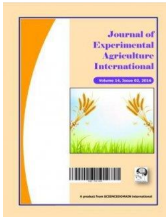

Journal of Experimental Agriculture International

20(5): 1-16, 2018; Article no.JEAI.37421
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Prevalence of Mosaic and Leaf Curl Diseases of Okra (*Abelmoschus esculentus* L. Moench) in the Central Region of Ghana

Elvis Asare-Bediako[1*], Faustina Agyarko[1], Kingsley J. Taah[1], Aaron Tettey Asare[2], Justice Sarfo[3], Kwame Agyei Frimpong[4] and Joseph Nyarko[1]

[1]Department of Crop Science, School of Agriculture, University of Cape Coast, Ghana.
[2]Department of Molecular Biology and Biotechnology, School of Biological Science, University of Cape Coast, Ghana.
[3]Department of Biochemistry, School of Biological Science, University of Cape Coast, Ghana.
[4]Department of Soil Science, School of Agriculture, University of Cape Coast, Ghana.

Authors' contributions

This work was carried out in collaboration between all authors. Author EAB designed the study and wrote the first draft of the manuscript. All authors took part in the data collection. Author KAF did the soil analyses. Author FA performed the statistical analysis, managed the analyses of the study and the literature searches. Author KJT was the agronomist on the project and helped in shaping the manuscript to its final version. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2018/37421
Editor(s):
(1) Moreira Martine Ramon Felipe, Associate Professor, Departamento de Enxeñaría Química, Universidade de Santiago de Compostela, Spain.
(2) Marco Aurelio Cristancho, Professor, National Center for Coffee Research, CENICAFÉ, Colombia.
(3) Rusu Teodor, Professor, Department of Technical and Soil Sciences, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Romania.
(4) Suleyman Korkut, Professor, Duzce University, Department of Forest Industrial Engineeering, Division of Wood Mechanic and Technology, Turkey.
Reviewers:
(1) Sunil Kumar Mukherjee, IARI, India.
(2) Andrew Sarkodie Appiah, Biotechnology and Nuclear Agriculture Research Institute, Ghana.
(3) Boniface David Kashina, Ahmadu Bello University, Nigeria.
(4) Babajide O. Odu, Obafemi Awolowo University, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/23236

Original Research Article

Received 15th October 2017
Accepted 8th January 2018
Published 17th February 2018

ABSTRACT

Aims: To determine the incidence and severity of okra mosaic (OMD) and okra leaf curl diseases (OLCD) in the Central region of Ghana and to assess farmers' perception on the incidence and management of these viral diseases.

**Corresponding author: E-mail: asrebediakoelvis@gmail.com;*

Study Design: Descriptive survey involving household and field surveys.
Place and Duration of Study: Komenda-Edina-Eguafo-Abirem (KEEA) municipality in the coastal savannah zone, Assin North district in the forest zone and Ajumako-Enyan-Essiam (AEE) district in the forest-coastal savannah transitional zone, between June 2009 and December 2015.
Methodology: Household data were collected using structured questionnaire from 180 respondents (60 farmers per district)using the multi-stage procedure, and analyzed using descriptive and inferential statistics. Disease incidence (DI) and severity scores (SS) of OMD and OLCD were determined in thirty-six (36) okra fields selected from each of the three districts. The field data were subjected to analysis of variance (ANOVA) and the means separated with least significant difference (LSD) method at 5% probability level.
Results: There was a high prevalence of OMD and OLCD in the districts surveyed. Incidence and severity scores of OLCD at the coastal savannah zone were not significantly different from the forest zone but were significantly higher (P=0.05) than the transition zone. The study also revealed that the majority of the farmers were males; had small farm holdings and practiced monocropping. The majority of the respondents had observed OMD and OLCD in their farms and had managed these viral diseases solely with pesticides. Pesticides have also been abused by the majority of the farmers who did fortnightly spraying, not observing appropriate pre-harvest intervals and also used insecticides not registered or recommended for vegetables.
Conclusion: Viral diseases are highly prevalent and severe in okra farms in the study area and this is partly due to poor agronomic practices by the farmers.

Keywords: Abelmoschus esculentus; okra leaf curl disease; okra mosaic disease; okra mosaic virus; okra leaf curl virus; disease incidence; severity.

1. INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) of the family Malvaceae, is a tropical, subtropical and warm temperate vegetable crop, cultivated for its immature edible green fruits, which are used as vegetable both in green and dried state [1,2]. The fresh leaves can be used as spinach in soups, while the seeds are good sources of oil [3]. It serves as a source of carbohydrate, dietary fiber, fat, protein, calcium, iron, thiamine, riboflavin, nicotinamide and ascorbic acid [4,5]. Okra consumption is beneficial in the management of blood pressure, fibrinogen concentration and plasma viscosity in hypertensives [6,7]. Apart from its nutritive and medicinal values, it is also a major source of income for many vegetable growers and retailers in Ghana and other parts of the world [8].

