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Research Article

Comparative Efficacy of Plant Extracts in Managing Whitefly (*Bemisia tabaci* Gen) and Leaf curl Disease in Okra (*Abelmoschus esculentus* L)

Elvis Asare-Bediako[1*], Albert Addo-Quaye[2], and Appiah Bi-Kusi[1]

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Abstract

Okra leaf curl disease (OLCD) is an important disease responsible for yield losses in okra in all okra growing regions in the world. Effective management of the OLCD is very important in order to improve yield. The study was conducted to evaluate the effectiveness of different botanicals in the management of the OLCD. The treatments applied were 10% (w/v) crude extract each of neem leaf, garlic, mahogany bark, chili pepper fruit, pawpaw dried leaf, bougainvillea leaf and the control (water), in a randomised complete block design with four replications. The plant extracts significantly reduced the population of whitefly vector, as well as the incidences and severities of OLCD infections and increased fruit yield compared to the control ($P < 0.05$). Neem leaf extract followed by garlic extract significantly ($P < 0.05$) reduced the populations of whitefly and the incidences and severities of OLCD but significantly increased (($P < 0.05$) fruit yield compared to crude extracts of mahogany, bougainvillea, chili pepper, and pawpaw leaves. The population of whitefly was positively correlated with severity of OLCD ($r = 0.679$; $P > 0.05$). Fruit yield was also negatively correlated with the severity of OLCD ($r = -0.857$; $P < 0.05$) and whitefly population ($r = -0.750$; $P < 0.05$). Farmers can manage OLCD in their okra fields by spraying with neem leaf or garlic extracts in order to improve fruit yields.

Keywords: Bemisia tabaci; Botanicals; Okra; Okra leaf curl disease; *Okra leaf curl virus*

1. Introduction

Okra (*Abelmoschus esculentus* (L.) Moench), is an important vegetable crop belonging to the family Malvaceae. It is reported that okra originated in Ethiopia and is now widely spread all over tropical, subtropical and warm temperate regions of the world, including in West Africa, India, Brazil and the

*Corresponding e-mail: easare-bediako@ucc.edu.gh
1* Department of Crop Science, School of Agriculture, University of Cape Coast, Cape Coat, Ghana.
2 School of Graduate Studies and Research, Central University College, Accra, Ghana.

United states (Lamont, 1999; Saifullah and Rabbani, 2009). The world production of common okra as fresh vegetable is estimated at 1.7 million tons year^{-1}(Schippers, 2000).

Okra is the most important vegetable crop in West Africa, and a source of calories (4550 kcal kg^{-1}) for human consumption and it ranks first before other vegetable crops (Babatunde et. al., 2007). The nutritive value of green okra includes water, protein, fat, carbohydrate, fibre, calcium, iron, thiamine, riboflavin, nicotinamide and ascorbic acid (Hamon, 1988; Schippers, 2000). Its production is a source of income for rural smallholder farmers and retailers in urban centres. In Ghana, yield potential of 2000-3000 kg ha^{-1} has been reported for Okra (MoFA, 2007), depending on the cultivar, harvesting frequency and period for harvesting (Cudjoe et al., 2005). However, actual yields of okra are usually low and have also decreased over the years in Ghana. Insect pests and plant viruses are major contributing factors to the low productivity of okra worldwide. The most important insect pests affecting the yield of okra are the leaf hopper (*Amrasca biguttula*), flea beetles (*Podagrica* spp.) the cotton stainer (*Dysdercus superstitious*) (Obeng-Ofori and Sackey, 2003; Dabiré-Binso et al., 2009; Singh et al., 2013) and whitefly (*Bemisia tabaci* Gen.) (Chhangani, 1994; Anaso and Lale, 2001; Singh et al., 2013). There are several viruses affecting growth and yield of okra but *Okra mosaic virus* (OMV)and *Okra leaf curl virus* (OLCV) are the most common and well-studied (Brunt *et al.,* 1990; Swanson and Harrison, 1993). Okra leaf curl virus, a persistent geminivirus transmitted by whitefly (*Bemisia tabaci* Gen.), causes a severe disease of okra which can cause yield losses of up to 80% (Brown and Bird, 1992; Basu, 1995). Okra leaf curl disease has been reported in several countries including Ghana (Bi-Kusi, 2013), Nigeria (Askira, 2012), Ivory Coast (N'Guessan et al., 1992) and Saudi Arabia (Ghanem, 2003)**.**The disease causes leaf wrinkle, curl, vein distortion, leaf yellowing, stunted growth and reduced yields (Askira, 2012).

