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Comparative Efficacy of Phytopesticides in the Management of *Podagrica* spp and Mosaic Disease on Okra (*Abelmoschus esculentus* L.)

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Authors' contributions

This work was carried out in collaboration between all authors. Author EAB designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author ABK collected field data. Authors AAQ and ABK performed the statistical analysis and managed the analyses of the study. All authors read and approved the final manuscript.

Original Research Article

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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, chili 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 pest 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 pest 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 pest damage (P=0.05) resulting in the highest fruit yield. Incidence and severity of the okra mosaic disease were significantly kept under control by

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the neem, garlic and bougainvillea extracts as compared to the other treatments. Population of the flea beetle was positively and significantly correlated with pest 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 pest 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 were effective in reducing flea beetle infestation and okra mosaic disease infection, resulting in 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 $year^{-1}$ [2]. Okra is the most important fruit vegetable crop in Ghana, and a source of calories ($4550kcalkg^{-1}$) for human consumption [3]. Consumption of 100g 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 ($2.5tha^{-1}$) compared to East ($6.2tha^{-1}$) and North Africa ($8.2tha^{-1}$) [4].

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 a 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 the whitefly [7-9]. 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 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 viruses and their 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 suffered the least leaf damage 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, compatible 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. These include neem, lemon grass, mahogany, chili pepper, citrus peel, black pepper, garlic, and bougainvillea [19-24]. In Ghana, there is little information on phytopesticides which are effective against pests and diseases of okra. It is therefore worthy to evaluate the efficacy of different phytopesticides for the management of field insect pests and viral diseases of okra. The objective of this study was to evaluate the effectiveness of the crude extracts of neem leaves, garlic, mahogany bark, chili pepper fruit, pawpaw leaf, and bougainvillea leaves in the management of flea beetles and mosaic disease in okra.

2. MATERIALS AND METHOD

2.1 Experimental Site

The experiment was conducted at the School of Agriculture Teaching and Research Farm of the University of Cape Coast, Ghana during the major rainy season of the 2012 crop season. This location (5°10'N, 1.2°50'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 1000mm and an average daily temperature of 25.8°C [25].

2.2 Experimental Design and Field Layout

The Randomized Complete Block Design (RCBD) with seven treatments and four replications was used. A total land area of 351m^2 measuring 27mx13m 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 blocks and each block was further divided into seven plots, with each plot measuring 2.5mx2.5m. 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 0.8mx0.8m 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, chili 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. Ten ml of mild soap was added to each prepared plant extract, enabling them to attach to the leaf surfaces. The treatments were applied to the plants on the field at 21 days after sowing (DAS) when the plants were about 30cm 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, the damage caused to the okra leaves, and the incidence and severity of okra mosaic disease were determined by observing visual symptoms from 21 DAS, and thereafter weekly until maturity. The severity of pest 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.

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

Score	% 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 of total number of plants observed, as described [27].

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].

$$DSI(\%) = \frac{\sum(PxQ)}{(MxN)} x\ 100$$

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

The yield of okra was obtained by harvesting the matured fruits on five plants from the middle of each 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 and the mean fruit weight per plant determined.

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 Gen Stat Release version 12.1 [29]. Means were separated using least significant difference at a probability of 5%.

3. RESULT

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=0.01). 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*=0.05). 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 pest damage to the leaves of the okra plants on which various treatments were applied. The ANOVA also showed that on the average, plants treated with the phytopesticides experienced less pest damage than the control (unprotected) ($F_{6,\ 18}$=16.3; P=0.01). Okra plants treated with neem leaf extract recorded the least mean pest 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 pest damage than those treated with mahogany, pawpaw, bougainvillea and chili pepper extracts (P=0.05). However, there was no significant difference among mahogany bark, chili pepper, pawpaw leaf, and bougainvillea leaf extracts which recorded mean pest damage of 5.3%,5.1%,5.2%,5.0% respectively in controlling the pest damage Table 3.

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

Treatments	Flea beetles	Damage score
Neem leaf extract	2.5	4.159
Mahogany bark extract	3.4	5.325
Garlic cloves extract	2.8	4.701
Chili 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=0.05)	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=0.05).

3.2 Effects of Phytopesticides on the Incidence and Severity of Okra Mosaic Disease

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=0.04), 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>0.05) 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, chili pepper, and pawpaw leaf extracts with mean incidences of 5.5%,4.9%,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 OMD was highest in the untreated control plants with a mean severity index of 3.2% but was not significantly different from those treated with mahogany bark extract, chili pepper extract, and dried pawpaw leaf extract with mean severity indices of 2.7%,2.5%,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
Chili 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=0.05).

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 to 84 DAS, indicating that the disease progressed with time Fig. 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 35 DAS, 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 garlic, and bougainvillea, whereas chili pepper and pawpaw leaf were less effective Fig. 1.

3.4 Effects of Phytopesticides on Fruit Yield of Okra

It was observed that okra plants treated with neem leaf extract recorded the highest fruit yield with a mean of 163.3kgha^{-1} which was significantly different (*P*=0.05) from those treated with the other phytopesticides as well as the untreated okra plants Table 5. The mean fruit yield of okra plants treated with garlic extract (128.7kgha^{-1}) and bougainvillea were also significantly different (*P*=0.05) from those treated with the aqueous extracts of mahogany, chili 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 fruit yield of 93.9kgha^{-1} Table 5.