Despite the importance of okra, its productivity worldwide is affected by plant viruses [9-11] and insect pests [12-14]. Okra plant is susceptible to at least 19 plant viruses, with okra leaf curl virus (OLCV) and okra mosaic virus (OkMV) being the most common and well-studied [15, 16], and the major diseases reported in Ghana [8,11]. The OMD can cause yield loss of up to 90% [9,10]; whereas OLCD causes yield losses up to 80% [17,18].

Okra leaf curl disease is transmitted in a persistent manner by the whitefly (*Bemisia tabaci* Gen.); whereas OMV is transmitted by *Podagrica* species [18]. Symptoms of OLCD include leaf wrinkle, curl, vein distortion, leaf yellowing, stunted growth and reduced yields [19] whereas that of OMD include mosaic, vein chlorosis and banding and stunted growth [20].

It is quite important to effectively manage these viral diseases in okra in order to improve yields and fruit quality. Information on the incidence and severity of these diseases is an important pre-requisite for the development of appropriate and effective management strategies [11]. Disease assessment recently conducted in selected okra fields in the Komenda-Edina-Eguafo-Abirem (KEEA) district of the Central region of Ghana, showed the prevalence of the OMD and OLCD [11]. However, the prevalence of these diseases and pest infestation in other parts of the Central Region is not known. Furthermore, information on farmers' knowledge level of these viral diseases and their agronomic practices is also important in the development of effective management strategies. This study was therefore conducted to ascertain the prevalence of OMD and OLCD in farmers' okra fields and to assess farmers' perception of the incidence and management of these viral diseases.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in three districts each in a different agro-ecological zone in the Central region of Ghana: Komenda-Edina-Eguafo-Abirem (KEEA) district in the coastal savannah zone, Assin North (AN) district in the forest zone, and Ajumako-Enyan-Essiam (AEE) district in the forest-coastal savannah transitional zone (Table 1) during the 2015 cropping season. These districts are major okra producing centers in the Central region of Ghana.

2.2 Research Design

The study was a descriptive survey carried out in two parts; the first part involved a household survey using a questionnaire to identify farmers' perception and how they managed OMD and OLCD in their various farms. The second part involved a field survey to determine the incidence and severity of these okra viral diseases in the various districts.

2.2.1 Household survey

2.2.1.1 Sampling approach

A multi-stage approach to sampling was adopted for the study because okra farmers were selected from different communities in different districts from the three important okra producing agro-ecological zones. Through interactions with personnel (District Directors and Agricultural Extension Agents [AEAs]) from the regional and district directorates of Ministry of Food and Agriculture (MoFA), information on the most important okra growing areas in the various ecological zones in the region was acquired. A reconnaissance survey was conducted for familiarization of the study area. This led to the selection of the three districts across the three ecological zones in the region for this study.

Four communities from each district were selected for the study based on the scale of okra production and population density. A total of 180 farmers were interviewed, comprising 15 farmers per community and 60 farmers per district. Males and females, as well as full-time and part-time okra farmers, were involved in the study.

2.2.1.2 Instrumentation and data collection

A structured interview schedule with both open-ended and closed-ended questions was prepared and pre-tested in the Cape Coast municipality because it has both coastal savannah and transitional agro-ecologies and it is also an important okra growing area. The questions were administered in the local dialect. The one-on-one survey instrument comprised of four categories of questions, namely (i) demographic and farm characteristics of respondent farmers (ii) farmers' knowledge about the OMD and OLCD (symptoms of diseases, effect of the diseases on yield of okra, time of the year when the disease infection is severe etc.), (iii) farmers' agronomic practices which could influence these diseases, and (iv) what farmers were doing to cope with these diseases.

2.2.2 Disease assessment

Twelve okra fields from each district were selected randomly. A transect (25 m^2) was made at three different points along the diagonal of each field and all plants within transects were assessed for incidence and severity of OMD and OLCD. The prevalence of the viral diseases was determined by visually observing and recording the presence or absence of okra plants showing the disease symptoms. Disease incidence (DI) per field for each of the OLCD and OMD were estimated as the percentage of plants along transects displaying disease symptoms.

The plants were scored for severity of OMD based on a 0–5 visual scale adopted from Alegbejo et al. [21] with modification as indicated in Table 2.

Table 1. Characteristics of the three selected agro-ecological zones

District	Ecological zone	Longitude/Latitude	Temperature ^{o}f	Rainfall (mm)
KEEA	Coastal Savannah	1^o20' W to 1^o 40' W 5^o 05' N to 5^o 15' N	26 – 30	750 - 1000
AN	Forest	1^o 05' E to 1^o 25' E 6^o 05' N to 6^o 04' N	26 – 30	1500 - 2000
AEE	Transition	0^o 53' to 1^o 08' W	26 – 30	1200 - 1500

Table 2. Visual scale for rating severity of okra mosaic disease in farmers' okra fields

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	Moderate chlorosis, mottle or mosaic with leaf malformation
4	Severe chlorosis, mottle or mosaic plus stunting or dwarfing of the whole plant
5	Score 4 plus drying and leaf drop

Table 3. Visual scale for rating severity of okra leaf curl disease on farmers' okra fields

Disease score	Description
0	No symptom
1	Curling of few top leaves
2	Top leaves curled and slight stunting of plant
3	All leaves curled and slight stunting of plant
4	Severe curling of leaves, stunting of plant and proliferation of auxiliary branches

The plants were also scored for severity of OLCD based on a 0–4 visual scale (Table 3), which is essentially a modification of the 0 - 7 scale developed by Alegbejo et al. [21].

