Pak. J. Biochem. Mol. Biol., 2024, 57(3):1-21

Pesticidal efficacy and phytochemical analysis of *Moringa oleifera* root, bark, and seed powders against major okra pests in Cross River State, Nigeria

Nta Abo Iso[1], Etim Daniel Offiong[2*], Effanga Emmanuel Offiong[1], Bassey Etta Agbo[3], Ikpeme Inyang Godwin[1]

[1]Department of Zoology and Environmental Biology, University of Calabar, Calabar, Nigeria.
[2]Department of Botany, Faculty of Biological Sciences, University of Calabar, Calabar, Nigeria.
[3]Department of Microbiology, University of Calabar, Calabar, Nigeria.

[*]Corresponding author Email: danielofiong@yahoo.com
ORCID ID: https://orchid.org/0000-0003-3404-9569

Abstract

Aim: The study aims to evaluate the phytochemical properties of *M. oleifera* dry roots and bark, with the view of determining the pesticidal efficacy on insect pests. Laboratory and field studies were conducted to test the insecticidal effect of powdered preparation of *M. oleifera* parts on major insect pests of okra.

Materials and Methods: Fifty grams (50g) of powdered preparations of different plant parts and their combination were mixed separately with water and applied on the okra plant using a dispenser. Data were collected before and after 1st and 2nd application of plant substance.

Results: This revealed four orders, seven families and seven species of insect pests including whiteflies, aphids, beetles, mealy bug, wingless grasshoppers, leaf-rollers, and fruit-borers, as the common pests responsible for damage at different stages of the crop growth. The highest counts (36.52%) in aphid infestation and occurrence were found in Calabar South compare to Biase which was the least. Highest mealy bug counts were observed in Akpabuyo (37.78%) and least (10.49%) in Biase. Results also revealed substantial decrease in infestation level in plots treated with bark powder preparation (37.52%), and combine powder preparation (37.75%). Root powder preparation was not as effective in reducing pest population.

Conclusion: Bark powder preparation is therefore recommended for the control of okra pest both in the field and during storage as this is readily available and economical. It can serve as suitable alternatives to synthetic chemicals in insect pest control and management of stored grains.

Key words: Efficacy, Pesticidal, *Moringa oleifera,* Root powder, Bark powder

INTRODUCTION

Okra (*Abelmoschus esculentus*, L. Moench), a representative of the Malvaceae family, constitutes a crucial warm-season agricultural product extensively cultivated across tropical and subtropical climates, including Nigeria. Within Nigeria, it is regarded as one of the predominant vegetables, frequently grown and consumed. Okra is esteemed for its high nutritional profile, being considered an essential constituent of the local dietary regimen. It contains a variety of nutrients including calories, carbohydrates, proteins, fats, vitamins A, C, and B6, folic acid, calcium, magnesium, potassium, iron, zinc, phosphorus, β-carotene, riboflavin, and dietary fiber [1]. Furthermore, research has indicated that okra mucilage may serve as a plasma substitute in medical applications. In industries, okra mucilage is commonly utilized for glazing certain types of paper and has various applications in confectionery, among other uses [2].

In numerous tropical nations globally, including Nigeria, okra is cultivated over an expanse of

approximately 0.37 million hectares, yielding an annual production of 3.53 million tons. Per capita production of green pods remains suboptimal, with reported yields in Nigeria scarcely reaching 7 tons per hectare [3]. This low yield can be attributed to multiple factors such as inadequate quality of seeds, infestation by insect pests and diseases, competition from weeds, suboptimal plant density, improper fertilizer application, limited space, and poor soil nutrient availability. Among these factors, a principal reason for the decreased yields is the extensive range of insect pests that adversely affect the crop from germination through to harvest, thereby sabotaging okra productivity [4]. Given that okra shares its growing season with cotton, it serves as a significant alternate host for cotton insect pests as well [5].

As reported by Iqbal et al. [6], up to 72 species of insect pests have been identified on okra crops throughout their growth cycle. The crop is vulnerable to numerous insect attacks during both vegetative and reproductive phases, including both sucking and chewing pests. The principal sucking pests include jassids (*Amrasca biguttula biguttula*), thrips (*Thrips tabaci*), and whiteflies (*Bemisia tabaci*). The significant chewing pests consist of shoot borers (*Earias spp.*) and fruit borers (*Helicoverpa armigera*), which can severely devastate okra crops. Among these, the cotton jassid, *Amrasca biguttula biguttula* (Ishida), along with shoot and fruit borers, *Earias vittella* (Fabricius) and *E. insulana* (Boisduval), are notably severe and act as major impediments to okra cultivation. These pests infest the crops throughout both vegetative and reproductive stages, resulting in substantial yield reductions [7].

To combat these sucking and boring pests, farmers typically resort to a minimum of 10 to 15 applications of pesticide sprays within a single cropping season [8]. This practice not only escalates cultivation costs but also leads to issues such as resistance to insecticides, resurgence of sucking pests, outbreaks of secondary pests, harmful residues in the final produce, groundwater contamination, negative effects on human health, and the indiscriminate killing of non-target organisms [9]. Increasing concern for environmental security, coupled with the global demand for food devoid of pesticide residues, has brought significant interest in the practice of organic agriculture. While the complete elimination of insecticides is unfeasible, as they are integral to pest management strategies, their application can undoubtedly be curtailed by employing safer pest management techniques, such as bio-pesticides derived from botanical sources, which are comparatively more environmentally sustainable than synthetic alternatives.

It was out of these concerns that the dry powder preparation of different plant parts of *M. oleifera* were tested against some major pests of okra for possible remedy for pest reduction both in the field and store. Different parts *M. oleifera* contain various useful minerals which include (potassium, calcium, iron, magnesium, selenium), Vitamins A, B, C, D, E and different polyphenolic compounds [10]. The leaves are widely consumed as vegetable and does not have any poisonous substance or adverse effect on humans. Owing to the substantial concentration of phytochemicals and diverse nutrients present in *M. oleifera*, traditional medical practitioners employ all components of the plant in the therapeutic management of numerous ailments [11]. The entire Moringa plant had been used successfully in the treatment and management of different ailments such as gastric discomfort, diarrhoea, stomach ulcers, arterial tension, diabetes and skin infection [12].

Aqueous extracts derived from roots and barks have demonstrated efficacy in averting implantation [13], while aqueous extracts from fruits have revealed notable anti-inflammatory properties, methanolic extracts from leaves have exhibited antiulcer effects, and ethanolic extracts from seeds have shown antitumor potential [14]. Collectively, these findings, among numerous others, contribute to the extensive documentation of *M. oleifera*

[15]. Notwithstanding this diverse application for various parts of the Moringa tree, there exists a paucity of literature regarding the utilization of *M. oleifera* in the management of insect pests affecting crops. The current investigation seeks to examine the prevalence and distribution of significant okra pests within key production regions of Cross River State, Nigeria. Additionally, it aims to analyze the phytochemical constituents of various parts of *M. oleifera*, including dried roots and bark, with the objective of assessing their pesticidal efficacy and the effects of their combinations at different concentrations on the insect pest populations.

MATERIALS AND METHODS

Study area and experimental site

Preliminary survey was carried out in four okra growing areas in Cross River State, Nigeria, which includes Calabar South, Akpabuyo, Odukpani and Biase. Supporting field experiment was carried out in the experimental site situated at Anwantim community along Mutala Mohammed highway, Calabar as well as laboratory study done in the laboratory of the Department of Zoology and Environmental Biology, Faculty of Biological Sciences, University of Calabar, Calabar.

Collection, washing and drying of M. oleifera parts

Fresh, healthy and matured roots, bark and seeds of *M. oleifera* growing along Winner's Road, Ekorinim I, were collected into uncovered cartons, and transported to the laboratory of the Department Zoology and Environmental Biology, University of Calabar, Calabar. Each of the plant parts were separately washed and rinsed with running water to eliminate dust and other foreign particles. Samples (1000-1500 g) were weighed with a weighing scale, and subsequently dried on ventilated racks under shade.

Preparation of dry powder of plant parts

Each dried sample (root, bark, and seeds) was ground into powder by using laboratory mortar and pestel. 500g of each ground plant part was weighed on an electronic scale and pulverized using a micro-pulveriser and sieved through 0.5 mm size mesh to obtain similar particle size. The resulting powder was placed in a labelled glass bottle with screw cap and kept at room temperature for use in phytochemical screening.

Phytochemical screening of the powder preparations of the test samples

The chemical screening was conducted in the Department of Chemistry Laboratory, University of Calabar, using the qualitative method described in Kambou and Guissou [16]. The active phytochemical substances, such as tannins, flavonoids, alkaloids and saponins were determined in the various powders tested, using characterisation tests such as: Ferric chloride test, Lead sub-acetate test, Wagner's test, Mayer's test, Dragendorff's test, Frothing test and Heamolysis test.