Effective management of the OLCD and its associated whitefly vector is critical in maximizing okra yield. Managing viral diseases and their vectors using chemical pesticides has not been effective due to the development of resistant pest strains, and inappropriate application rate and frequency. The use of synthetic pesticides is hazardous to human health and the environment. It is reported (NPAS, 2012) that exposure to chemical pesticides can cause nervous system damage, birth defects, cancer, and even death. The World Health Organization (WHO) has estimated that about 20,000 people die each year from pesticide poisoning and at least 3 million people suffer acute health effects (Barabara, 1993).Botanical pesticides which are non-toxic to man and also environmentally friendly can be used as alternatives to the synthetic pesticides. They are also compatible with other pests and disease management strategies (Ahmedani et al*.,* 2007).

Plant extracts which have shown various degrees of toxicity against many insect pests include basil, neem, lemon grass, mahogany, chili pepper, citrus peel, black pepper, and bougainvillea (Ajavi et al, 1987; Schmutterer, 1990; Echerobia et al., 2010; Oladimeji and Kannike, 2009). Several botanicals including bougainvillea, garlic, and neem have also been shown to inhibit the infection and multiplication of plant viruses (Baranwal and Verma, 1992; Bhyan et al., 2007; Madhusudhan et al., 2011). There is however, limited information on the use of botanicals to manage pests and diseases of okra. It is therefore quite relevant to evaluate the efficacy of different botanicals for the management of field insect pests and viral diseases of okra. This study was aimed at evaluating the efficacy of extracts of neem leaves, garlic, mahogany bark, chili pepper fruit, pawpaw leaves, and bougainvillea leaves in the management of whitefly vector and OLCD in okra.

2. Main Research

2.1 *Experimental Site and Field Layout*
The experiment was conducted at the School of Agriculture Teaching and Research farm of the University of Cape Coast during the 2012 major rains crop season. This site is located within the coastal savannah vegetation zone, with Acrisol soil type (Parker et al., 2010) and is a highly endemic site for OLCD. The area has a bi-modal rainy season from May to June and August to October with an annual rainfall ranging 99 between 750 and 1000 mm (Parker et al., 2010) and temperatures ranging between 23.2-33.2 ºC 100 with an annual mean of 27.6 ºC (Owusu Sekyere et al., 2011).

The study involved seven treatments (10% crude extract each of neem leaf, dried pawpaw leaf, bougainvillea leaf, garlic, chili pepper, mahogany bark) laid out in a randomized complete block design (RCBD) with four replicates. The plot size was 2.5 m x 2.5 m = 6.25 m2, with 1 m between plots. Early maturing okra seeds variety "Asontem", were directly sown at two (2) seeds per hole at a planting distance of 0.8 m x 0.8 m, resulting in a plant population of sixteen (16) plants per plot. Weeding was done manually using a hoe or a machete when necessary. The experiment was set out under rain-fed conditions; hence no artificial irrigation was applied.

2.2 Preparation and application of treatments (botanicals)
Ten percent crude extract each of neem leaf, dried pawpaw leaf, bougainvillea leaf, garlic, chili pepper fruits and mahogany bark was prepared by weighing 100 g of blended air-dried plant material using the ADP 2100 series electronic balance (Sartorius and Adam equipment, New Jersey, USA) and then steeped in 1 litre of tap water. Twenty-four hours later, the mixture was strained using cheesecloth to obtain the aqueous extract. Ten ml of mild soap was added to each prepared plant extract, enabling them to attach to the leaf surfaces. Each of the prepared aqueous plant extracts was sprayed on the okra plant by the use of a knapsack sprayer, 21 days after sowing (DAS). Subsequent applications of the treatments were carried out at weekly intervals until the plants reached the fruiting stage. The spraying was done after 3pm while the sun was low in the sky. This was done to prevent the possibility of the sun rays disintegrating the active ingredients in the aqueous extracts after application. All exposed surfaces of the plant including leaves, buds, twigs, branches and fruits were sprayed according to Bhyan et al. (2007) recommendation.