2.3 Data Analyses

The data from the household survey was analyzed using descriptive statistics (means, frequency distributions, and percentages), and inferential statistics (chi-square test). Microsoft 'EXCEL' and IBM 'Statistical Package for the Service Solutions (SPSS) Software Package Version 16 was used to process the elicited data. Data on disease incidence was transformed with angular transformations in order to homogenize the variance before being subjected to analysis of variance (ANOVA).The other quantitative data (severity scores of OMD, OLCD) were subjected to ANOVA and the means separated by least significance difference (LSD) at 5% level of probability using GenStat Discovery version 4 (VSN International).

3. RESULTS

3.1 Household and Farm Characteristics

A total of 180 respondents (58.3% males; 41.7% females) participated in the study (Table 4). Majority of the respondents (71%) were within the age groups 20-29 years and 50-59 years. Most respondent farmers (31.1%) were Junior High School graduates, followed by Primary School (22.8%), and Middle School (21.1%) leavers as indicated in Fig. 1. Farmers who had completed Senior High School and Tertiary Education were 6.1% and 2.2%, respectively of the total respondents, whereas 16.7% had not received any formal education (Fig. 1). Majority of the farmers (53.3%) had farm sizes of less than 0.4 ha followed by (39.4%) with farm sizes ranging from 1 to 1.2 ha, whereas only 7.3% had farm sizes larger than 1.2 ha (Table 4).

With respect to land tenure system, most farmers (47.7%) farmed on rented land, 27.1% farmed on family land, 11.7% acquired their own land, whereas 10.6% practiced sharecropping. Only a few of them (2.9%) practiced a combination of the above-mentioned land tenure systems (Table 4). Most farmers (42.2%) employed both families and hired labor, 23.8% used only family labor, 22.2% used both self and hired labor, whereas 10.6% used only self-labor, only 1.2% of the respondent farmers employed "nnoboa" either alone or in combination with hired labour (Fig. 2).

3.2 Farmers' Agronomic Practices

Most farmers (43.3%) prepared their land using slash and burn method, 18.3% practiced zero tillage, 11.7% used the tractor, 1.1% used hoe; whereas 25.6% used an integrated approach involving different tillage operations (Table 5). The majority of the respondents (70.9%) practiced monocropping, whereas the others (29.1%) practiced mixed cropping (Table 5). However, the majority of the farmers practiced crop rotation (60.9%), whereas the others (39.1%) did not (Table 8). The majority of the farmers (81.5%) cultivated their crops in both the major and minor farming seasons; 11.8% practiced only major season farming; whereas the other 6.7% practiced only minor season farming (Table 8). Majority of the farmers (80.6%) used local cultivars of okra, whereas the others (29.4%) planted improved and exotic cultivars (Table 8). Surprisingly, the majority of the farmers (81.6%) did not know the names of the okra cultivars they cultivate. Among the respondents who knew the names of cultivated okra cultivars 11.2% mentioned 'Anthem', 5.6% indicated 'Avalavi' and 1.7% pointed to 'Nkrankruma' as shown in Fig. 3.

Table 4. Demographic characteristics of respondent okra farmers in the study area

Variable	Frequency	Percentage (%)
Sex		
Male	105	58.3
Female	75	41.7
Total	**180**	**100**
Age (years)		
<20	2	1.1
20-29	32	17.8
30-39	45	25.0
40-49	39	21.7
50-59	45	25.0
60-69	11	6.1
70-79	6	3.3
Total	**180**	**100**
Size of farms (ha)		
<0.4	96	53.3
0.4-1.2	71	39.4
>1.2	13	7.3
Total	**180**	**100**
Land tenure system		
Self-owned	21	11.7
Rent	86	47.7
Share cropping	19	10.6
Family land	49	27.1
Self-owned and rent	3	1.7
Rent and family land	1	0.6
Self-owned and share cropping	1	0.6
Total	**180**	**100**

3.3 Farmers' Knowledge of Viral Diseases

Majority of the farmers indicated that they were aware of the incidence of the OLCD (98.9%) and OMD (98.1%); and the damage caused to the plants on their farms (Table 6). About half of the farmers (47%) reported that incidences of OLCD and OMD occurred during the vegetative growth stage, followed by those who said the diseases occurred during the flowering and fruiting stages, only a few of them (less than 4%) reported disease incidence at the seedling stage (Table 6). Majority of the farmers (80.9%) reported that incidences of these viral diseases occurred during both major and minor farming seasons. However, 12.9% and 6.2% of the respondents indicated the incidence of the disease only in the major and minor seasons respectively (Table 6). Majority of the farmers (65.6%) did not know the cause of OLCD, with 19.9%, 6.8%, 4% and 1.7% attributing it to insects, soil pathogens, bad weather, and pesticides respectively (Fig. 4). Similarly, majority of the respondents (65%) reported ignorance of the cause of OMD; however, the rest (35%) attributed it to a variety of causes including insects, soil pathogens, bad weather, pesticides, hard land (poor soil structure), soil salinity and nutrient deficiency (Fig. 5).

