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Comparative efficacies of phytopesticides in the management of *Podagrica* spp and mosaic disease on okra (*Abelmoschus esculentus* L.)

ABSTRACT

Aims: To evaluate the effectiveness of different aqueous plant extracts on the management of flea beetles (*Podagrica* spp) and mosaic disease on okra

Study design: The treatments applied were 10% (w/v) crude extract each of neem leaf, garlic, mahogany bark, chilli pepper fruit, pawpaw leaf, bougainvillea leaf and the control (water), laid out in a Randomized Complete Block Design with four replications

Place and Duration of Study: School of Agriculture Teaching and Research Farm, University of Cape Coast, Ghana during the 2012 crop season.

Methodology: The treatments were applied weekly starting 21 days after sowing. Data was taken on the population of *Podagrica* species, severity of leaf damage, incidence and severity of okra mosaic disease. Data was subjected to analysis of variance and means separated with least significant difference.

Results: All the phytopesticides significantly reduced the flea beetle populations and the corresponding leaf damage on the okra plants than the control (P = 0.05). However, neem leaf and garlic extracts were significantly better than the other phytopesticides in reducing the pest population and the leaf damage (P = 0.05) resulting in the highest fruit yield. Incidence and severity of the okra mosaic disease were significantly kept under control by the neem, garlic and bougainvillea extracts as compared to the other treatments. Population of the flea beetle was positively and significantly correlated with leaf damage (r = 0.821; P = 0.05), and severity of okra mosaic disease (r = 0.786; P = 0.05) but negatively correlated with fruit yield (r = -0.750; P = 0.05). Fruit yield was also negatively and highly correlated with leaf damage (r = -0.857; P = 0.05) and the severity of okra mosaic disease (r = -0.821; P = 0.05).

Conclusion: Neem leaf and garlic extracts are effective in reducing flea beetle infestation and okra mosaic disease infection, resulting in a high fruit yield in okra.

Keywords: Okra, okra mosaic disease, *Okra mosaic virus, phytopesticides, Podagrica* spp.

1. INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench), a Malvaceae, is an important vegetable crop in West Africa, India, Brazil and the United States of America [1]. The world production of common okra as fresh fruit vegetable is estimated at 1.7 million t/year [2]. Okra is the most important fruit vegetable crop in Ghana, and a source of calories (4550 kcal/kg) for human consumption [3]. Consumption of 100 g of fresh okra fruit provides 0.066g, 0.0015g and 0.013g of the daily requirement of calcium, iron and vitamin C, respectively [2]. The West and Central African region including Ghana account for more than 75% of okra produced in Africa, but average productivity in the region is very low (2.5 t./ha) compared to East (6.2 t/ha) and North Africa (8.2 t/ha) [4].

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The low productivity of okra in Ghana could be due to several production constraints including biotic and abiotic factors. Insect pests and plant viruses are important biotic factors causing severe constraints on the productivity of wide range of economically important crops worldwide [5, 6]. The most important pests infesting okra are the leaf hopper (*Amrasca biguttula*), flea beetles (*Podagrica* spp.) and the cotton stainer (*Dysdercus superstitious*) and whitefly [7, 8, 9]. In Ghana, *Podagrica* spp is the most important pest affecting okra production [7]. Okra is also susceptible to at least 19 plant viruses with *Okra mosaic virus* (OkMV) and *Okra leaf curl virus* (OLCV) being the most common and well-studied [10, 11]. Okra mosaic virus disease (OMD) caused by the OkMV transmitted by *Podagrica* species [12] and okra leaf curl disease caused by the OLCV transmitted by *Bemisia tabaci* have currently been reported on okra in Ghana. The OkMV induces mosaic, vein chlorosis and banding and plant stunting [10, 13]. Okra mosaic virus disease infection has been reported to cause up to 90% yield loss [14, 15].