2.3 *Data collection*
The number of whiteflies was visually counted and the incidence and severity of OLCD was determined by observing visual symptoms starting 21 DAS, and thereafter fortnightly until senescence. Fruit yield was based on when the fruit reached physiological maturity. In each case, the data were taken on six plants per plot and the mean determined.

Whitefly counting was usually done between 0600 and 0800 hours when the environment was cooler and whiteflies were relatively immobile than later in the day as reported by Fauquet et al. (1987). The total adult whitefly populations on the five topmost expanded leaves of five plants were determined and the mean number of whitefly per plant calculated.

Disease incidence (DI) was calculated as the proportion of infected plants per plot and expressed as a percentage of the total number of plants observed, according to Galanihe et al. (2004).

Disease severity was rated on individual plants using a visual scale of (1-7) developed by Alegbejo(1997) (Table 1).

Table 1 Disease severity rating used for assessing the severity of okra leaf curl disease (OLCD)

Disease rating	Description
0	No symptom
1	No visible disease symptom
3	Top leaves curled and slight stunting of plant
5	All leaves curled and slight stunting of plant
7	Severe curling of leaves, stunting of plant and proliferation of auxiliary branches

The disease severity index (DSI) was calculated according to the formula below (Galanihe et al., 2004):

$$\text{DSI}\ (\%) = \frac{\sum(\text{P} \times \text{Q})}{(\text{M} \times \text{N})} \times 100$$

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

The fruit yield of okra per plot was obtained by harvesting the mature fruits on each plant per plot to get the number of fruits per plot. The harvested fruits were weighed using the electronic balance (ADP 2100 series), to obtain the fruit weight per plot. The total fruit yield per plot was determined as a sum of the fruit yield taken as and when the fruits reached physiological maturity until senescence. An average of the weights of fruits per replication of each treatment was determined to obtain the yield per treatment.

2.4 Data Analysis

Data on OLCD incidences and severity indices were transformed using the Arcsine transformation, and that of whitefly population was by square root transformation, in order to ensure homogeneity of the variance and normal distribution of the data as prescribed by McDonald (2009). The data was then subjected to statistical analysis (ANOVA) using GenStat Discovery 9th edition (Payne et al., 2009). The graphical representation was done using Microsoft Excel.

3. Results

3.1 Population of whitefly (Bemisia tabaci)

While the whitefly populations on the untreated plots (control) increased steadily from 21 DAS to 77 DAS, those treated with the plant extracts showed fluctuating and relatively lower populations of whitefly (Table 2). At 21 DAS, there was no significant difference in the populations of whitefly recorded for the control and plants treated with the plant extracts ($P > 0.05$). However, at 35, 49, 63 and 77 DAS, the populations of whitefly recorded on the unprotected plot (control) were significantly higher than those treated with the plant extracts ($P < 0.05$), which did not differ significantly among them. This indicates that the plant extracts (botanicals) were effective in reducing the whitefly population.

Table 2 Mean population of whitefly on okra plants treated with botanicals

Treatment	Mean whitefly (*Bemisia tabaci*) population at				
	21 DAS	35 DAS	49 DAS	63 DAS	77 DAS
Neem leaf extract	0.837 (0.20)	0.926 (0.36)	0.707 (0.00)	0.707 (0.00)	0.707 (0.00)
Mahogany bark extract	0.926 (0.36)	0.966 (0.43)	0.966 (0.43)	0.707 (0.00)	0.707 (0.00)
Garlic cloves extract	0.837 (0.20)	0.707 (0.00	0.926 (0.36)	1.00 (0.50)	0.837 (0.20)
Chili pepper fruit extract	1.095 (0.70	0.707 (0.00	1.055 (0.61)	1.00 (0.50)	0.837 (0.20)
Pawpaw leaf extract	0.998 (0.50)	0.707 (0.00	1.127 (0.77)	1.41 (1.49)	1.246 (1.05)
Bougainvillea leaf extract	0.966 (0.43)	0.707 (0.00	1.055 (0.61)	1.12 (0.75)	1.168 (0.86)
Untreated or control	0.707 (0.00)	1.346 (1.31)	1.861 (2.96)	2.22 (4.43)	2.691 (6.74)
l.s.d ($P < 0.05$)	0.5023	0.3816	0.5643	0.870	0.7505