Table 5. Agronomic practices of the respondent okra farmers

Variable	Frequency	Percentage
Method of land preparation		
Zero tillage	33	18.3
Slash & burn	78	43.3
Tractor plough	21	11.7
Hoe weeding	2	1.1
Integrated land preparation	46	25.6
Total	**180**	**100**
Cropping system		
Mono cropping	127	70.9
Mixed cropping	52	29.1
Total	**179**	**100**
Cropping season		
Major	21	11.8
Minor	12	6.7
Both major & minor	145	81.5
Total	**178**	**100**
Okra variety planted		
Local	145	80.6
Improved	34	18.8
Exotic	1	0.6
Total	**180**	**100**
Crop rotation practice		
Yes	109	60.9
No	70	39.1
Total	**179**	**100**

Yield loss of 50% due to the OLCD and OMD was reported by the respondents (Fig. 7). Most farmers reported yield losses ranging from 41-50% to be due to OLCD (32.6%); and OMD

(28.6%) (Fig. 6).This was followed by farmers who noted that OLCD (27.5%) and OMD (15.4%) could cause yield losses of over 50%.

3.4 Disease Management Practices

Majority of the farmers (80%) managed diseases on their okra farms by using only synthetic pesticides, with only 0.6% using botanicals (Table 7). About 10.5% of the farmers used pesticides and also practiced roguing, 1.7% practiced only roguing but 7.2% did not apply any disease management method (Table 7). Majority of the farmers (97.7%) relied on agro-input shops for the pesticides; whereas only 1.2% relied on agricultural extension agents. However, there were few farmers who relied on neighbors (0.6%) and pesticides peddlers (0.6%) for a recommendation on the types of pesticides to use (Table 8). Majority of the farmers (59.1%) used the same chemicals season after season but 40.9% of the farmers varied them from time to time (Table 7).