Phytochemical screening for alkaloids: Two grams (2g) of the test sample was dissolved in 1000 ml solution of ethanol, distilled water, and lime separately. One gram (1g) of each solution was mixed in 16 ml of concentrated hydrochloric acid (HCl), warmed and filtered. Thereafter, 4 ml of each filtrate was treated with Mayer's reagent. Turbidity or formation of precipitate was a positive test for the presence of alkaloid. This examination was conducted for each test sample with respect to the comprehensive phytochemical analysis for alkaloids.

Phytochemical analysis for tannins: One gram (1g) of each specimen was dissolved in 4 ml of distilled water, followed by the

addition of 4 drops of diluted ferric chloride solution. The emergence of a dark green or blue-green hue indicated the presence of tannins.

Phytochemical analysis for flavonoids: One gram (1g) of each specimen was dissolved in 5 ml of ethanol, after which 2 ml of concentrated sulphuric acid and 1g of magnesium were introduced into the solution. The appearance of a pink or red coloration that faded after approximately 5 minutes was indicative of flavonoids.

Phytochemical analysis for saponins: One gram (1g) of each specimen was combined with 10 ml of distilled water in a test tube. The mixture was shaken vigorously and monitored for the formation of a stable persistent froth lasting about 20 minutes.

Phytochemical analysis for phenols: Fifteen grams (15g) of each specimen was treated with two drops of ferric chloride solution. The development of a blue-black coloration suggested the presence of phenols.

Collection of seeds of okra (A. esculentus) for planting

Seeds from an early-maturing variety of okra (NHae 47-4) were procured from the Cross River State Ministry of Agriculture, placed in a perforated container, and promptly transported to the Department of Crop Science at the University of Calabar for accurate identification and authentication. Subsequently, the verified specimens were relocated to the Zoology and Environmental Biology laboratory and appropriately stored for cultivation.

Selection of survey site

The survey sites were selected to determine the occurrence and distribution of okra pests within Cross River State. The selection was based on field sizes and average between 0.1-0.5 ha per site. Okra fields cultivated and owned by local farmers in the area were selected from each of the four okra producing Local Government Areas in Cross River State. A total of five fields were chosen from each of the localities of Calabar South, Akpabuyo, Odukpani, and Biase, culminating in an aggregate of 20 fields for this research. Each of the selected fields underwent four visitation periods throughout each cropping season—specifically at the vegetative, fruiting, flowering, and harvesting stages of the okra fruit. This systematic approach aimed to evaluate the distribution and prevalence of insect pests across the four distinct regions, as well as to examine the specific insect species affecting the okra plants during various growth stages in these locations.

Field experiment

The experimental design employed for the field investigation was the Randomized Complete Block Design (RCBD). This was replicated thrice, with six treatments which included root, bark, seed, and their combinations alongside a single untreated control group, in accordance with the guidelines established by Benson [17]. The dimensions of each plot were established at 4 x 3 m^2 for the cultivation of okra seeds. The total area designated for the experiment measured 13.0 m x 24.0 m and was replicated thrice, with an inter-row spacing of 0.5 m, and a planting distance of 0.5 m between plants, thereby achieving a density of 18 plants per plot. Prior to sowing, well-cured poultry manure was thoroughly integrated into the soil.

The planting procedure involved sowing three seeds per hole. After a duration of five days post-planting, any seeds that failed to germinate in their respective holes were substituted with additional okra seeds. All recommended agronomic practices for crop cultivation—including weeding and thinning—were diligently executed two weeks after germination. Further weeding

efforts were done as weeds appeared, with the objective of minimizing insect infestation within the field to the greatest extent possible, in alignment with established standards.

Collection of okra pests

The plots were visited after three weeks of planting for insect collection. Adult insect pests were collected using sweep net and also by hand picking directly from the plants. This was done early in the morning between 7 am – 8 am and evening around 5 pm – 6 pm. The insects collected were placed in glass vials and taken to the laboratory for sorting based on species before being preserved in alcohol for further morphological studies.

Field evaluation of insecticidal efficacy of M. oleifera plant parts against okra pests

Fifty grams (50g) of powder made from each of the three different parts of *M. oleifera* was mixed with water and applied with a dispenser on the respective experimental plot when pest population increased, which was roughly 8-weeks after planting. A combination of powder made from the three plant parts was also applied in a single treatment as T6. Field evaluation of the level of infestation was carried out on ten (10) randomly selected okra plants from each plot as recommended by Ray [18]. Pre-treatment observations were recorded, a day prior to spraying and thereafter one, five, nine, thirteen and seventeen days of post treatments. Prior to statistical analysis, observations were angular-transformed using the arcsine square root transformation reported in Ray [18] as follows:

$$g(x) = \arcsin\left(\sqrt{x}\right) X\ 180/\pi$$

Where:

g(x) = angular-transformed value

arcsin = inverse sine function of x when $-1 \leq x \leq 1$; arcsin $x = \sin^{-1} x = y$.

Pi (π) = 3.14159265358979

Collection of dry okra fruits and preparation of seeds for rearing of okra grain beetle

Okra fruits were allowed to dry in the field and the dry fruits were randomly obtained from the field in February 2019 with plastic containers and transferred immediately to the laboratory for further studies. Thereafter, some dry fruits were cut opened with a sharp blade, the seeds collected and stored in glass vials. Prior to the rearing of okra weevil, the okra seeds were cleaned, well-sieved and stored at room temperature for further studies.

Mass rearing of okra grain beetle

Rearing was done using the methods of Parugrug and Roxas [19] as well as Ogunsina *et al*. [20] with some modifications to suit the study. Dry okra pods were placed in a sterilized glass jar (12 cm high x 6.5 cm diameter) with little humus and covered with banded 0.05 meshed net.

The medium was conditioned to room temperature and relative humidity in order to provide enabling environment for weevil infestation. The setup was checked weekly for emergence of okra grain beetle. After 16 days of exposure, emerged adult weevils were isolated and then introduced into a plastic container of sterilized okra seeds. To avoid escape of the pest and the invasion of mites or other insects, the plastic container was covered with a net of 0.05mm mesh size and fastened tightly with rubber bands. Rearing was allowed to take place at normal room temperature and pressure for weeks till the emergence of new adults.

Identification of insect pest of stored okra seeds

The beetles were identified following the identification key provided in Kedar *et al* [21]. They were kept in a jar covered with net fastened by a rubber band to avoid escape of the insects. A handful of okra seeds from the experimental plots and little humus were put inside the jar so that the insects could feed on

them and be sustained. The jar was labelled accordingly and kept under room temperature for further studies.

Statistical analysis

All data were subjected to statistical examination utilizing Analysis of Variance (ANOVA). Mean values were compared and separated through Duncan's Multiple Range Test (DMRT) at a significance level of 5%. All statistical evaluations were conducted using Predictive Analytical Software (PASW ver. 20). The following analysis of variance table was utilized to determine significant differences among treatments at the $P<0.05$ α-level of significance (Table 1).

TABLE 1: Framework of analysis of variance (ANOVA)

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F-critical
Replication	(r-1)	RSS	RMSS	RMSS/ErMSS
Treatment	(t-1)	TrSS	TrMSS	TrMSS/ErMSS
Error	(r-1)*(t-1)	ErSS	ErMSS	-
Total	n-1	TSS	-	-

Where:

RSS= sum of square for replication

r= number of replicates

TrSS= sum of square for treatment

t= number of treatments

ErSS= error sum of square

n= r*t

MSS= mean sum of square

RESULTS

Occurrence and distribution of major pests of okra in agro ecological regions of Cross River State

A total of 1388 insects which comprises of 7 species belonging to 4 orders, 7 families were collected from the field survey (Table 2) as major pests of okra in four Local Governments Areas (Calabar South, Odukpani, Akpabuyo and Biase) of Cross River State. Okra pests were observed to destroy different growth stages of development of the plant such as the shooting, flowering, vegetative, fruiting and harvesting. In this study, infestation and destruction was done by whiteflies (*Bemisia tabaci*), aphids (*Aphis gossypii*), mealy bugs (*Phenacoccus solenopsis*), flea beetles (*Podagrica malvae*), grasshoppers (*Phaulacridium vittatum*), leaf-rollers (*Haritalodes derogate*) and fruit-borers (*Helicoverpa armigera*). It was observed in the field survey that Coleoptera (flea beetles) were the most prevalent and destructive insect pest accounting for 50% of the population in the four study sites while Orthoptera was (17%), Hemiptera (17%) and lepidotera (16%) made up the remaining population (Fig. 1).