Mean values in the same column with differences less than the l.s.d are not significantly different from each other ($P < 0.05$). DAS =Days after sowing. Figures in parenthesis are back-transformed

3.2 Incidence of okra leaf curl virus disease (OLCD)

The results revealed an increasing trend of plant infection over time, with the control being the highest in most cases. At 21 DAS, none of the treatments recorded an incidence of OLCD but at later stages, there were significant differences among the treatments (Table 3). At 35, 49 and 63 DAS, the control plots recorded significantly higher ($P < 0.05$) incidences of OLCD than the plots which were treated with the botanicals. Plots treated with neem leaf extract had no incidence of OLCD as at 49 DAS, but this was not significantly different from plots treated with garlic and pawpaw leaf extracts but significantly higher than those treated with mahogany bark, chili pepper fruit and bougainvillea leaf extract ($P < 0.05$). Similarly at 63 DAS, the mean incidence of OLCD recorded for plot treated with neem leaf extract was not significantly different from the plot treated with garlic extract, but significantly higher ($P < 0.05$) than those treated with the extracts of mahogany leaves, chili pepper fruits, pawpaw leaves and bougainvillea leaves. However, at 77 DAS, the control plots were not significantly different from those treated with the botanicals.

Table 3 Mean incidence of okra leaf curl disease on okra plants

Treatment	Mean incidence of Okra leaf curl disease (%) recorded at				
	21 DAS	35 DAS	49 DAS	63 DAS	77 DAS
Neem leaf extract	0 (0.00)	0 (0.00)	0 (0.00)	7.5 (6.25)	37.5 39.65)
Mahogany bark extract	0 (0.00)	0 (0.00)	22.5 (18.80)	37.5 (39.65)	41.2 (43.80)
Garlic cloves extract	0 (0.00)	0 (0.00)	7.5 (6.30)	22.5 (18.80)	33.8 (35.20)
Chili pepper fruit extract	0 (0.00)	0 (0.00)	22.5 (18.80)	41.2 (43.80)	45 (50.00)
Pawpaw leaf extract	0 (0.00)	0 (0.00)	18.8 (16.80)	37.5 (39.65)	41.2 (43.80)
Bougainvillea leaf extract	0 (0.00)	7.5 (6.25)	26.2 (25.00)	37.5 (39.65)	41.2 (43.80)
Untreated or control	0 (0.00)	30 (27.00)	37.5 (39.65)	45 (50.00)	45 (50.00)
l.s.d ($P < 0.05$)		8.42	21.06	16.07	12.56

Mean values in the same column with differences less than the l.s.d are not significantly different from each other ($P < 0.05$). Figures in parenthesis are back-transformed.

3.3 Severity of okra leaf curl disease

The treatments showed varying levels of effectiveness on the severity of OLCD after initial infection (Fig. 1). Severity of OLCD in the untreated plot and the one treated with bougainvillea leaf extract were recorded after 21 DAS, though that of the control increased sharply afterwards whilst that of the bougainvillea leaf extract was steady. Infection of OLCD in plots treated with the extracts of mahogany bark, chili pepper fruit, garlic cloves and pawpaw leaves became severe after 35 DAS whereas that of neem–treated plot became severe after 49 DAS.

The phytopesticides also reduced the level of severity of OLCD as compared to the control which recorded an increasing level of severity of the disease over time (Fig. 1). Garlic cloves and neem leaf extract performed significantly better than the other plant extracts in reducing the level of OLCD severity over growth periods of 35 DAS to 77 DAS.