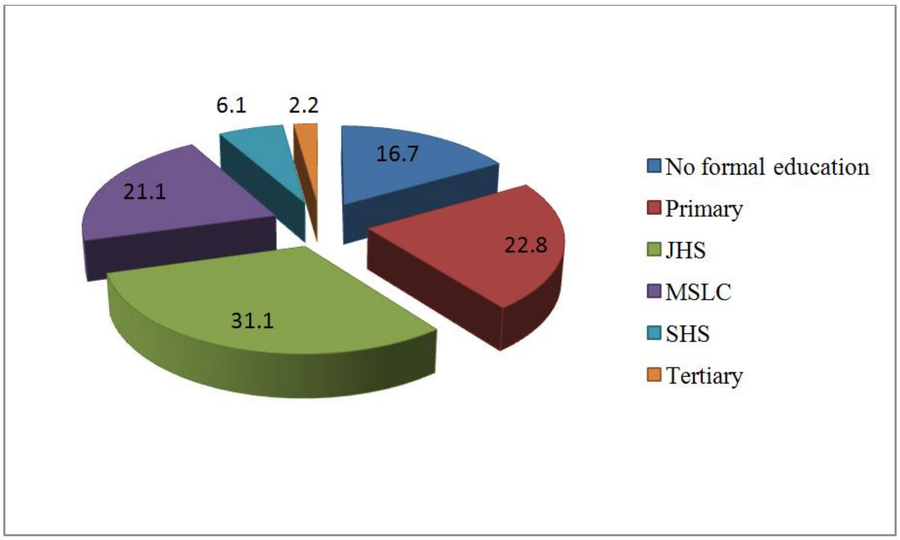

Fig. 1. Level of education of respondent okra farmers

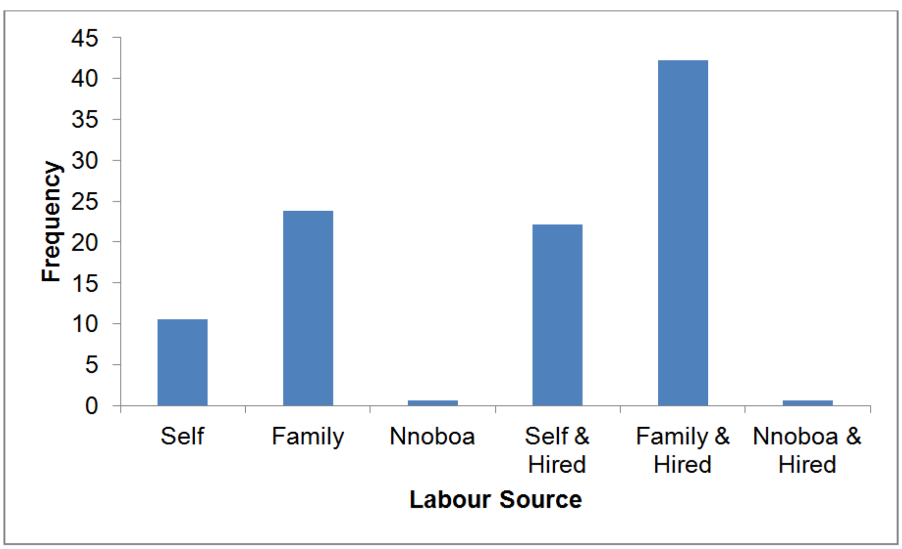

Fig. 2. Source of labor used by the respondent okra farmers

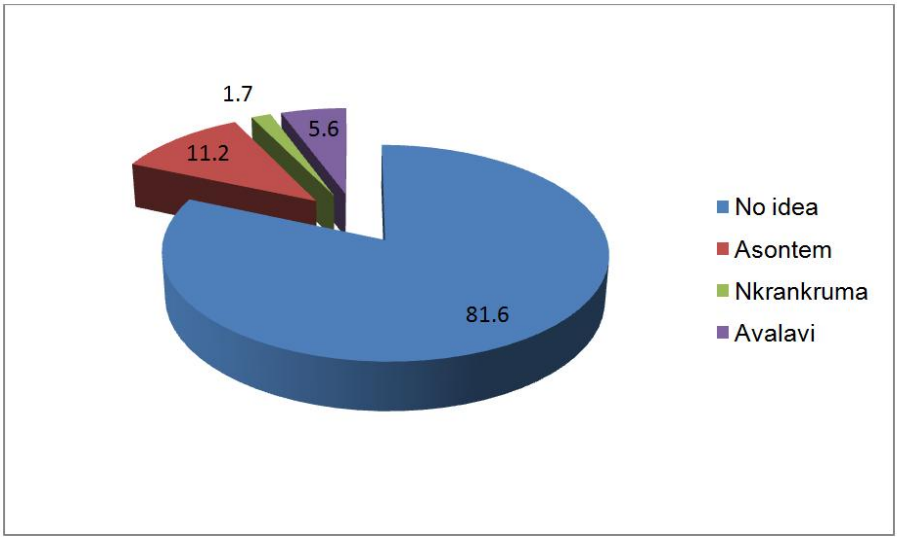

Fig. 3. Names of okra cultivars cultivated by the respondent farmers in the study area

Table 6. Farmers' awareness of okra viral diseases and flea beetle infestation

Variable	Frequency	Percentage
Observation of OLCD		
Yes	178	98.9
No	2	1.1
Total	**180**	**100**
Observation of OMD		
Yes	177	98.3
No	3	1.7
Total	**180**	**100**
Okra growth stage at OLCD incidence		
Seedling Stage	7	3.9
Vegetative Stage	81	45.5
Flowering Stage	62	34.8
Fruiting Stage	28	15.8
Total	**178**	**100**
Okra growth stage at OMD incidence		
Seedling Stage	6	3.4
Vegetative Stage	82	46.8
Flowering Stage	47	26.9
Fruiting Stage	40	22.9
Total	**173**	**100**
Disease incidence by season		
Major	22	12.9
Minor	11	6.2
Both major & minor	144	80.9
Total	**177**	**100**

Majority of the respondents (62.7%) applied pesticides fortnightly; 25.9% applied the chemicals weekly, whereas 11.4% of the respondents applied the pesticides at more than 2 weeks intervals (Fig. 8). Many of the farmers (39.8%) observed pre-harvest intervals (PHI) of 3 days, followed by 39.3% at 4 days, 17.2% at 7 days and 3.7% observed a PHI of only 2 days. In response to the question of whether the pesticides they applied was effective in managing the target pests and diseases, the majority of the respondents (85.7%) reported that the pesticides were not effective whereas the rest (14.3%) said they were effective (Table 7).

3.5 Gender, Educational Level, and Farming Experience

Farmers' educational level had significant influence on their knowledge on the causes of OMD (χ^2=62.2; df=35; *P*=0.003) and OLCD (χ^2=64.572; df=20; *P*<0.0001), but did not have significant effect on the source of planting material (χ^2= 46.653; df = 55; *P*= 0.781) and the cropping system (χ^2= 10.365; df = 5; *P*=0.066) practiced by the respondents, as indicated in Table 8.

The gender of the respondents had significant relationships with the management of OMD and OLCD (χ^2=13.758; df=4; *P*=0.008), as well as their cropping patterns (χ^2=4.726; df=1; *P*=0.030) as shown in Table 8.

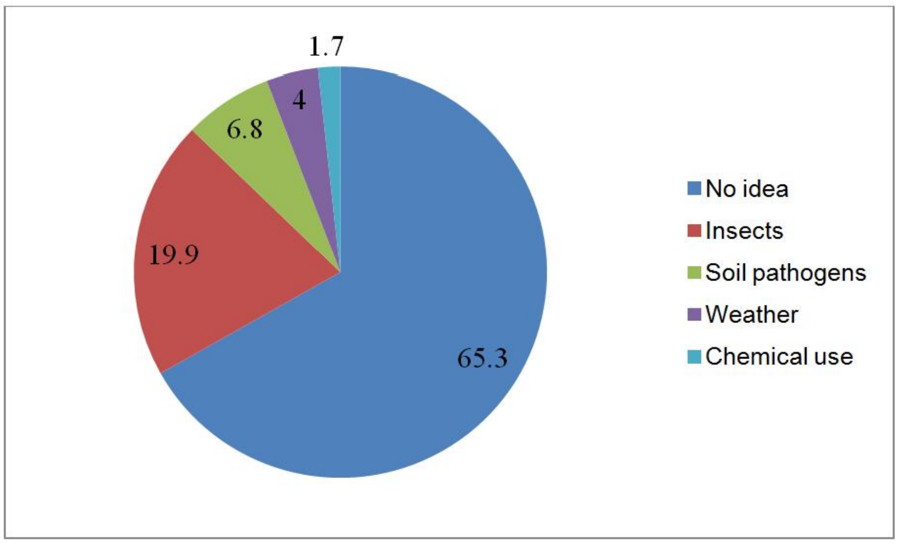

Fig. 4. Farmers' perceptions of the causes of okra leaf curl disease (OLCD) in the study area