Comparison of aphid infestation in the four cropping areas surveyed showed significantly higher prevalence in Calabar South L.G.A. (36.52%, $P<0.05$) and Akpabuyo L.G.A. (34.17%) than any other local government area with lowest prevalence (10.49%) in Biase L.G.A. Significantly higher mealy bug prevalence was observed in Akpabuyo L.G.A (37.78%, $P<0.05$) and followed by Odukpani L.G.A (28.92%) (Fig. 2). Other insect pests did not show any significant difference ($P>0.05$) in their distribution, as such were not included in the chart.

Phytochemical properties of M. oleifera

The result of phytochemical screening in this study revealed the presence of alkaloids, flavonoids, saponins and tannins in all plant parts except seed which had no tannins and

root which had no alkaloids and saponins (Table 3).

Field evaluation of powdery preparations of M. oleifera dry plant parts against major insect pests of okra

The mean okra infestation with the different pest ranged between 31.3% - 54.7%. A gradual decline in the population of whitefly, leaf roller, fruit borer, mealy bug and flea beetle was recorded on plots treated with bark powder preparations (BPP) but an increased in mean population of Aphid (38.0%) and grasshopper (46.7%) was observed after 1st and 2nd application with BPP.

TABLE 2: Taxonomic description of insect-pests observed on okra during field experiments

No.	Order	Family	Genus	Species	Common name	Reference
1.	Hemiptera	Pseudococcidae	*Phenacoccus*	*P. solenopsis*	Mealy bug	Tinsley 1898
2.	Hemiptera	Aleyrodidae	*Bemisia*	*B. tabaci*	Whitefly	Gennadius 1889
3.	Hemiptera	Aphididae	*Aphis*	*A. gossypii*	Aphid	Glover 1877
4.	Coleoptera	Chrysomelidae	*Podagrica*	*P. malvae*	Flea beetle	Illiger 1807
5.	Orthoptera	Acrididae	*Phaulacridium*	*P. vittatum*	Wingless grasshopper	Sjostedt 1920
6.	Lepidoptera	Crambidae	*Haritalodes*	*H. derogate*	Leaf roller	Fabricius, 1775
7	Lepidoptera	Noctuidae	*Helicoverpa*	*H. armigera*	Okra Fruit borer	Hübner, 1808

TABLE 3: Phytochemical constituent of *Moringa oleifera* plant parts powder

No.	Phyto-constituent	Method used	Root	Leaf	Bark	Seed	Flower	Combined
1.	Tannins	Ferric chloride Test	+	+	+	-	+	+
2.	Flavonoids	Lead sub-acetate Test	+	+	+	+	+	+
		Ferric chloride Test	+	+	+	+	+	+
3.	Alkaloids	Wagner's Test	-	+	+	+	+	+
		Mayer's Test	-	+	+	+	+	+
		Dragendorff's Test	-	+	+	+	+	+
4.	Saponins	Frothing Test	-	+	+	+	+	+
		Heamolysis test	-	+	+	+	+	+

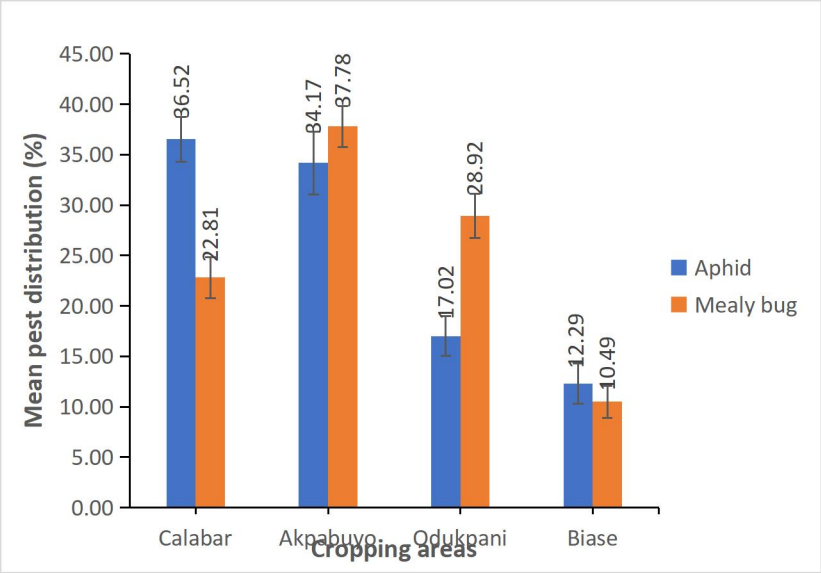


FIGURE 1: Mean pest occurrence in okra agro ecological regions

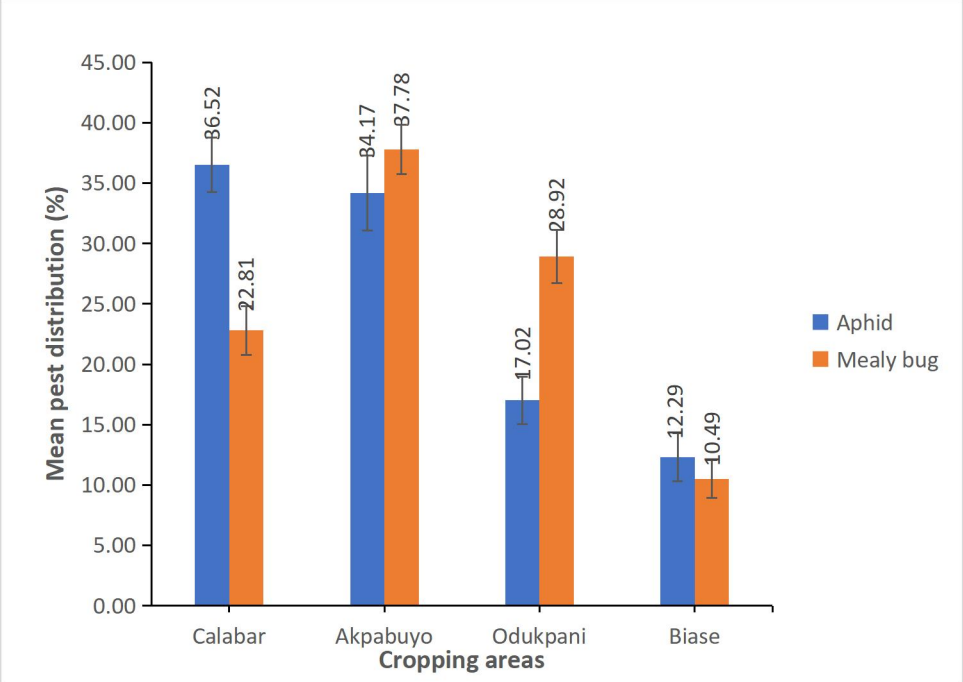


FIGURE 2: Mean pest occurrence in okra agro ecological regions

The overall mean result showed BPP to be most effective in reducing leaf roller population to 33. 7% (Table 4). Plots treated with BPP showed no significant difference ($P < 0.05$) in okra yield.

There was minimal reduction in the population of flea beetle, whitefly, leaf roller, mealy bug and fruit borer after 1st and 2nd application of seed powder preparation (Table 5). Conversely, the population of Aphids and fruit borer was observed to have increased.

Plots treated with RPP showed no significant decrease in terms of major pest of okra encountered in the study. There was an increase in the population of all the pest except grasshopper and mealy bug. Grasshopper population was observed to build up after 1st application of RPP but a gradual decline was recorded after 2nd spray (Table 6).

Plots treated with RPP showed significant difference with those treated with BPP, and CPP in terms of insect population, pest infestation, plant growth and yield. An increased in Mealy bug population to 36.7% was observed after 1st application of CPP (Table 7). Also, population build up of Aphids (40.0%) was recorded after 2nd spray CPP. The population of other insect pests were gradually reduced after application of CPP (Table 7). Plots treated with CPP was statistically different in terms of increase in yield, and decrease in pest population from those treated with RPP.

Variation in the efficacy of M. oleifera bark powder on percentage infestation of Okra pests

The result revealed an increase in pest population before second application of BPP on the different treatment days but thereafter a gradual decline was observed. Lowest mean infestation (27.23± 0.43%) was recorded on day 17 of 2nd spray while highest (40.60%±0.92%) was recorded before 2nd spray (Fig. 3). An increased in the population of leaf roller and fruit borer was recorded after second application of test substance. Lowest mean infestation (32.35± 1.97 %) was recorded on second spray by mealy bug while highest (36.46±2.26%) was recorded on first spray by wingless grasshopper (Fig. 4).