Managing these pests and diseases is therefore very necessary in order to improve yield and quality of okra. Most of the research work on the control of virus and its vector has been oriented towards chemical method. The use of synthetic pesticides however results in the development of resistant pest strains; toxicity to man and animals, environmental pollution, and it is also expensive. It has been estimated by the World Health Organization (WHO) that about 20,000 people die each year from pesticide poisoning and at least 3 million people suffer acute health effects [16]. It was reported that plants treated with lambda-cyhalothrin, a conventional pesticide, at 5 mL/litre suffered the least damage to their leaves by the insects but it was slightly phytotoxic as the leaves were seen to show deformity [17]. Searching for new alternatives to synthetic pesticides is therefore very important. Phytopesticides have been shown to be important promising alternative, compatibility with other pest and disease management methods [18]. They are non-phytotoxic, environmentally friendly, non-toxic to man and also cheap. The use of aqueous plant extracts with pesticidal properties for insect pest control in crops has been well documented. Botanical powder, oils and extracts which have shown various degrees of toxicity against many insect pests and diseases include neem, lemon grass, mahogany, chilli pepper, citrus peel, black pepper, garlic, and bougainvillea [19-23]. In Ghana, there is little information on botanicals which are effective against pests and diseases of okra. It is therefore worthy to evaluate the efficacy of different botanicals for the management of field insect pests and viral diseases of okra. The aim of this study was to evaluate the effectiveness of the crude extracts of neem leaves, garlic, mahogany bark, chilli pepper fruit, pawpaw leaf, and bougainvillea leaves in the management of flea beetles and okra mosaic disease in okra.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at the School of Agriculture Teaching and Research Farm of the University of Cape Coast during the 2012 crop season. This location (5.1000° N, 1.2500° W) falls within the coastal savannah agro-ecological zone of the country with Acrisol soil type [25] and is a highly endemic site for OkMV disease. The area has a bi-modal rainy season from May to June and August to October with an annual rainfall ranging between 750 and 1000 mm and .an average daily temperature of 25.8 ^{0}C [25].

2.2 Experimental design and field layout

The Randomized Complete Block Design (RCBD) was used with seven treatments and four replications. A total land area of 351m^2 measuring 27 m x 13 m was used for the study. The land was cleared of all vegetation cover and was then ploughed and harrowed with a disc plough and disc harrow respectively to render the soil loose. It was then partitioned into four

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blocks and each block was further divided into seven plots, with each plot measuring 2.5 m x 2.5 m. A distance of 1 m was left as walkway between the blocks and the plots. Planting was done in May, 2012. The seeds of an early maturing okra variety "Asontem" obtained from an agro-chemical store in Cape Coast were directly sown at two seeds per hole at a planting distance of 0.8m x 0.8m and a planting depth of not more than 0.5cm, resulting in sixteen plants per plot. Weeding and watering were done when necessary.

2.3 Preparation and application of treatments

The treatments were 10% (w/v) crude extracts each of neem leaf, pawpaw leaf, bougainvillea leaf, garlic cloves, chilli pepper fruits, mahogany bark, and control (distilled water). Each of these treatments was prepared by weighing 100g of air-dried plant material with an electronic balance (ADP 2100 series, Sartorius and Adam equipment, New Jersey, USA), homogenized with pestle and mortar and then allowed to seep overnight in 1 litre distilled water. The extracts were then filtered through cheesecloth to obtain aqueous extracts. Mild soap was added to each of the prepared plant extract to serve as an additive which allowed the extract to stick to the leaves' surfaces and undersides. The treatments were applied to the plants on the field at 21 days after sowing (DAS) when the plants were about 30 cm tall. Subsequent application of the treatments was carried out at weekly intervals till the plants reached the fruiting stage.

2.4 Data collection

Data on the population of *Podagrica* spp, and the damage caused to the okra leaves, as well as the incidence and severity of okra mosaic disease were collected, starting 21DAS, and then weekly till maturity. Fruit yield was also determined. In each case data was taken on five plants selected from the middle of each plot, and the mean determined. The population of the *Podagrica* spp was determined based on their visual count on the okra plants. The severity of leaf damage by the *Podagrica* spp was assessed using a modification of Peterson's scale for damage assessment as has been used by other worker [26] (Table 1).

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Table 1. Assessment of leaf damage by *Podagrica* spp

Code	% Damage	Description
0	0	No apparent damage
1	25	About a quarter ($\frac{1}{4}$) of total leaf area were damaged
2	50	About half ($\frac{1}{2}$) of total leaf area were damaged
3	75	Three quarters ($\frac{3}{4}$) of total leaf area were damaged
4	95	Only few leaves, leaves green, stem green
5	100	All leaves and stem eaten

Incidence of okra mosaic disease (DI), based on visual symptoms, was determined as the proportion of infected plants per plot, expressed as a percentage, as described [27]. Thus, DI = $\frac{x}{n}\ x\ 100$ where 'x' is the number of plants infected with the mosaic disease and 'n' is the total number of plants observed.