3.5 Relationship among the Populations of *Podagrica* spp, Pest Damage, Okra Mosaic Disease on Leaves, and Fruit Yield of Okra Plants

Table 6 shows the relationships among the parameters studied**.** Population of flea beetle was positively and significantly correlated with pest 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). This implies that the flea beetle was directly associated with the pest damage and the viral disease observed on the okra.

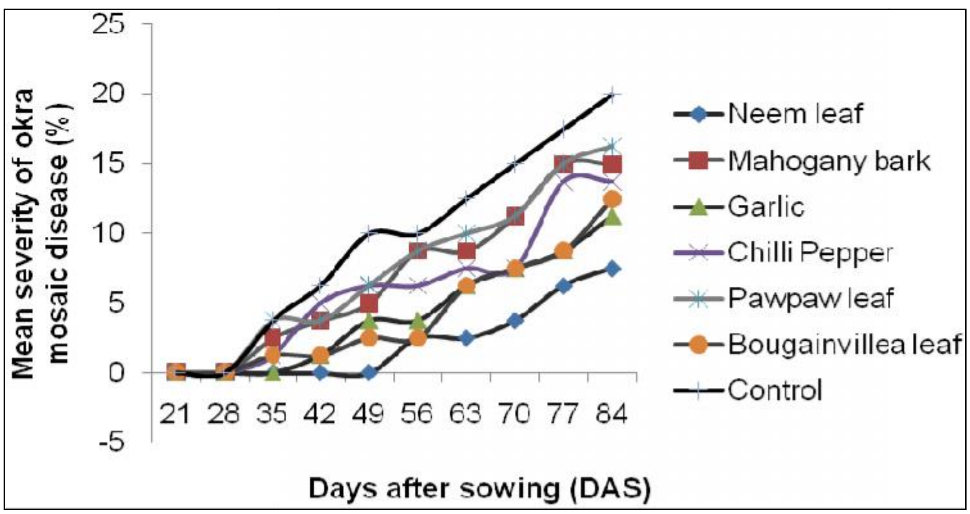

Fig. 1. Disease progress curves of okra mosaic virus infection of okra plants treated with different phytopesticides

However, fruit yield was negatively and tightly correlated with pest damage (r=-0.857; *P*=0.05) and the severity of okra mosaic disease (r=-0.929; *P*=0.05).This indicates that the higher the pest damage by the flea beetle and the higher the severity of the okra mosaic disease, the lower the fruit yield of okra.

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

Treatments	Mean fruit yield (kg ha^{-1})
Neem leaf extract	163.3
Mahogany bark extract	117.2
Garlic clove extract	128.7
Chili pepper fruit extract	111.9
Pawpaw leaf extract	114.1
Bougainvillea leaf extract	122.4
Control	93.9
l.s.d (P=0.05)	29.5
CV (%)	16.3

Mean values with differences less than the l.s.d are not significantly different from each other (P=0.05).

Table 6. Correlation among *Podagrica* spp. population, pest damage on leaves, severity of mosaic disease and fruit 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=0 .05, **P=0.01) (NS, not significant (P>0.05), * significant at P=0.05 and **significant at P=0.01)*

4. DISCUSSION

Different types of phytopesticides have been used for the management of pests and diseases of crop plants [24,30]. In the present study the phytopesticides exhibited moderate to high level of efficacy 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, garlic and chili peppers have been reported to possess anti-feedant properties, repellent properties, anti-oviposition properties and also suppresses hatching of insect pests from their eggs [17,20,23,32]. 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].

The significant reduction in the population of flea beetles on the okra plants by the phytopesticides might have resulted in the significant reduction in the pest damage on the leaves of the okra plants. This is supported by the significant positive correlation between the population of the flea beetle and the pest 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]. Neem and garlic extracts were significantly more effective than the other phytopesticides in reducing the pest damage. This work thus confirms the findings of other researchers [31].

The effectiveness of neem, garlic and bougainvillea extracts in significantly reducing the incidence and severity of OMD in the okra plants could be due to the ability of these phytopesticides to either control the flea beetle vector or inhibit 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 these phytopesticides can be used for effective management of OMD on okra plants.

The present study demonstrated that neem leaf extract and garlic were the most effective phytopesticides in reducing the progress of the OMV disease on the okra plants and consequently produced higher fruit yield. The ability of the phytopesticides to reduce the progress of the OMV diseases on the okra plants as compared to the control could be due to their efficacy in either inhibiting the multiplication of the virus in the okra plants or reducing the population of the insect vector as reported by other researchers [22,36,37]. Besides the neem leaf extract presumably had an added advantage of being able to release certain nutrients such as nitrogen to the okra plants for faster vegetative growth and development of the fruits (pods) [13,17].

5. CONCLUSION

Podagrica spp was found to be associated with pest damage and OMD infection in okra. The phytopesticides evaluated were found to be effective in reducing the vector population and the incidence and severity of OMD, resulting in high yield of 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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