There were significant variations in pest infestation in spray interval and pest type during the application of BPP.

Two-way analysis of variance (ANOVA two-factor) revealed significant variations ($P<0.05$) in percentage infestation based on spray interval and type of pest.

Variation in the efficacy of M. oleifera root powder preparation (RPP) on percentage infestation of Okra pests

The result of this study revealed population build up before 2nd spray of RPP. This increase in pest population was also recorded on day 1, day 5 and day 13 after 2nd spray (Fig. 5). Increased in pest population was also recorded on day 9 and 13 after 2nd application. All insects were present and continued to increase in population until the end of 1st spray. However, the pest population of some insects declined in the 17th day of 2nd application except for those of aphids, flea beetle, fruit borer and leaf roller. Highest mean infestation (42.29± 1.63%) was recorded on day 1 of 2nd spray while lowest (29.71± 1.55%) was recorded on day 17 of 2nd spray (Fig. 5).

Also, aphid recorded the highest mean infestation (41.15%± 1.32%) on second spray `

while lowest infestation (33.82± 1.48%) was recorded by mealy bug on second spray (Fig. 6). Two-way analysis of variance (ANOVA two-factor) revealed significant variations ($P<0.05$) in percentage infestation based on spray interval and type of pest.

TABLE 4: Effect of *M. olifera* dry bark powder (DBP) 1st and 2nd spray, April and June, 2019.

			Mean infestation (%)				
No.	Treatment	Dosage	Before 1st spray	1st spray	Before 2nd spray	2nd spray	Overall mean
1	Aphid	50g	33.3	35.3	36.7	40.7	38.0
2	whitefly	50g	43.3	42.0	43.3	36.7	39.0
3	Mealy bug	50g	40.0.	38.0	36.7	34.7	36.3
4	Flea beetle	50g	43.3	36.7	40.0	36.0	36.3
5	Leaf roller	50g	50.0	43.3	43.3	30.0	33.7
6	Grasshopper	50g	43.3	44.7	46.7	48.7	46.7
7	Fruit borer	50g	46.7	38.7	40.7	38.0	38.3

TABLE 5: Effect of *Moringa oleifera* dry seed powder (SPP) on different pest of Okra 1st and 2nd spray, April and June 2019.

			Mean infestation (%)				
No.	Treatment	Dosage	Before 1st spray	1st spray	Before 2nd spray	2nd spray	Overall mean
1	Aphids	50g	41.7	45.3	46.7	52.0	48.7
2	Whitefly	50g	36.7	36.0	36.0	35.3	35.7
3	Mealy bug	50g	38.0	37.0	37.3	36.7	36.4
4	Flea beetle	50g	42.3	41.7	41.3	41.0	41.4
5	Leaf roller	50g	46.7	45.7	45.0	44.3	45.0
6	Grasshopper	50g	50.0	41.7	41.7	37.7	39.7
7	Fruit borer	50g	43.3	43.7	46.0	46.3	45.0

TABLE 6: Effect of *Moringa oleifera* dry root powder (RPP) on different pest of okra; 1st and 2nd spray, April and June 2019.

			Mean infestation				
No.	PESTS	Dosage	Before 1st spray	1st spray	Before 2nd spray	2nd spray	Overall mean
1	Aphids	50g	33.3	43.3	40.0	61.4	52.4
2	whitefly	50g	46.7	48.7	48.7	50.3	47.7
3	Mealy bug	50g	36.7	35.7	35.7	35.0	35.3
4	Flea beetle	50g	54.7	55.3	56.0	58.8	57.1
5	Leaf roller	50g	33.3	40.7	40.0	44.0	42.3
6	grasshopper	50g	53.3	54.7	54.7	50.0	52.3
7	Fruit borer	50g	43.3	48.7	50.0	52.7	50.7

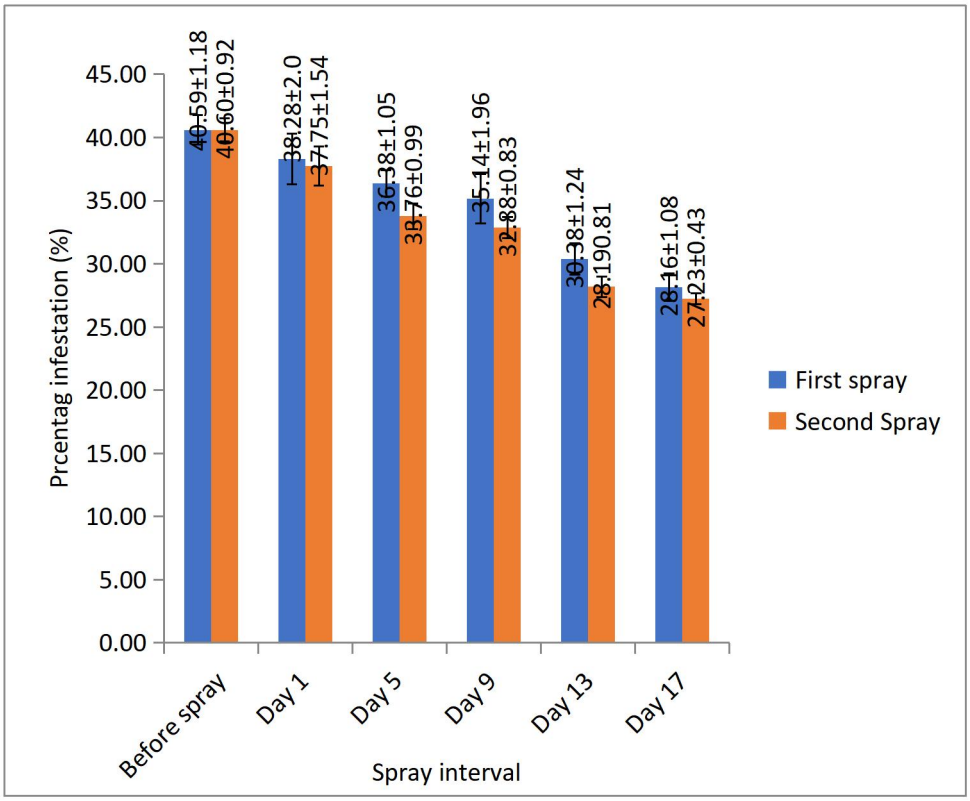


FIGURE 3: Variation in pest infestation based on spray interval with moringa bark powder

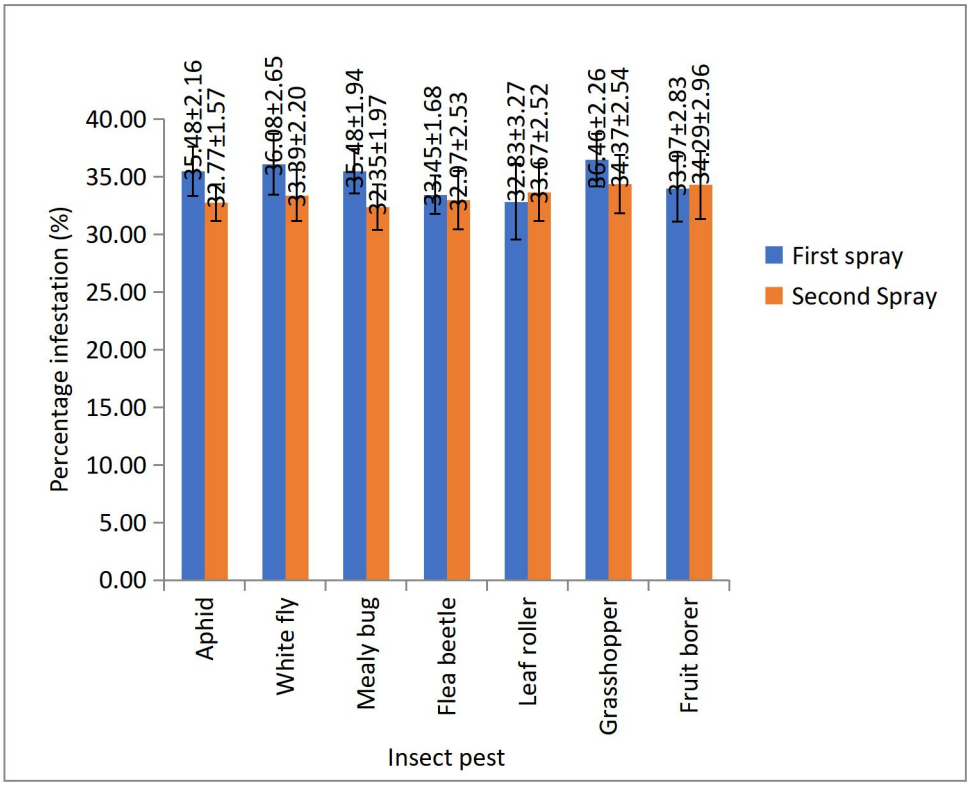


FIGURE 4: Variation in mean incidence of insect pests to the spray moringa bark powder.