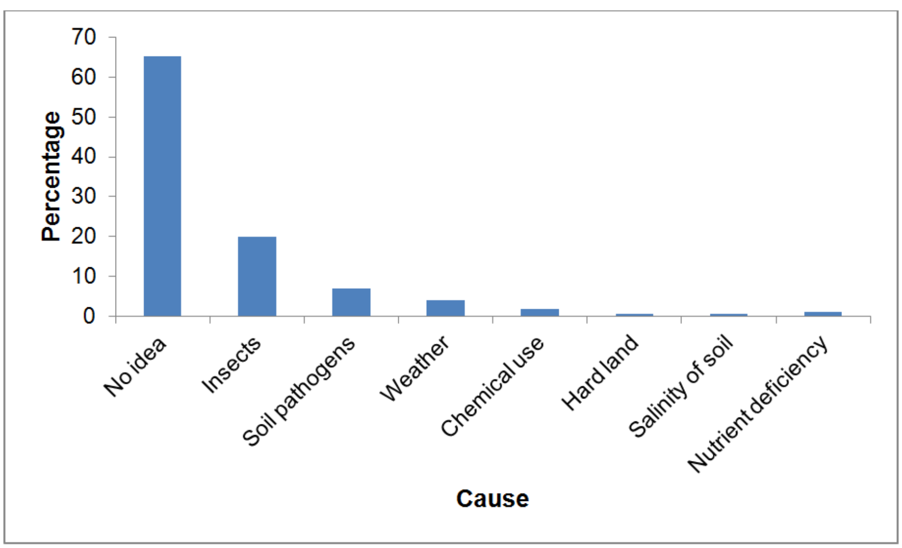

Fig. 5. Farmers' perception of the causes of okra mosaic disease (OMD)

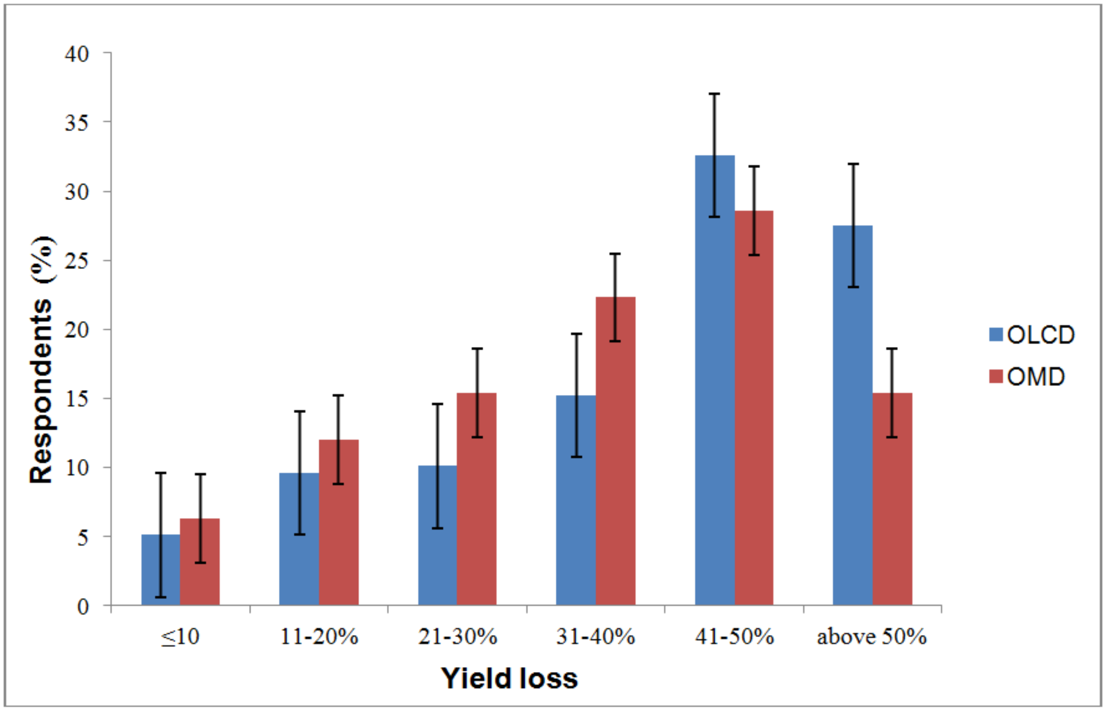

Fig. 6. Yield losses of okra by the respondent farmers due to okra mosaic disease (OMD) and okra leaf curl disease (OLCD) in the study area. (Error bars = SED)