Disease severity was assessed on the basis of rating scale [28] indicated in Table 2.

Table 2. Rating of okra mosaic disease

Score	Description
0	Healthy, asymptomatic plant
1	Mild mosaic, mottle or chlorosis on leaves
2	Moderate chlorosis, mottle or mosaic without significant leaf distortion
3	Score 1 or 2 plus leaf malformation
4	Severe chlorosis, mottle or mosaic plus stunting or dwarfing of the whole plant
5	Score 4 plus leaf drop, and dying

The disease severity index (DSI) was then calculated according to the formula below [27].

DSI (%) = $\frac{\{(P\ x\ Q)\}}{(M\ xN)} \times 100$

Where P = severity score, Q = number of infected plants having the same score; M = Total number of plants observed, N = Maximum rating scale number.

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The yield of okra was obtained by harvesting the matured fruits on each plant per plot. The harvested fruits were weighed using the electronic balance (ADP 2100 series, Sartorius and Adam equipment, New Jersey, USA) to obtain the fruit weight per plot.

2.5 Data Analysis

Data collected was transformed using the square root transformation method to ensure homogeneity of the variance and normal distribution of the data. The data was later subjected to analysis of variance (ANOVA) using Genstat Release version 12.1 [29]. Means were separated using least significant difference at a probability of 5%.

3. RESULTS

3.1 Effects of phytopesticides on the population of flea beetles (*Podagrica* spp)

The effects of plant extracts on the population of *Podagrica* spp on the okra plants are presented in Table 3. An ANOVA revealed that the protected plants had on average significantly fewer pest populations than the unprotected plants (control) ($F_{6, 18}$ = 6.5; P = .01). This indicates that the population of the flea beetles was affected by all the phytopesticides as compared to the untreated plants (control). The control plot recorded the highest mean population of 4.1 flea beetles per plant whereas the neem-protected plot recorded the least population of 2.5 flea beetles per plant. The mean flea beetle populations recorded for the protected plants also differed significantly among them (P = .05). The mean flea beetle population recorded for the neem extract-treated plants was not significantly different from those treated with garlic extract but was significantly lower than those treated with mahogany, pawpaw and bougainvillea extracts, which did not differ significantly among them. This suggests that both neem and garlic extracts were more effective in reducing the population of flea beetles on the okra plants than the other treatments.

Table 3 also shows the level of leaf damage by the flea beetle infesting the okra plants which were given the various treatments. The ANOVA also showed that on the average, plants treated with the phytopesticides experienced less leaf damage due to pest attack, than the control (unprotected) ($F_{6, 18}$ = 16.3; P = .01). Okra plants treated with neem leaf extract recorded the least mean leaf damage of 4.2% which was significantly different from those recorded for the other treatments and the control. Plants treated with garlic extract also recorded significantly lower leaf damage than those treated with mahogany, pawpaw, bougainvillea and chilli pepper extracts (P = .05). However, there was no significant difference among mahogany bark, chilli pepper, pawpaw leaf, and bougainvillea leaf extracts which recorded mean leaf damage of 5.3%, 5.1%, 5.2%, and 5.0% respectively in controlling the leaf damage (Table 3).

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Table 3. Mean population of *Podagrica* spp and the level of leaf damage caused to the okra plants treated with different phytopesticides

Treatments	Flea beetles	Leaf damage
Neem leaf extract	2.5	4.159
Mahogany bark extract	3.4	5.325
Garlic cloves extract	2.8	4.701
Chilli pepper fruit extract	2.9	5.169
Pawpaw leaf extract	3.4	5.211
Bougainvillea leaf extract	3.4	5.038
Untreated or control	4.1	5.996
l.s.d (P = .05)	0.61	0.42
CV (%)	12.8	5.5

Mean values with differences less than the l.s.d are not significantly different from each other (P = .05).

3.2 Effects of phytopesticides on the incidence and severity of okra mosaic disease (OMD)

The ANOVA of the effect of the phytopesticides on the incidence of okra mosaic disease showed significant differences between the treatments ($F_{6, 27}$ = 2.81; P = .04), indicating that the okra plants differ on their mean disease incidence independent of whether they were protected with phytopesticides or not (Table 4). Okra plants treated with the neem leaf extract recorded the lowest incidence of okra mosaic disease with a mean incidence of 2.8% but this was not significantly different (P >.05) from those treated with garlic and bougainvillea extracts with mean incidences of 4.3% and 4.2% respectively (Table 4). However, the untreated okra plants recorded the highest mean incidence of OMD (5.9%), which was not significantly different from those treated with mahogany bark, chilli pepper, and pawpaw leaf extracts with mean incidences of 5.5%, 4.9%, and 5.5% respectively (Table 4).

