	160.87	13.92^{abc}	96.89	6.53^{c}	48.75	6.60^{bc}	120.00	6.60^{bcde}	200.00
	Once in 3 weeks	14.00^{a}	204.35	14.44^{abc}	104.24	5.51^{c}	25.51	5.60^{bc}	86.67	4.20^{cde}	90.91
	Once in 4 weeks	14.40^{a}	213.04	11.98^{abc}	69.45	4.91^{c}	11.85	6.60^{bc}	120.00	5.60^{bcde}	154.55
200	Once a week	11.00^{a}	139.13	18.53^{abc}	162.09	10.22^{ab}	132.80	8.60^{bc}	186.67	8.60^{bc}	290.91
	Twice a week	12.00^{a}	160.87	25.57^{a}	261.67	11.80^{a}	168.79	10.00^{b}	233.33	10.00^{b}	354.55
	Once in 2 weeks	10.40^{a}	126.09	14.35^{abc}	102.97	5.94^{c}	35.31	7.4^{bc}	146.67	6.00^{bcde}	172.73
	Once in 3 weeks	10.60^{a}	130.43	12.14^{abc}	71.71	5.06^{c}	15.26	4.00^{c}	33.33	4.00^{cde}	81.82
	Once in 4 weeks	10.00^{a}	117.39	10.07^{bc}	42.43	5.25^{c}	19.59	3.60^{c}	20.00	3.20^{de}	45.45

Mean values along the column followed by the same alphabets are not significantly different using Student Newman Keuls test (p>0.05) and IOC: Increment over control

Table 9: Fruit damage and fresh fruit yield of okra sprayed at different rates and frequencies of biopesticide in early season, 2023

Rates (mL)	Frequencies	Fruit damage (%)	Yield per plant (g)	Yield per hectare (ton)
0	Control	90.00^{a}	1.02^{c}	0.04^{c}
50	Once a week	11.94^{e}	15.73^{ab}	0.63^{ab}
	Twice a week	4.78^{e}	25.09^{ab}	1.00^{ab}
	Once in 2 weeks	22.49^{de}	8.44^{ab}	0.34^{ab}
	Once in 3 weeks	47.62^{c}	4.42^{ab}	0.18^{ab}
	Once in 4 weeks	68.52^{b}	2.50^{b}	0.10^{b}
100	Once a week	8.34^{e}	18.98^{a}	0.79^{ab}
	Twice a week	0.76^{e}	50.47^{a}	2.02^{a}
	Once in 2 weeks	10.05^{e}	21.65^{ab}	0.87^{ab}
	Once in 3 weeks	32.85^{cd}	6.77^{ab}	0.27^{ab}
	Once in 4 weeks	45.60^{c}	24.93^{ab}	0.99^{ab}
200	Once a week	9.23^{e}	41.24^{ab}	1.65^{ab}
	Twice a week	1.11^{e}	29.54^{ab}	1.18^{ab}
	Once in 2 weeks	14.14^{e}	19.97^{ab}	0.80^{ab}
	Once in 3 weeks	33.70^{cd}	15.14^{ab}	0.61^{ab}
	Once in 4 weeks	40.28^{cd}	17.85^{ab}	0.71^{ab}

Mean values along the column followed by the same alphabets are not significantly different using Student Newman Keuls test (p>0.05)

Relationship between insect pest densities, damage induced and yield parameters

Early season 2023: In the early season of 2023, there were strong relationships between insect pest densities, the extent of damage they induced and key yield parameters in crops. Leaf damage percentage showed a significant positive correlation with the total number of insect pests (r = 0.74) and specific pests like *Podagrica* spp. (r = 0.94) and *Aphis gossypii* (r = 0.91), This implied that high densities of these pests were closely associated with increased leaf damage. Conversely, leaf damage percentage was negatively correlated with the number of leaves per plant (r = -0.71), the number of fruits per plant (r = -0.73) and yield per plant (r = -0.70), which showed that increased pest damage significantly impaired plant growth and productivity. The damage caused specifically by *Podagrica* spp. also showed negative correlations with the number of leaves per plant (r = -0.54) and yield per plant (r = -0.74). Similarly, damage by other insects exhibited negative relationships with the number of leaves (r = -0.65) and yield (r = -0.52). Each pest group contributed variably to reduced yield parameters, with *Podagrica* species and *Aphis gossypii* having the most significant adverse impacts on plant health and productivity (Table 10).