Table 7. Management of okra mosaic disease (OMD) and okra leaf curl disease (OLCD) by the okra farmers in the study area

Variable	Frequency	Percentage
Disease management method		
Chemical	144	80
Cultural (Roguing)	3	1.7
Botanicals	1	0.6
Chemical + Roguing	19	10.5
No control method	3	7.2
Source of pesticides used		
Agro-input shops	159	97.6
Pesticide peddlers	1	0.6
Neighbours	1	0.6
Agricultural Extension Agents	2	1.2
Use of the same pesticide		
Yes	97	59.9
No	66	40.1
Pre-harvest interval		
2 days	6	3.7
3 days	65	39.8
4 days	64	39.3
7 days	28	17.2
Effectiveness of chemical control		
Yes	25	14.7
No	150	85.7

The farming experience of the respondents had significant influence on the source (type) of planting materials (χ^2= 36.862; df = 22; *P*=0.024) and their varietal names (χ^2= 19.979; df= 4; *P*=0.001). The number of years in farming, however, did not have significant influence on their knowledge on the causes of OMD (χ^2= 7.065; df= 14; *P*=0.932) and OLCD (χ^2=6.931; df=8; *P*= 0.544) and their management (*P*< 0.05), as indicated in Table 8.

3.6 Pesticides Applied

A total of 18 pesticides were identified as being used in the study area for the management of viral diseases. The pesticides consisted of 14 insecticides and 4 fungicides (Table 9).The classification of these pesticides by the category of pests they control, the active ingredient, chemical group and the World Health Organization (WHO) Hazard category is presented in Table 9.Two out of 12 insecticides used by the farmers were not registered by the Ghana Environmental Protection Agency. Generally, most farmers used pesticides that have not been registered for vegetable production by the Environmental Protection Agency (EPA). For instance, Aceta Star EC (Bifenthrin+Acetamiprid), Confidor 200SL (Imidacloprid) and Akatemaster (Bifenthrin) are registered only for use in cocoa production, but the farmers were using them for okra and other vegetable production. Besides, some of the farmers used DDT which is a banned chemical in Ghana. Furthermore, farmers used fungicides (Mancozeb, Copper hydroxide, Cupric hydroxide, Thiophanate methyl) to control viral diseases and insect vectors (flea beetle and whitefly) as shown in Table 9. These were indicators that the farmers were using wrong chemicals in the management of insect vectors and the viral diseases.

3.7 Prevalence of Okra Mosaic Disease (OMD) and Okra Leaf Curl Disease (OLCD)

Symptoms OLCD and OMD were prevalent in all the agro-ecological zones surveyed but at varying degrees (Table 10).The overall mean incidences of OLCD recorded for the coastal savannah (69.7%) was not significantly different (*P*>0.05) from that of forest zone (64.2%) but significantly higher (*P*< 0.001) than the transitional zone (36.4%) (Table 10).

ANOVA of the incidence of OMD in the three zones showed no significant differences among them (F = 2.15; df = 24; *P* = 0.139) (Table 10). However, the highest incidence (76.2%) occurred in the forest zone, followed by the transitional zone (75%) whereas the coastal savannah zone recorded the lowest (67.6%).

Table 8. Effect of farmers' gender, educational level and farming experience on their perception and management of okra mosaic disease (OMD) and okra leaf curl disease (OLCD) in the study area

Variables	Pearson Chi-square	df	*P*-value
Level of education of respondents* Awareness of OMD	4.476	5	.483
Level of education of respondents* Awareness of OLCD	1.82	5	.873
Level of education of respondents * Causes of OMD	62.92	35	.003
Level of education of respondents * Causes of OLCD	64.57	20	.000
Level of education of respondents * Control of OLCD and OMD	33.24	20	.032
Level of education of respondents * Source of planting material	46.65	55	.781
Level of education of respondents * Cropping system	10.37	5	.066
Sex of respondents * Control of OLCD and OMD	13.76	4	.008
Sex of respondents * Cropping system	4.73	1	.030
Years of cultivating okra * Awareness of OMD	1.09	2	.580
Years of cultivating okra * Awareness of OLCD	23.84	2	.000
Years of cultivating okra * Causes of OMD	7.07	14	.932
Years of cultivating okra * Causes of OLCD	6.93	8	.544
Years of cultivating okra * Control of OLCD and OMD	10.19	8	.252
Years of cultivating okra * Source of planting material	36.86	22	.024
Years of cultivating okra * Variety of okra	19.98	4	.001

Table 9. Types of pesticides used by farmers in managing okra mosaic disease and okra leaf curl disease and their vectors flea beetles and whiteflies, respectively in the study area