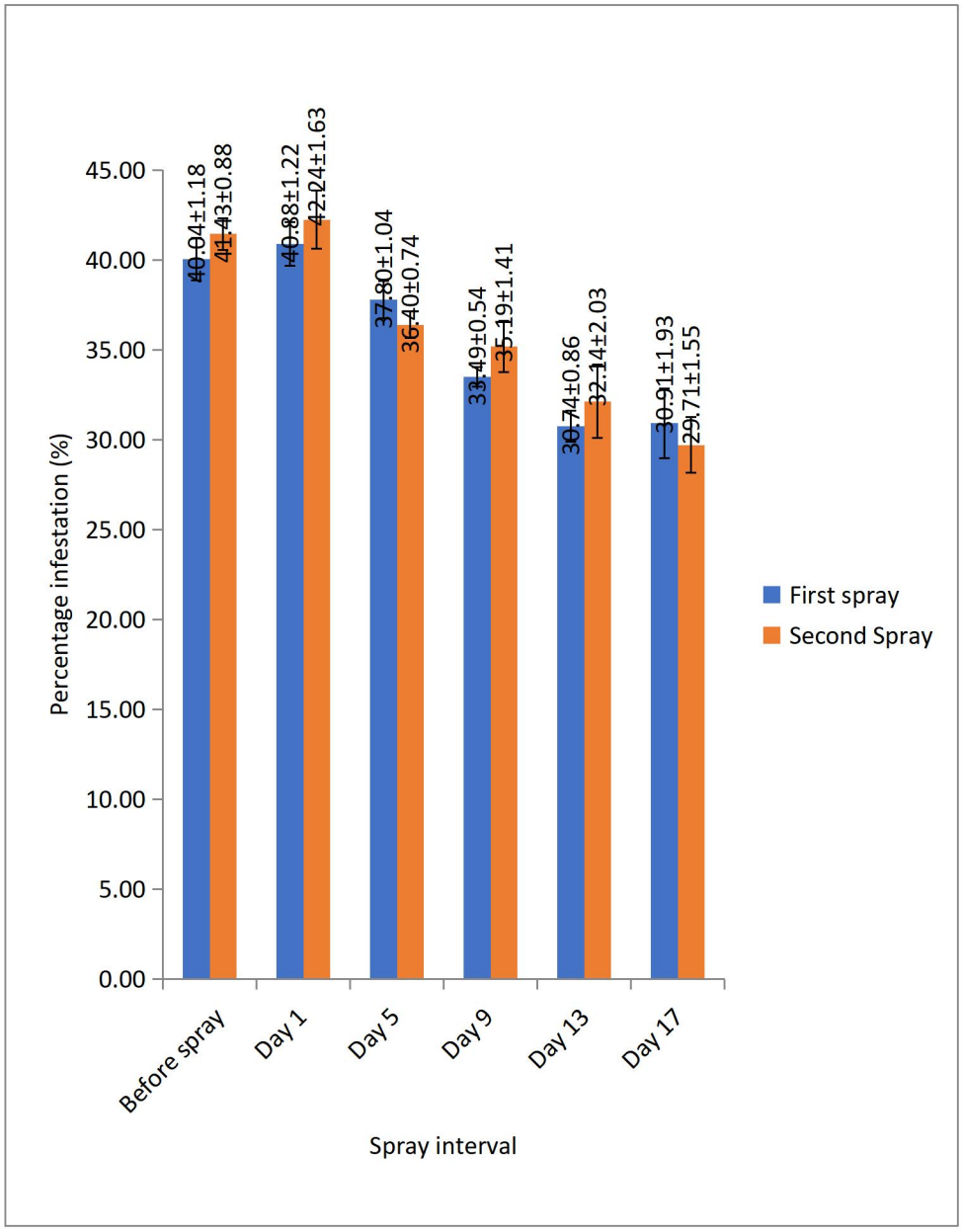


FIGURE 5: Variation in pest infestation based on spray interval with moringa root powder.

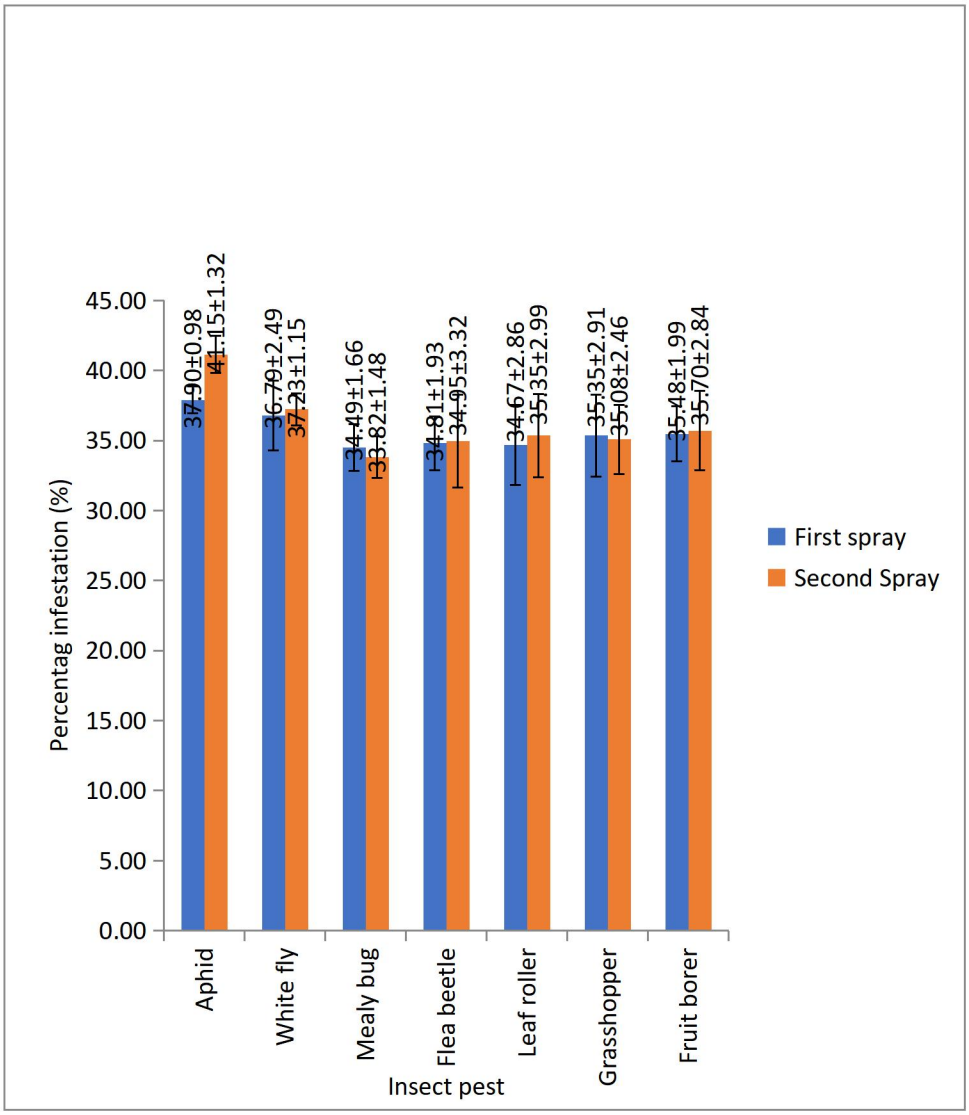


FIGURE 6: Variation in mean incidence of insect pests to the spray of moringa root powder (DRP).

Variation in the efficacy of combined treatment of M. oleifera parts powder on percentage infestation of Okra pests

The result revealed gradual decrease in pest population in all the periods of treatment after 1st application of combined powder preparation. However, an increase in population was observed on day 9 and day 17 of 2nd spray of (Fig. 7). There was a gradual increase in population of aphid and whitefly after 1st application of moringa combined powder and this continued to the 2nd spray of the test material (Fig 8).

Lowest mean infestation (27.52±0.86%) was recorded on day 17 of 1st spray while highest (40.29±1.79%) was recorded before 1st spray (Fig. 7). Flea beetle recorded lowest mean infestation (31.60±2.23 %) on second spray while grasshopper recorded the highest (36.70±3.09%) mean infestation after 1st application (Fig. 8).