Table 10: Relationship between insect pest densities, damage induced and yield parameters in early season, 2023

Parameter	Number of leaf/plant	Number of fruit per plant	Yield per plant (g)	Leaf damage (%)
Leaf damage (%)	-0.71	-0.73	-0.70	-
Damage leaf by *Podagrica* spp. (%)	-0.54	-0.13	-0.74	-
Damage leaf by other insects (%)	-0.65	-0.48	-0.52	-
Total number of insect pests	-0.41	-0.39	-0.57	0.74
Podagrica uniforma	-0.42	-0.41	-0.59	0.94
Podagrica sjostedti	-0.42	-0.38	-0.58	0.92
Podagrica fuscicornis	-0.27	-0.21	-0.54	0.80
Aphis gossypii	-0.36	-0.32	-0.58	0.91
Bemisia tabaci	-0.43	-0.43	-0.43	0.69
Amrasca biguttulla biguttulla	-0.41	-0.37	-0.47	0.75

Table 11: Relationship between insect pest densities, damage induced and yield parameters in late season, 2023

Parameter	Number of leaf /plant	Number of fruit per plant	Yield per plant (g)	Leaf damage (%)
Leaf damage (%)	-0.24	-0.50	-0.60	-
Damage leaf by *Podagrica* spp. (%)	-0.46	-0.59	-0.42	-
Damage leaf by other insects (%)	-0.75	-0.54	-0.37	-
Total number of insect pests	-0.68	-0.82	-0.56	0.49
Podagrica uniforma	-0.66	-0.33	-0.41	0.44
Podagrica sjostedti	-0.72	-0.43	-0.68	0.52
Aphis gossypii	-0.87	-0.21	-0.45	0.40
Bemisia tabaci	-0.34	-0.60	-0.48	0.41
Amrasca biguttulla biguttulla	-0.86	-0.39	-0.31	0.25
Zonocerus spp.	-0.89	-0.39	-0.34	0.56
Mylabris pustulatus	-0.81	-0.47	-0.37	0.62
Dysdercus spp.	-0.24	-0.52	-0.37	0.74

Late season 2023: The late season of 2023, the, correlations between insect pest densities and yield parameters remained evident but with variations in strength. Leaf damage percentage showed a moderate negative correlation with the number of leaves per plant (r = -0.24), number of fruits per plant (r = -0.50) and yield per plant (r = -0.60). The total number of insect pests exhibited a strong negative effect on the number of fruits per plant (r = -0.82) and leaves (r = -0.68), which indicated that high pest densities critically hindered plant growth and overall productivity. Analysis of the specific pests revealed that *Podagrica sjostedti* had a significant negative impact on the number of leaves (r = -0.72) and yield per plant (r = -0.68). *Aphis gossypii* showed a very strong negative effect on the number of leaves (r = -0.87), this highlighted its substantial role in overall plant damage. Additional pests, such as *Zonocerus* spp. (r = -0.89 for leaf number) and *Mylabris pustulatus* (r = -0.81 for leaf number), also displayed pronounced negative impacts on plant structure and yields (Table 11).

DISCUSSION

This study documented a variety of insect pests affecting okra, including *Podagrica uniforma*, *Podagrica sjostedti*, *Podagrica fuscicornis*, *Aphis gossypii*, *Bemisia tabaci*, *Zonocerus* spp., *Amrasca biguttula*, *Dysdercus* spp. and *Mylabris pustulatus*. In the early 2023 season, the pest species recorded were *P. uniforma*, *P. sjostedti*, *P. fuscicornis*, *A. gossypii*, *B. tabaci* and *A. biguttula*. By the late season, the pest list expanded to include *Zonocerus* spp., *Dysdercus* spp. and *Mylabris pustulatus*. These study underscored the detrimental effects of insect pest infestations on plant growth and yield, thus, this study has highlighted the critical need for effective pest management strategies, to mitigate pest-related damage that is essential to safeguard okra crop productivity and to enhance sustainable agricultural outcome as the findings were consistent with previous research that reported that aphids, leafhoppers, grasshoppers, whiteflies, mites and flea beetles are common okra pests in forest zones[22].