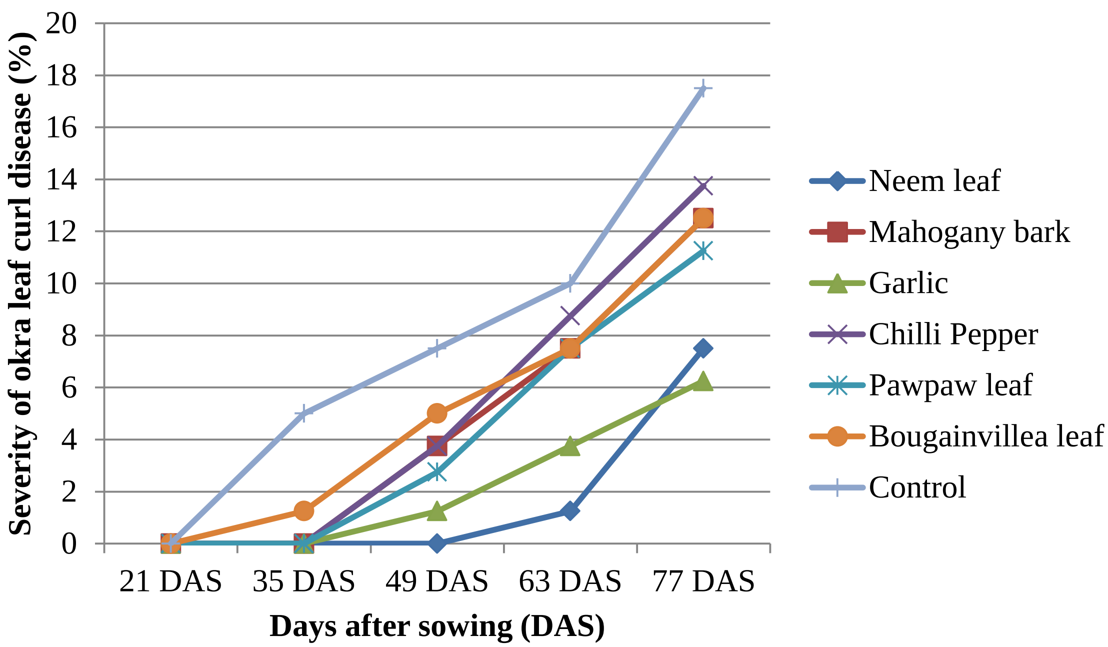

Fig 1. Severity of of okra leaf curl disease in okra plant treated with plant extracts

3.4 Fruit yield of okra

Okra plants treated with neem leaf extract recorded the highest mean yield of 163.3 kg ha^{-1} which was significantly different from those treated with the other botanicals and the control ($P< 0.05$). Okra plants protected with garlic extract recorded the second highest yield (128.7 kg ha^{-1}) which was also significantly different from the mean yield of okra plants protected with the other plant extracts and the control ($P< 0.05$). The unprotected okra plants (control) recorded the lowest mean yield of 93.9 kg ha^{-1}but it was not significantly different from those protected with mahogany bark extract, chili pepper fruit extract, pawpaw leaf extract, and bougainvillea leaf extract (Table 4).

Table 4 Mean fruit yield of okra plants treated with phytopesticides

Treatments	Mean yield (kg ha^{-1})
Neem leaf extract	163.3
Mahogany bark extract	117.2
Garlic cloves extract	128.7
Chili pepper fruit extract	111.9
Pawpaw leaf extract	114.1
Bougainvillea leaf extract	122.4
Untreated or control	93.9
l.s.d ($P< 0.05$)	29.53
CV (%)	16.3

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

3.5 Relationship between disease severities, pest populations, pests damage on leaves, and fruit yield of okra plants

The population of whitefly was positively correlated with severity of OLCD recorded at 77 DAS (r = 0.679; $P > 0.05$). Fruit yield was also negatively correlated with the severity of OLCD recorded at 77 DAS (r = -0.857; $P < 0.05$) and whitefly population recorded at 77 DAS (r = -0.750; $P < 0.05$) (Table 5). This implies that the higher the severity of OLCD, the lower the fruit yield.