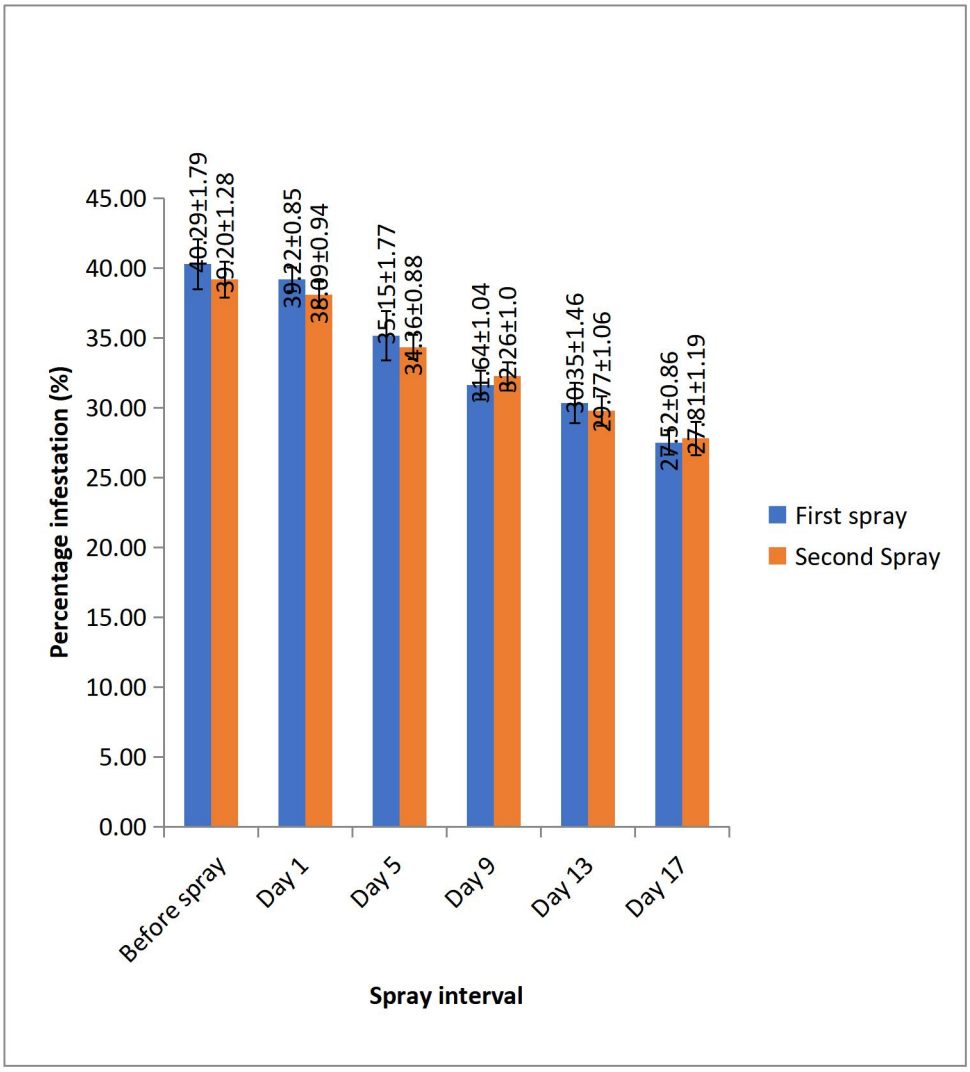


FIGURE 7: Variation in pest infestation based on spray interval with combined treatment.

S/N	Treatment	Dosage	Mean infestation (%) Before 1st spray	1st spray	Before 2nd spray	2nd spray	Overall mean
1	Aphid	50g	35.0	34.7	35.3	40.0	37.3
2	Whitefly	50g	46.7	38.0	33.3	39.3	38.7
3	Mealy bug	50g	33.3	36.7	36.7	34.7	35.7
4	Flea beetle	50g	40.0	36.0	33.7	33.3	34.7
5	Leaf roller	50g	43.7	41.0	43.3	35.3	38.2
6	Grasshopper	50g	46.7	43.3	43.0	40.3	41.8
7	Fruit borer	50g	46.7	40.7	40.0	39.3	40.0

TABLE 7: Effect of *M. oleifera* combined powder (CPP) on different pest of okra. 1st and 2nd spray, April and June 2019.

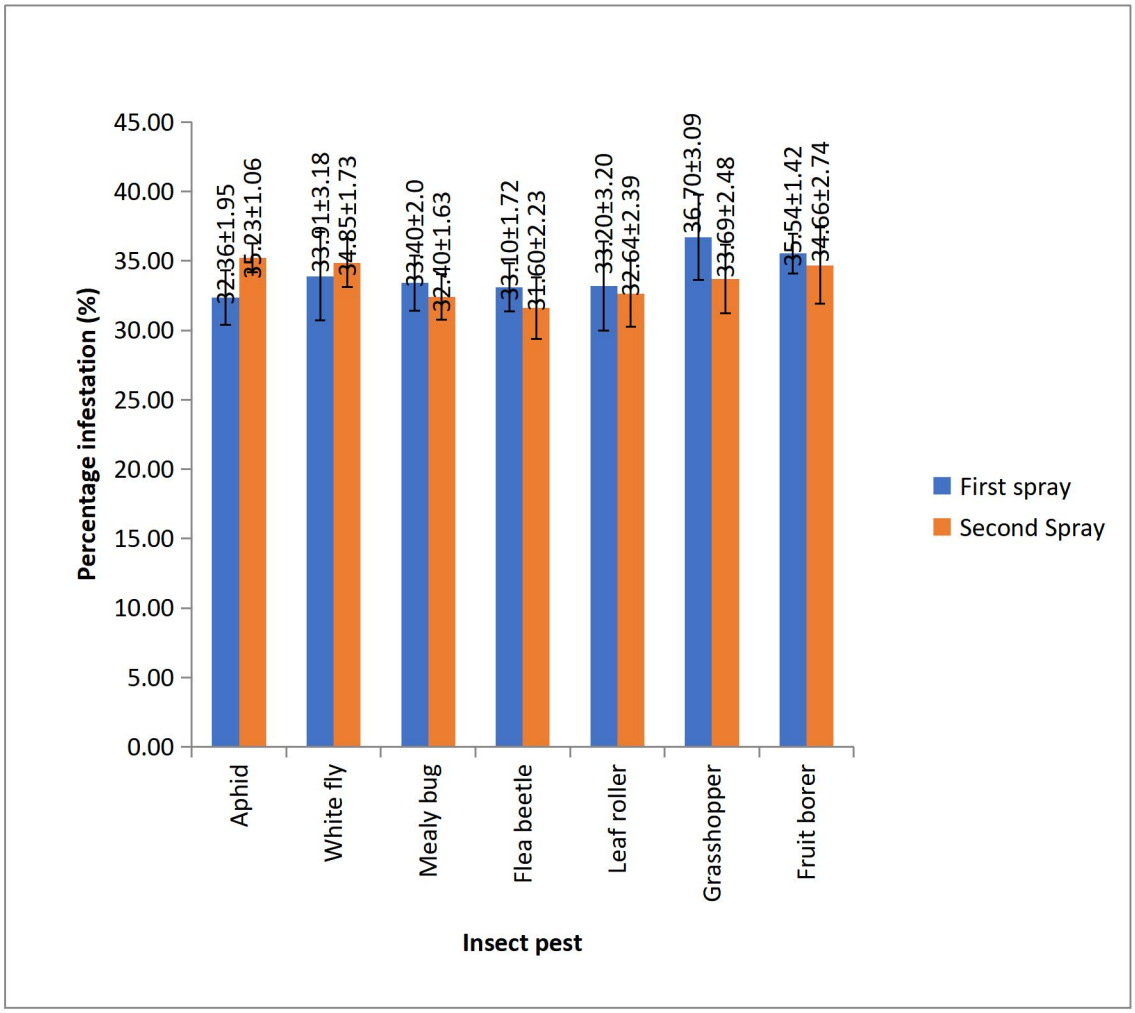


FIGURE 8: Variation in mean incidence of insect pests to the spray of combined treatment.

DISCUSSION

Occurrence and distribution of major pests of okra

Surveillance studies conducted in four agro-regions in Cross River State revealed that in terms of occurrence seven (7) different species of insect pests of okra collected belong to the order coleoptera, orthoptera, hemiptera and Lepidoptera. This information is important for effective pest management in the okra cultivation and it agrees with the findings of Djieto [22,23] that the insect pests of okra belong to the following orders: coleopteran, homoptera, Lepidoptera, orthoptera and heteroptera. The result revealed that flea beetle (*Podagrica malvae*) was the most prevalent insect pest infesting okra plant from the shooting stage to fruiting stage and this confirms the findings of Yeboue et al., Obeng- Ofori and Sockey and, Ogbalu and Ekweozor [24,25,26] who reported that in okra cultivation *P. malvae* is the major insect infesting the crop, often resulting in reducing the photosynthetic ability of leaves and subsequently result in poor yield.