The identification of *P. fuscicornis* in the early 2023 season is noteworthy as it diverges from earlier reports that *P. uniforma* and *P. sjostedti* were the primary flea beetles found on okra in West Africa[23]. While *P. fuscicornis* has previously been recorded on cowpea in Northern Nigeria[24], its presence on okra in Nigeria is a new observation. This addition to the pest community might be attributed to ecological changes influenced by climate change[24]. Despite its low occurrence of 1.51% in the early season, the absence of *P. fuscicornis* in the late season could be due to interspecific competition among flea beetles, a dynamic documented in other pest interactions[25]. The biopesticide treatments tested-50-OAW, 100-OAW, 200-OAW, 50-TAW, 100-TAW and 200-TAW-demonstrated effective control of *P. uniforma*, *P. sjostedti* and *P. fuscicornis*. These results aligned with Ivase *et al.*[26], who observed that neem extract was effective against tomato pests. In the late season, biopesticides reduced the populations of *P. uniforma* and *Zonocerus* spp. while also reducing the densities of sucking pests such as *A. gossypii* and *A. biguttula biguttula*[27]. This effectiveness is attributed to the translaminar and systemic properties of neem and clove[28], as supported by Arora *et al.*[29].

Late-season reductions in *Mylabris pustulatus* and *Dysdercus* spp. were notably significant, particularly at higher application frequencies. *Dysdercus* spp. was only found on okra treated with 50-O4W, 100-O4W, 200-O4W and in the control plots, likely due to the combined effects of contact and systemic action of the neem and clove powder[30,31]. Natural enemy populations, including *Dictynia* spp., *Coccinella* spp. and *Camponotus* spp., were recorded in both seasons, with no significant impact from biopesticide applications[32]. These findings highlighted the effectiveness of biopesticide treatments in the reduction of fruit damage and to increase yield of okra fruits compared to the control and other treatments.

CONCLUSION AND RECOMMENDATION

Podagrica fuscicornis represents a new addition to the okra pest community. Biopesticide treatments effectively reduced pest numbers and damage without impacting natural enemy populations or the agronomic quality of okra. The most cost-effective treatment was 100 mL/ha applied once every 4 weeks, which significantly improved pest control and increased yield. It is recommended to incorporate this biopesticide application rate and frequency into Integrated Pest Management (IPM) and insecticide resistance management programs for optimal okra production in other agro ecological zones.

SIGNIFICANCE STATEMENT

This research highlights the potential of an eco-friendly biopesticide formulation comprising neem extract, wood ash and clove powder as a sustainable alternative to synthetic insecticides in okra cultivation. The study demonstrated that optimal application rates and frequencies significantly reduce pest infestations and fruit damage without harming beneficial natural enemies. By improving growth parameters and maximizing cost-benefit ratios, this biopesticide offers an effective and economical solution for managing okra pests, thereby enhancing yield. The findings contribute to sustainable agricultural practices and encourage further exploration of biopesticides in diverse agro-ecological settings.

REFERENCES

1. Durazzo, A., M. Lucarini, E. Novellino, E.B. Souto, P. Daliu and A. Santini, 2019. *Abelmoschus esculentus* (L.): Bioactive components' beneficial properties-focused on antidiabetic role-for sustainable health applications. Molecules, Vol. 24. 10.3390/molecules24010038.
2. Tindall, H.D., 1983. Vegetables in the Tropics. 1st Edn., Macmillan Publishers Limited, New York, United States, Pages: 534.
3. Chowdhury, N.S., S. Jamaly, F. Farjana, N. Begum and E.A. Zenat, 2019. A review on ethnomedicinal, pharmacological, phytochemical and pharmaceutical profile of lady's finger (*Abelmoschus esculentus* L.) plant. Pharmacol. Pharm., 10: 94-108.
4. Nkongho, R.N., J.T. Efouba-Mbong, L.M. Ndam, G.A. Ketchem, E.G. Etchu-Takang and D.T. Agbor, 2022. Seed production system and adaptability of okra (*Abelmoschus esculentus* L.) cultivars in Buea, Cameroon. PLoS ONE, Vol. 17. 10.1371/journal.pone.0278771.
5. Adekiya, A.O., T.M. Agbede, C.M. Aboyeji and O. Dunsin, 2017. Response of okra (*Abelmoschus esculentus* (L.) Moench) and soil properties to different mulch materials in different cropping seasons. Sci. Hortic., 217: 209-216.