Moreover, the level of severity of okra mosaic disease was lowest in plants treated with neem leaf extract with a mean severity index of 1.5% but was not significantly different from those treated with garlic extract and bougainvillea leaf extract with mean incidence of 2.1% each. On the other hand, severity of OMV disease was highest in the untreated control plants with a mean severity index of 3.2% but was not significantly different from those

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treated with mahogany bark extract, chilli pepper extract, and dried pawpaw leaf extract with mean severity indices of 2.7%, 2.5%, and 2.8% respectively (Table 4).

Table 4. Incidence and severity of okra mosaic disease on okra plants treated with different phytopesticides

Treatments	Mean incidence of okra mosaic disease (%)	Mean severity index of okra mosaic disease (%)
Neem leaf extract	2.82	1.52
Mahogany bark extract	5.49	2.70
Garlic clove extract	4.29	2.12
Chilli pepper fruit extract	4.91	2.54
Pawpaw leaf extract	**5.54**	2.80
Bougainvillea leaf extract	4.21	2.11
Untreated or control	5.96	3.16
L.s.d (*P* = 0.05)	1.89	0.84
CV (%)	26.8	23.4

Mean values with differences less than the l.s.d are not significantly different from each other (P = .05).

3.3 Effects of phytopesticides on the progress or spread of OMV disease on the okra plants

Whether treated or not, the severity of the OMD infection of the okra plants increased from 28 DAS till 84 DAS, indicating that the disease progressed with time (Figure 1). However, the phytopesticides were able to reduce the degree of the OMV disease infection and / or delay the onset of the disease infection on the okra plants as compared to the control. Whilst the level of OMV infection of the untreated okra plants increased after 28 DAS, plants treated with garlic and neem extracts became severe after 35 DAS and 49 DAS respectively. Although OMD infection of plants treated with bougainvillea and mahogany were severe at 35DAS, they were less severe than the control. This indicates that neem extract was the most effective phytopesticide in reducing and/or delaying the OMD infection, followed by

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garlic, and bougainvillea, whereas chilli pepper and pawpaw leaf were less effective (Figure 1).

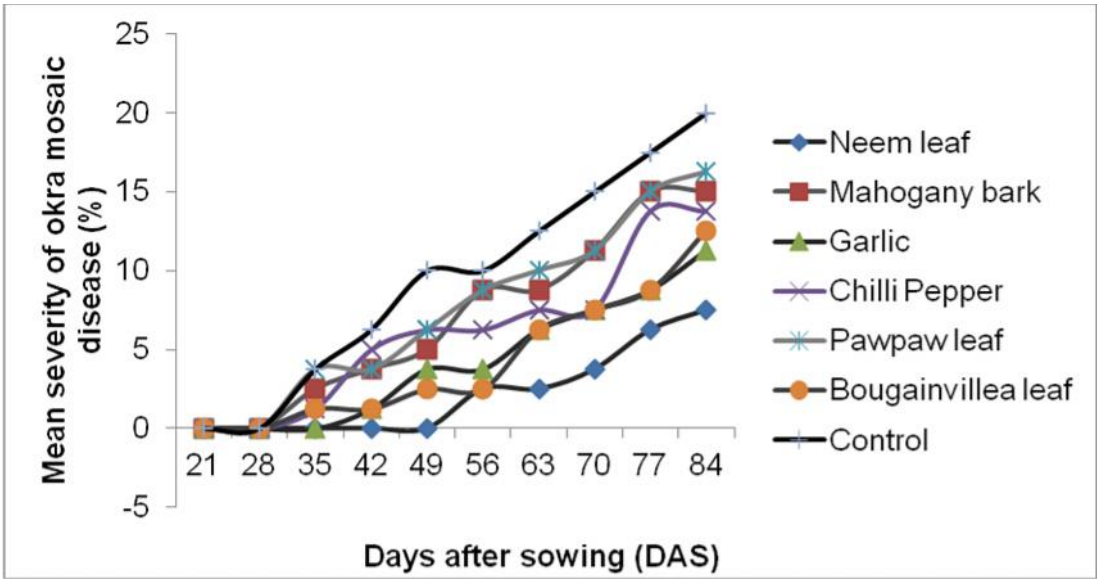

Fig. 1. Disease progress curves of okra mosaic virus infection of okra plants treated with different phytopesticides