Table 5 Correlation between whitefly population, severity of okra leaf curl disease and fruit yield of okra

	Population of whitefly	Severity of OLCD	Fruit yield
Population of whitefly	-		
Severity of OLCD	0.679NS	-	
Yield of okra	-0.750*	-0.857*	-

(NS means not significant, * significant at $P < 0.05$)

4. Discussion

In the present investigation the aqueous extracts of *Azadirachta indica*, *Allium sitavum*, *Carica papaya*, *Khaya* sp., *Bougainvillea* sp. and *Capsicum frutescens* exhibited moderate to high level of pesticidal activity in effectively reducing the populations of whitefly as well as reducing the incidence and severity of okra leaf curl virus disease on okra plants. These botanicals have been reported to possess repellent and antifeedant properties (Schmutterer, 1990; Revkin, 2000; Nevala, 2000). Jayakumar (2002) studied the efficacy of some indigenous products against, *Bemisia tabaci* on okra, and found out that combination of neem oil and garlic extract at 2 - 5% was effective against whitefly even at 7 days after spraying. The efficacy of neem extract against whitefly on several crops has been reported by several researchers (Singh et al., 1988; Ragupathi and Veeraragavathatham, 2002). Neem has important compounds (Azadirachtin, Salanin, Nimbin and Malentroil) which have feeding deterrence, repellent, ovipositional inhibiting and growth regulating activities against a great variety of insects (Jacobson, 1988).

The ability of neem leaf extract and garlic extract to reduce the incidence and severity of OLCV disease on the okra plants may also be due to their virus inhibition properties as reported by Schmuterer (1990) and Baranwal and Verma (1992). This suggests that both neem leaf extract and garlic extract can be used for effective management of OLCV disease on okra plants. A positive correlation between whitefly population and severity of OLCD was also observed in this present study. Thus a successful control of the population of whiteflies by the plant extracts might have contributed to their ability to reduce the incidence and rate of infection of the OLCV.

The botanicals were able to reduce the progress or the spread of the viral diseases on the okra plants as compared to the untreated control, with garlic and neem extract being the most effective, at least up till 70 DAS. This suggests that plant extracts can be used as good pesticide to keep the rate of infection under control. This finding is corroborated by that of Bhyan et al. (2007) who showed that the number of plants infected with tobamovirus increased rapidly in plots with no phytopesticide application and steadily in plots under phytopesticide application. 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 (Bhyan et al., 2007). Usually viral infections can be controlled by preventing their vectors from attacking the host plants as there is a positive correlation between disease incidence and population of the vector (Bhagati and Goswami, 1992). In most research works however, plant extracts had been used as virus inhibitor (Baranwal and Verma, 1992). Madhusudhan et al. (2011) showed a reduction in virus concentration in bell pepper and tomato plants when treated with plant extracts compared to the untreated plants; they found *Bougainvillea spectabilis* as the most effective in reducing the virus concentration in the bell pepper and the tomato plants.

Both neem extract and garlic extract were very effective in improving yields of okra, suggesting that they effectively reduced the biotic stress imposed on the okra plants through whitefly and okra leaf curl attacks. Neem-treated plants however gave the highest yield, and this could be due to the release of nutrient such as nitrogen by the neem to the okra plants for faster vegetative growth and development of the fruits. It has been reported that neem leaf extract has high values of nitrogen and phosphorus (Moyin-Jesu, 2010) and modified neem leaf extract has been found to increase the leaf area, plant height, stem girth and seed yield of maize (Moyin-Jesu, 2010). An increase in yield of okra plants treated with neem extract has also been reported by Oladimeji and Kannike (2009).

The significant negative correlation observed between the severity of the OLCVD and the fruit yield of okra plants is a clear indication that any treatment which recorded lower yields had high severity of OLCD. This suggests that successful control of the incidence and severity of the OLCD on okra plants by the plant extracts will lead to the achievement of higher yields.

5. Conclusions

The plant extracts were able to reduce the population of whitefly, and reduce incidence and severity and spread of OLCD in the okra crop. Neem and garlic extracts were the most effective botanicals in managing OLCV and its whitefly vector, thereby producing high fruit yield in okra.

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