6. Ibitoye, D.O. and A.O. Kolawole, 2022. Farmers' appraisal on okra [*Abelmoschus esculentus* (L.)] production and phenotypic characterization: A synergistic approach for improvement. Front. Plant Sci., Vol. 13. 10.3389/fpls.2022.787577.
7. FAOUN, 2022. World Food and Agriculture-Statistical Yearbook 2022. Food & Agriculture Org., Rome, Italy, ISBN: 9789251369302, Pages: 382.
8. Amadi, R.C.C., 2023. Impact of socioeconomic characteristics and productivity on output of okra farmers in Ikwerre Local Government Area, Rivers State, Nigeria. Int. J. Integr. Sci., 2: 565-580.
9. Ngbede S.O., H.N. Ibekwe, S.C. Okpara, U.N. Onyegbule and L. Adejumo, 2014. An overview of okra production, processing, marketing, utilization and constraints in Ayaragu in Ivo Local Government Area of Ebonyi State, Nigeria. Greener J. Agric. Sci., 4: 136-143.
10. Ekunwe, P.A., G. Alufohai and C.F. Adolue, 2018. Economic viability of okra (*Abelmoschus esculentus*) production in Ika South and North East Local Government Areas of Delta State, Nigeria. Agro-Science, 17: 57-62.
11. Elkhalifa, A.E.O., E. Alshammari, M. Adnan, J.C. Alcantara and A.M. Awadelkareem *et al*., 2021. Okra (*Abelmoschus esculentus*) as a potential dietary medicine with nutraceutical importance for sustainable health applications. Molecules, Vol. 26. 10.3390/molecules26030696.
12. Torequl Islam, M., 2019. Phytochemical information and pharmacological activities of okra (*Abelmoschus esculentus*): A literature based review. Phytother. Res., 33: 72-80.
13. Fatima, M., Allah Rakha, A.B. Altemimi, F. van Bocktaele, A.I. Khan, M. Ayyub and R.M. Aadil, 2024. Okra: Mucilage extraction, composition, applications, and potential health benefits. Eur. Polym. J., Vol. 215. 10.1016/j.eurpolymj.2024.113193.
14. Adebayo, A.S., F.A. Azeez, O.O. Abegunrin, O.G. Ogunwale, O.O. Oyewole and F.F. Ojo, 2020. Introduction of improved okra (NHAe47-4) variety as a means of economic enhancement of farmers in Ido Village, Ido Local Government Area, Oyo State, Nigeria. J. Appl. Sci. Environ. Manage., 24: 2055-2060.
15. Danjuma, S., I. Muhammed and G. Yahaya, 2021. Evaluation of the efficacy of plant materials for the control of flea beetles *Podagrica* spp on okra *Abelmoschus esculentus* L. J. Appl. Sci. Environ. Manage., 25: 529-535.
16. Jan, Q., I.A. Khan, L.A. Al-Shuraym, M.A. Alshehri and N. Ahmed *et al*., 2022. Comparative conventional preventive strategies for insect pest of okra. Saudi J. Biol. Sci., 29: 3114-3121.
17. Amiteye, S., A.S. Appiah, F. Boateng, J.T. Kutufam and H.M. Amoatey, 2021. Physiological changes associated with *Okra mosaic virus* infection in field grown okra plants. Asian J. Agric. Biol., Vol. 2021. 10.35495/ajab.2021.02.097.
18. Umeri, C., S.E. Nwajei, H. Moseri and M.C. Bamidele, 2023. Growth and yield of seven varieties of okra (*Abelmoschus esculentus* (L.) Moench) in Agbor, Delta State, Nigeria. J. Agric. Environ., 19: 135-143.
19. Ofuya, T.I., A.I. Okunlola and G.N. Mbata, 2023. A review of insect pest management in vegetable crop production in Nigeria. Insects, Vol. 14. 10.3390/insects14020111.
20. Tudi, M., H.D. Ruan, L. Wang, J. Lyu and R. Sadler *et al*., 2021. Agriculture development, pesticide application and its impact on the environment. Int. J. Environ. Res. Public Health, Vol. 18. 10.3390/ijerph18031112.
21. Ekoja, E.E., P.H. Kumaga and D. Abah, 2022. Flea beetle infestation and control strategies as perceived by farmers of Malvaceae crops in Benue State, Nigeria. Aust. J. Sci. Technol., 6: 78-85.
22. Mobolade, A.J., I.J. Ejemen, J.A. Rufus and E.A. Festus, 2014. Control of flea beetles *Podagrica* spp. (Coleoptera: Chrysomelidae) infestation on okra (*Abelmoschus esculentus*(L.) Moench) using *Piper guineense* seed extracts. Arch. Phytopathol. Plant Prot., 47: 2332-2339.
23. Audi, A.H. and F.B. Mukhtar, 2019. Evaluation of salicylic acid pre-hardening treatments of cowpea for resistance against the flea beetle, *Podagrica fuscicornis* Linn. (Coleoptera: Chrysomelidae). Int. J. Environ. Agric. Biotechnol., 4: 33-40.