3.4 Effects of botanicals on the yield of Okra

It was observed that okra plants treated with neem leaf extract recorded the highest yield with a mean of 163.3 kg/ha which was significantly different (P = .05) from those treated with the other botanicals as well as the untreated okra plants (Table 5). The mean yield of okra plants treated with garlic extract (128.7 kg/ha) was also significantly different (P = .05) from those treated with the aqueous extracts of mahogany, bougainvillea, chilli pepper, pawpaw leaf and the control (untreated plants), which did not differ significantly among them (P > 0.05. However, the untreated okra plants recorded the lowest yield of 93.9 kg/ha (Table 5).

Table 5. Mean yield of okra plants treated with different phytopesticides

Treatments	Mean yield (kg/ha)
Neem leaf extract	163.3
Mahogany bark extract	117.2
Garlic clove extract	128.7
Chilli pepper fruit extract	111.9
Pawpaw leaf extract	114.1

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Bougainvillea leaf extract	122.4
Control	93.9
l.s.d (*P* = .05)	29.5
CV (%)	16.3

Mean values with differences less than the l.s.d are not significantly different from each other (P = .05).

3.5 Relationship between the population of *Podagrica* spp, leaf damage, okra mosaic disease on leaves, and yield of okra plants

Table 6 shows the relationships amongst the parameters studied**.** Population of flea beetle was positively and significantly correlated with leaf damage (r = .821; *P* = .05), and severity of okra mosaic disease (r = .786; *P* = .05) but negatively correlated with fruit yield (r = -.750; *P* > .05). This implies that the flea beetles was directly associated with the leaf damage and the viral disease observed on the okra.

However, fruit yield was negatively and tightly correlated with leaf damage (r = -0.857; *P* = .05) and the severity of okra mosaic disease (r = -.929; *P* = .05).This indicates that the higher the leaf damage by the flea beetle and the higher the severity of the okra mosaic disease, the lower the fruit yield of okra.

Table 6. Correlation between *Podagrica* spp population, pest damage on leaves, severity of mosaic disease and yield of okra.

	***Podagrica* spp**	**Pest damage**	**Mosaic disease**	**Fruit yield**
Podagrica spp.	-			
Pest damage	0.821*	-		
Mosaic disease	0.786*	0.929**	-	
Fruit yield	-0.750 ns	-0.857*	-0.821*	**-**

*Probability levels (*P = .05, **P = .01)*

(NS, not significant (*P* > 0.05), * significant at *P* = .05 and **significant at *P* = 0.01)

4. DISCUSSION

The management of plant viral diseases involves two main aspects viz protecting the host plant with disease inhibiting materials, so that either virus multiplication in them decreases or stops or insect vector fails to acquire viruses from infected host, and the use of disease inhibiting materials for the control of vectors [30]. Phytopesticides are used in the

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management of plant viral diseases because they contain active ingredients such as azadirachtin, allicin, capsaicin, and papain which have properties such as repellent, anti-feedant, anti-oviposition, virus inhibitor, and growth regulating [24, 30].

In the present study, the effectiveness of aqueous extracts of *Azadirachta indica*, *Allium sitavum*, *Carica papaya*, *Khaya* sp., *Bougainvillea* sp., and *Capsicum frutescens* for the control of flea beetles (*Podagrica* spp.) and okra mosaic virus disease on okra crop plants were evaluated. The plant extracts exhibited moderate to high level of activity in reducing the populations of flea beetles as well as reducing the incidence and severity of okra mosaic virus disease. Neem leaf extract followed by garlic extract were the most effective in reducing the population of flea beetles on the okra plants. This work, therefore, confirms the findings of other researchers [31]. Neem has been reported to possess anti-feedant properties, repellent properties, anti-oviposition properties and also suppresses hatching of insect pests from their eggs [20]. It has been shown that 10% aqueous extract of *Piper guineense* and *Azadirachta indica* has significant repellence activity against okra flea beetle, *Podagrica uniforma* [23]. The potential insecticidal properties of neem against the flea beetle, *Podagrica nemoru* has also been demonstrated [32]. It has however, been reported that *Azadirachta indica* leaf extract is comparatively less effective than chemical pesticide (lambda-Cyhalothrin) in the control of *Podagrica* spp on okra [17]. Garlic has also been reported to possess repellent and anti-feedant properties [20]. Chili peppers has broad spectrum of activity against insect pests, acting effectively as a stomach poison, repellent and antifeedant [32].