The higher aphid infestations of okra grown in Calabar South and Akpabuyo when compared with the other two cropping areas (Biase and Odukpani) could be due to farming practice of okra in Calabar South and Akpabuyo. It is believed that the mono-cropping system employed would, without a doubt, enhance the ability of pests to locate

hosts and disperse compared to other surveyed regions where okra is cultivated alongside legumes and various vegetable crops. This finding corroborates the research by Gayi et al. [27], which concluded that intercropping reduces the host-seeking capability of pests relative to mono-crop systems utilized in agricultural practices. Additionally, Kalidas and Sahayaraj [28] argued that intercropping decreases pest populations by curtailing immigration into the crops or augmenting emigration from the agricultural fields.

In contrast to aphids, the highest populations of mealybugs were documented in Akpabuyo, whereas the lowest counts were recorded in Biase. In Biase, okra is intercropped with other vegetables, and the findings of this study corroborate the assertions made by Nagrare et al. [29], which indicate that the presence of alternative host plants and a high density of natural predators can result in reduced mealybug populations. Nonetheless, a considerable number of mealybugs were noted in Calabar South. It is recognized that mealybugs in Nigeria may infest various crops; consequently, the spread and prevalence observed in the surveyed locations may signify an expanded host range for this pest.

The insecticidal properties of M. oleifera powder against okra pests in the field

The present study illustrates less pest infestation, healthy plant growth, and enhanced yield in plots treated with *M. oleifera* powder compared to untreated plots. These findings align with previous studies conducted by Gerard and Ruf, Russel and Lane, and Emimal [30,31,32], which indicated that plant extracts comprise intricate mixtures of bioactive compounds and metabolites capable of inducing toxic effects upon ingestion by insect pests. The results indicate a significant decrease in insect infestation and damage in the treated plots, suggesting that the recorded insects exhibited susceptibility to Quercetin and Kaempferol, which have been identified as insecticidal agents in *M. oleifera* by Alao et al. [33]. Furthermore, it was noted that the untreated plots experienced the highest degree of infestation, substantiating the findings of Usman [34], who reported that fruiting vegetables are susceptible to insect pests when not adequately managed.

The present investigation demonstrated that the dry powder formulation derived from *M. oleifera* bark possesses potential for managing okra pest infestations. Indeed, prior research has indicated that variations in the secondary metabolites of botanical extracts are influenced by factors such as age, geographic location, seasonal changes, and the timing of collection [35]. The effectiveness of each evaluated plant powder also varied according to the application rate. Alao [36] noted that the efficacy of extracts in mitigating pest infestations was contingent upon their concentration. This observation was previously reported by Seljasen and Meadow, and Alao and Adebayo [37,38], who asserted that the application of plant extracts exhibited a dose-dependent relationship in controlling insect pests.

The results presented herein indicate that the utilization of moringa plant powder formulations effectively mitigated the infestation of leaf rollers, albeit with varying degrees of efficacy among the different plant powders when compared to the chemical control (Carbaryl). This phenomenon can be attributed to the bioactive compounds in these botanical materials. According to Isman [35,39], these bioactive compounds include triterpenes, limonoids, salamin, meliantriol, and nimbin, which serve to deter and inhibit the feeding behavior of the leaf roller larvae on the leaves of eggplant. The successful application of plant powders in this

investigation to curtail leaf roller populations aligns with the recommendations put forth by Scarratt [40], who advocated for the incorporation of buckwheat in the management strategies for leaf rollers in New Zealand as part of an integrated pest management framework. Furthermore, Adline and Devi [13] documented that Moringa could be effectively employed as a natural biopesticide, thereby making it a viable component in integrated pest management (IPM) approaches. Additionally, the current study corroborates the findings of Amutha and Raj [41], who established the efficacy of the botanical product, Azadirachta indica extract, in managing leaf roller infestations (*Sylepta derogate*).

The outcomes of this empirical investigation have demonstrated that the application of moringa plant powders resulted in a significant reduction of flea beetle populations (*P. malvae*) on okra plants, thereby diminishing the damage to leaf surface area and subsequently leading to enhanced yields in comparison to the untreated okra specimens. This observation is consistent with the findings of Mohammed-Ahmed and Ahmed et al. [42,43], who reported that treated plots exhibited a markedly lower flea beetle population than their untreated counterparts. The results from the present study indicate that the use of dry bark powder preparations significantly curtailed flea beetle populations, thereby alleviating infestation levels and promoting plant growth and yield. These findings are in agreement with the reports of Adesina and Idoko (2013) and Adesina and Afolabi (2014) [44,45], who indicated in their respective studies that okra plants treated with plant extracts yielded more than untreated okra plants. The effectiveness of plant-derived insecticides against okra flea beetles has been previously documented by various researchers (Dike and Mbah, 1992; Attieri, 1993) [46,47]. It is unequivocally established that certain plant materials possess insecticidal properties, as evidenced by numerous studies conducted by researchers and as corroborated by the findings of the current investigation.

CONCLUSION

M. oleifera bark powder has been demonstrated to be an effective and eco-friendly alternative to synthetic chemicals for managing insect pests of okra. The powdered bark preparation significantly reduced pest infestation, particularly in comparison to the less effective root powder treatment. Given its availability, affordability, and minimal environmental impact, *M. oleifera* bark powder is recommended for use in both field pest management and stored grain protection, offering a sustainable solution for pest control in okra production.

ACKNOWLEDGEMENT

The authors are grateful to Prof E. E. Oku for her role in identification of insects in the field.

REFERENCES

1. Varmudy, V. (2011). Market survey needed to boost okra exports. Puttur (IN): Department of Economics, Vivekananda College. p. 33.

2. Onunkun, O. (2012). Evaluation of aqueous extracts of five plants in the control of flea beetles on okra (*Abelmoschus esculentus* (L.) Moench). *Journal of Biopesticides*, 5(Suppl): 62–67.

3. Schippers, R. R. (2000). *African indigenous vegetables: An overview of the cultivated species*. Chatham (UK): Natural Resources Institute/ACP-EU Technical Centre for Agricultural and Rural Cooperation. p. 103–113.

4. Kuma, N. K. K., Srinivasan, K., & Saradana, H. R. (1989). Evaluation of time of insecticidal application on the control of leafhopper, *Amrasca biguttula biguttula* Ishida and aphid, *Aphis gossypii* Glover on okra. *Insect Science and its Application*, 10(3): 333–339.

5. Sharma, H. C., Sharma, K. K., Seetharama, N., & Ortiz, R. (2010). Genetic transformation of crop plants: Risk and opportunities for the rural poor. *Current Science*, 80(12): 1495–1508.

6. Iqbal, J., Ali, H., Hassan, M. W., & Jamil, M. (2015). Evaluation of indigenous plant extracts against sucking insect pests of okra crop. *Pakistan Entomologist*, 37(1): 39–44.

7. Mandal, S. K., Sah, S. B., & Gupta, S. C. (2006). Efficacy and economics of biopesticide and insecticide combinations against okra pests. *International Journal of Agricultural Sciences*, 2(2): 377–380.

8. Swarnam, V. (2013). Pesticide residues in vegetable samples from the Andaman Islands. *Environmental Monitoring and Assessment*, 185(7): 6119–6127.

9. Halder, J., Sanwal, S. K., Deb, D., Rai, A. B., & Singh, B. (2016). Mechanisms of physical and biochemical basis of resistance against leaf-hopper (*Amrasca biguttula biguttula*) in different okra (*Abelmoschus esculentus*) genotypes. *Indian Journal of Agricultural Sciences*, 86: 480–481.

10. Patel, P., Patel, N., Patel, D., Desai, S., & Dhananjay, M. (2014). Phytochemical analysis and antifungal activity of *Moringa oleifera*. *International Journal of Pharmacy and Pharmaceutical Sciences*, 6(5): 144–147.

11. Abalaka, M. E., Daniyan, S. Y., Oyeleke, S. B., & Adeyemo, S. O. (2012). The antibacterial evaluation of *Moringa oleifera* leaf extracts on selected bacterial pathogens. *Journal of Microbiology Research*, 2: 1–4.

12. Nweze, N. O., & Nwafor, F. I. (2014). Phytochemical, proximate and mineral composition of leaf extracts of *Moringa oleifera* Lam from Nsukka, Southern Nigeria. *Journal of Pharmaceutical and Biological Sciences*, 9(1): 99–103.

13. Adline, J., & Devi, J. (2014). A study on phytochemical screening and antibacterial activity of *Moringa oleifera*. *International Journal of Research Applications*, 2: 169–176.