24. Onyeneke, R.U., F.F. Agyarko, C.J. Onyeneke, E.E. Osuji, P.A. Ibeneme and I.J. Esfahani, 2023. How does climate change affect tomato and okra production? Evidence from Nigeria. Plants, Vol. 12. 10.3390/plants12193477.
25. Caniço, A., A. Mexia and L. Santos, 2020. Seasonal dynamics of the alien invasive insect pest *Spodoptera frugiperda* Smith (Lepidoptera: Noctuidae) in Manica Province, Central Mozambique. Insects, Vol. 11. 10.3390/insects11080512.
26. Ivase, T.J.P., B.B. Nyakuma, B.U. Ogenyi, A.D. Balogun and M.N. Hassan, 2017. Current status, challenges, and prospects of biopesticide utilization in Nigeria. Acta Universitatis Sapientiae Agric. Environ., 9: 95-106.
27. Senthil-Nathan, S., 2013. Physiological and biochemical effect of neem and other Meliaceae plants secondary metabolites against Lepidopteran insects. Front. Physiol., Vol. 4. 10.3389/fphys.2013.00359.
28. Bansal, V., M. Gupta, T. Bhaduri, S.A. Shaikh, S. Fazlur Rahman, V. Bansal and A. Agrawal, 2019. Assessment of antimicrobial effectiveness of neem and clove extract against *Streptococcus mutans* and *Candida albicans*: An *in vitro* study. Niger. Med. J., 60: 285-289.
29. Arora, M.S., P.K. Chanda and G.V.Arak, 2018. Effect of clove oil (*Syzygium aromaticum*) and neem oil (*Azedirecta indica*) on *Tribolium castaneum* (Herbst) (Coleopteran: Tenebrionidae). J. Emerging Technol. Innovative Res., 5: 90-98.
30. Kofi, H.W.H., 2024. Efficacy of water soaked neem (*Azadiarachta indica*) leaf filtrate on three insect pests on okra [*Abelmoschus esculentus* (L.) Moench] plants. J. Biol. Life Sci., 15: 1-15.
31. Idowu, G.A., R.O. Oyewale, M.H. Bolajoko, R.O. Ibrahim and C. Isah, 2022. Management of insect pests of okra (*Abelmoschus esculentus* L.). Int. J. Life Sci. Study, 3: 7-13.
32. Meseguer, R., A. Levi-Mourao and X. Pons, 2021. Species complex and temporal associations between coccinellids and aphids in alfalfa stands in Spain. Insects, Vol. 12. 10.3390/insects12110971.