Okra plants protected with the plant extracts recorded significantly lower leaf damage than the control. This may be due to the ability of the phytopesticides to control the population of the flea beetles on the okra plants as compared to the control. This is supported by the significant positive correlation between the population of the flea beetle and the leaf damage observed in this study (Table 4). *Podagrica* sp is a major okra defoliator and fruit feeder [33] reported to cause heavy defoliation of up to 80% of the okra leaves surface [8].Therefore, substantial reduction or controlling of the population of flea beetles on the okra plants by the plant extracts also resulted in a significant reduction in the pest damage on leaves of the okra plants treated with the plant extracts. Neem and garlic extracts were significantly more effective than the other botanicals in reducing the leaf damage. This work thus confirms the findings of Ackah et al. (2013) which showed that neem leaf and garlic extracts are very effective in reducing the severity of pest damage on okra plants. This could be due to the reported effectiveness of the neem and garlic aqueous extracts in controlling the population of *Podagrica* spp [20, 23, 32]

Okra plants protected with the aqueous extracts of neem, garlic and bougainvillea recorded significantly lower incidence and severity of OMD than those treated with the other botanicals and the control. This could be due to the ability of these phytopesticides to either control the flea beetle vector or inhibition of the OMD infection. Significantly positive correlation between the population of *Podagrica* spp and the severity of OMD was also realized in this present study, suggesting that the insect vector was at least partly responsible for the severity of the OMD observed. Okra mosaic virus has been reported to be transmitted by insects belonging to *Podagrica* species [12, 34]. The virus inhibition properties of the active ingredients of the neem leaf extract [20, 35], garlic extract [36]) and bougainvillea leaf extract [24] are well documented. This suggests that the neem leaf extract, garlic extract and bougainvillea leaf extract can be used for effective management of OMD on okra plants.

All the phytopesticides were able to reduce the progress of the OMV diseases on the okra plants as compared to the untreated control. This suggests that the plant extracts possess

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virus inhibitory phytochemicals which inhibits the multiplication of the viruses in the okra plants. This finding is supported by other workers [22]. The lower rate of plant infection may be due to the effect of the phytopesticides on the vectors of the virus or directly on the disease. In most research works, however, plant extracts had been used as virus inhibitor [36]. Neem leaf extract was the most effective phytopesticide in reducing the progress of the OMV disease on the okra plants, followed by garlic extract and bougainvillea leaf extract respectively. It has also been revealed that neem leaf extracts are more effective in controlling OMV infection in okra as compared to garlic extracts [22].

Okra plants treated with neem leaf extract recorded the highest yield, followed by those treated with garlic extract which was significantly different from those treated with all the other botanicals as well as the untreated okra plants which had the lowest yield. This could be due to the effect of the neem and garlic extracts in reducing the population of *Podagrica* spp as well as reducing leaf damage and the severity of OMD infection. It was observed in the present study that fruit yield was negatively correlated with the population of *Podagrica* spp, leaf damage and the severity of okra mosaic disease. This confirms the findings of other workers [17] which showed a significant inverse relationship between dry pod yield and surface area of leaf damage. The neem leaf extract had an added advantage of being able to release certain nutrients like nitrogen to the okra plants for faster vegetative growth and development of the fruits (pods) hence recording the highest significant yield in the okra plants with which it was treated. It was reported that neem leaf extract has high percent nitrogen and phosphorus of 1.56% and 0.83% respectively [37]. This work confirms the findings of other workers [13] which showed that okra plants treated with the plant extracts recorded higher yield as compared to the yield of the untreated control okra plants. Okra mosaic virus (OMV) disease infection has been reported to cause a yield loss of 26% of total achievable yields in okra [15]. This indicates that successful control of the incidence and severity of the disease on okra plants by plant extracts will lead to the achievement of higher yields.

5. CONCLUSION

Podagrica spp was found to be associated with leaf damage and OMD infection in okra. The phytopesticides were effective in reducing the vector population as well as reducing the incidence and severity of OMD, resulting in a high yield of the okra. Aqueous neem leaf extract, followed by garlic and bougainvillea were the most effective phytopesticides in the study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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