14. Rameshwar, P. K., Manish, M. P., Nilesh, R. K., Kirit, R. V., & Patel, R. K. (2010). *In vitro* hepatoprotective activity of *Moringa oleifera* Lam. leaves on isolated rat hepatocytes. *International Journal of Physical Sciences*, 2(1): 457–463.

15. Manikandan, R., Subramanian, S., & Murugan, K. (2016). *Efficacy of botanical insecticides against okra leafhopper, Amrasca biguttula biguttula (Ishida).* Journal of Biopesticides, 9(2), 182–186.

16. Kambou, G., & Guissou, I. P. (2011). Phytochemical composition and insecticidal effects of aqueous spice extracts on insect pests found on green

beans (*Phaseolus vulgaris*) in Burkina Faso. *Tropicultura*, 29(4): 212–217.

17. Benson, G. A. S. (2017). Efficacy of selected insecticides and botanicals in the control of field insect pest of okra (*Abelmoschus esculentus*) in Akure. *International Journal of Horticulture*, 3(4): 1–5.

18. Ray, A. (2018). Studies on insect-pests of okra (*Abelmoschus esculentus*) with special reference to seasonal incidence and bio-rational management of okra shoot and fruit borer (*Earias* spp.) [MSc thesis]. Bilaspur (IN): Barrister Thakur Chhedilal College of Agriculture and Research Station. [Accessed 2019 Sep 9]. Available from: https://www.researchgate.net/publication/329363006.

19. Parugrug, M. L., & Roxas, A. C. (2008). Insecticidal action of five botanical plants against maize weevil (Sitophilus zeamais Motsch.) in stored corn. Philippine Entomologist, 22(1): 51–61.

20. Ogunsina, O. O., Oladimeji, M. O., & Lajide, L. (2011). Insecticidal action of hexane extracts of three plants against bean weevil, Callosobruchus maculates (F.) and maize weevil, Sitophilus zeamais Motsch. Journal of Entomology and Natural Environment, 3(1): 23–28.

21. Kedar, S. C., Kumaranag, K. M., & Thodsare, N. (2013). Integrated pest management of 12 important pests of okra. Krishisewa. [Accessed 2019 Mar 20]. Available from: www.krishisewa.com.

22. Djieto, L., Kouakou, B., & Kouassi, R. (2007). Contribution à la connaissance des insectes associés aux cultures maraîchères dans les environs de Yaoundé-Cameroun. Journal of Biological Chemistry, p. 151–153.

23. Kouassi, A. E. (2010). Étude comparée de l'efficacité des extraits de neem (Azadirachta indica) et de papaye (Carica papaya) dans la lutte contre les ravageurs du gombo (Abelmoschus esculentus) [Undergraduate thesis]. Yamoussoukro (CI): ESA Yamoussokro. p. 80.

25. Obeng, O. D., & Sockey, J. (2003). Field evaluation of non-synthetic insecticides for the management of insect pests of okra, Abelmoschus esculentus (L.) Moench in Ghana. Sinet Ethiopian Journal of Science, 26(2): 145–150.

25. Yeboue, N. I., Foua, B. K., & Kehe, M. (2002). Inventaire de l'entomofaune associée à la culture du gombo (Abelmoschus esculentus) en zone forestière de Côte d'Ivoire. Agronomie Africaine, 14(13): 165–181.

26. Ogbalu, O. K., & Ekweozor, I. (2002). The distribution of okra flea beetles on three varieties of okra in traditional farms of Niger Delta. Tropical Science, 42: 52–56.

27. Gayi, D., Lubbadde, G., Biruma, M., Echaku, S., Ejiet, E., & Ocen, D. (2017). Distribution and seasonal occurrence of major insect pests of cotton in Uganda. International Journal of Environment Agriculture and Biotechnology, 2(5): 2279–2287.

28. Kalidas, S., & Sahayaraj, K. (2012). Survey of Reduviids in cotton agro-ecosystem of Tamil Nadu, India. Crop Protection Research Centre. Palayamkottai: St. Xavier's College.

29. Nagrare, M. G., Inhsha, P., Penmani, L., & Olafama, F. (2011). Population dynamics of mealy bugs in tropical wetlands. Journal of Applied Science, 4: 122–128.

30. Gerard, P. J., & Ruf, L. D. (1991). Screening of plants and plant extracts for repellency to Tinea dubiella, a major New Zealand wool pest. In: Proceedings of the 44th New Zealand Weed and Pest Control Conference. p. 205–208.

31. Russell, G. B., & Lane, G. A. (1993). Insect antifeedants: A New Zealand perspective. In: Proceedings of the 46th New Zealand Plant Protection Conference. p. 179–186.

32. Emimal, V. E. (2010). Pest infestation on the biochemical modulation of Adhatoda vasica. Journal of Biopesticides, 3(2): 413–419.

33. Alao, F. O., Adebayo, T. A., & Olaniran, A. O. (2018). Bioefficacy of Moringa oleifera and Anacardium occidentale against insect pests of watermelon (Citrullus lanatus Thumb) and their effects on watermelon fatty acid profile. Acta Fytotechnica et Zootechnica, 21(3): 84–92.

34. Usman, I. (2004). Prospects and problems of vegetable production under Fadama area of Bauchi, Nigeria. Nigerian Journal of Horticultural Science, 9(1): 1118–2733.

35. Isman, M. B. (2006). Botanical insecticides, deterrents and repellents in modern agriculture and increasingly regulated world. Annual Review of Entomology, 51: 45–66.

36. Alao, F. O. (2015). Effects of plant extracts in the control of field insect pests associated with watermelon [PhD thesis]. Ogbomosho (NG): Ladoke Akintola University of Technology.

37. Seljasen, R., & Meadow, R. (2006). Effect of neem on oviposition and egg and larval development of Mamestra brassicae L: Dose response, residual activity, repellent effect, and systemic activity in cabbage plants. Crop Protection, 25: 238–345.

38. Alao, F. O., & Adebayo, T. A. (2015). Comparative efficacy of Tephrosia vogelii and Moringa oleifera against insect pests of watermelon (Citrullus lanatus Thumb). International Letters of Natural Sciences, 36: 71–78.

39. Degri, M. M. (2014). The effect of spacing of eggplant (Solanum melongena L.) (Solanaceae) on shoot and fruit borer (Leucinodes orbonalis Guen.) (Lepidoptera: Pyralidae) infestation in the dry Savanna zone of Nigeria. Agriculture and Biology Journal of North America, 5(1): 10–14.

40. Scarratt, S. L. (2005). Enhancing the biological control of leafrollers (Lepidoptera: Tortricidae) using floral resource subsidies in an organic vineyard in Marlborough, New Zealand [PhD dissertation]. Lincoln (NZ): Lincoln University. p. 132.

41. Amutha, R. C., & Raj, D. P. (2016). Assessment of a botanical pesticide

against the okra leaf roller Sylepta derogata. Journal of Global Biosciences, 5(8): 4463–4466.

42. Mohamed-Ahmed, M. M. (2000). Studies on the control of insect pest in vegetable (okra, tomatoes, and onions) in Sudan with special reference to neem preparations [PhD dissertation]. Giessen (DE): University of Giessen.

43. Ahmed, B. I., Yusuf, S. R., Yusuf, A. U., & Aliyu, M. (2007). Comparative efficacy of different concentrations of some insecticides for the control of Podagrica sp. (Coleoptera: Chrysomelidae) on okra. Global Journal of Agricultural Science, 6: 311–314.

44. Adesina, J. M., & Idoko, J. E. (2013). Field evaluation of insecticidal activity of Chemopodium ambrosiodes and Spondias mombin crude extract for the control of okra flea beetle Podagrica uniforma Jacq. (Coleoptera: Chrysomelidae). Research Journal of Agricultural Sciences, 4(1): 37–39.

45. Adesina, J. M., & Afolabi, L. A. (2014). Comparative bio-efficacy of aqueous extracts of Loncarpous cyanescens and Trema orientalis against flea beetle (Podagrica spp.) (Coleoptera: Chrysomelidae) infestation and yield of okra. International Journal of Horticulture, 4(2): 4–9.

46. Dike, M. C., & Mbah, O. I. (1992). Evaluation of lemon grass (Cymbopogon citratus Staph.) products in the control of Callosobruchus maculatus Fab. (Coleoptera: Bruchidae) on stored cowpea. Nigerian Journal of Plant Protection, 14: 88–91.

47. Attieri, M. A. (1993). Designing and improving pest management systems for subsistence farmers. In: Attieri, M. A. (Ed.), Boulder (CO): West View Press. p. 1–20.