Pesticides group	Trade name	Active ingredient	Hazard class	Pre-harvest interval (days)	Specific crops/uses
Insecticides	Golan 20%SP	Acetamiprid	III	7	Vegetables and fruits
	Lambda Super 2.5EC	Lambda-cyhalothrin	II	7-9	Vegetables
	Aceta Star EC	Bifenthrin + Acetamiprid	II	7-14	Cocoa
	Dursban 4E	Chlorpyrifos	II	15-30	Scale insects, borers
	Sunpyrifos	Chlorpyrifos-ethyl	II	15-30	nk
	Confidor 200SL	Imidacloprid	II	14	Cocoa
	Karate 5EC	Lambda-cyhalothrin	II	7-9	Vegetables and flowers
	Akate Master	Bifenthrin	II	7	Cocoa
	Super Agro Blaster	Pyrethrum	II	-	Stored Produce
	Actellic 50EC	Pirimiphos-methyl	III	-	Crawling and flying insects
	Sulphur 80WP	Sulphur	III	-	Ornamentals and Crops
	Akape 20SC	Imidacloprid	II	14	Vegetables
	* DDT	DDT	I	-	-
	Attack	Emamectin Benzoate	II	1	vegetables
Fungicides	FokoSuper 80%WP	Mancozeb	III	-	Vegetables
	Champion 80WP	Copper hydroxide	III	-	Cocoa and Coffee
	Kocide 2000	Cupric hydroxide	III	0	Cocoa
	The opsin 70 WP	Thiophanate methyl	III	1	Crops

** Banned; nk – not known*

ANOVA showed highly significant differences among the three agro-ecological zones with respect to recorded mean OLCD severity scores (F = 18.15; df = 24; $P< 0.001$). The highest mean severity score was recorded for the coastal savannah zone (2.023), followed by forest zone (1.811) whereas the transition zone had the lowest (0.675) as shown in Table 11.

There were no significant differences among the three agro-ecological zones in respect of their mean OMD severity scores (F = 1.43; df = 24; $P=$ 0.259). The forest zone, however, had the highest severity score of 2.04, followed by the transitional zone with a mean severity score of 1.93, and the coastal savannah zone recorded the lowest (1.60) (Table 11).

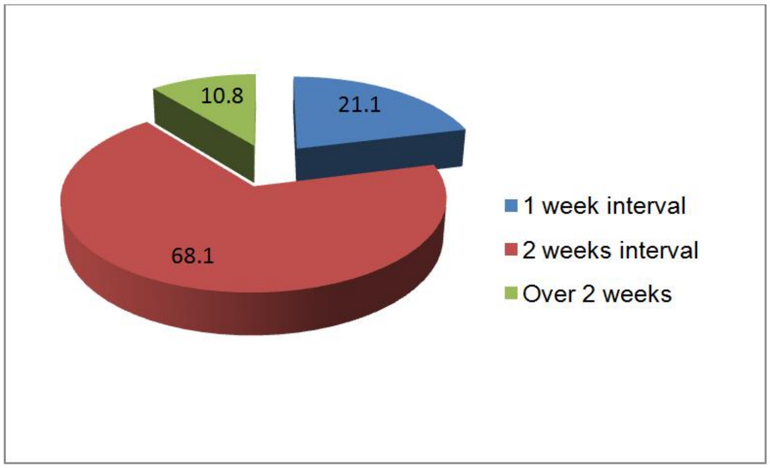

Fig. 7. The frequency of pesticide application by the respondent farmers in the study area

Table 10. Incidence of okra leaf curl disease (OLCD) and okra mosaic disease (OMD) for Okra farmers in the study area

Ecological zones (Districts)	Incidence of OLCD (%)	Incidence of OMD (%)
Coastal savannah (KEEA)	69.7^{a}	67.6^{ns}
Forest (Assin North)	64.2^{a}	76.2
Transitional (AEE)	36.4^{b}	75.0
Mean	56.8	72.9
LSD	11.75	9.31
P value	<0.001	0.139

Means in the same column bearing the same letters are not significantly different (P< 0.05)
NS: not significant (P> 0.05).
KEEA: Komenda-Edina-Eguafo-Abirem; AEE: Ajumako-Enyan-Essiam

Table 11. Severity of okra leaf curl (OLCD) and okra mosaic diseases (OMD) in the study area

Ecological zones (District)	Severity of OLCD	Severity of OMD
Coastal savannah (KEEA)	2.023^{a}	1.60^{ns}
Forest (Assin North)	1.811^{a}	2.04
Transition (AEE)	0.675^{b}	1.93
Mean	1.503	1.86
LSD	0.4967	-
P value	<0.001	0.259

NS-not significant (P> 0.05).
KEEA-Komenda-Edina-Eguafo-Abirem, AEE- Ajumako-Enyan-Essiam

4. DISCUSSION

The study has shown high prevalence and severity of okra mosaic disease (OMD) and okra leaf curl disease (OLCD) in the three agro-ecological zones in the Central region of Ghana (Tables 6,10,11). This is consistent with the research findings where a high prevalence of these viral diseases was recorded at farmers' okra fields in KEEA [11] and other parts of the country [11,12]. The incidence of viral diseases in okra had also been reported in several other countries [9,10,19,22,23]. The farms surveyed were seriously devastated by the OMD and OLCD, as was reported by Asare-Bediako et al. [11] in a survey on the incidence and severity of OMD and OLCD of okra farms in the KEEA district of the Central region of Ghana. These findings thus support the assertion that OLCD and OMD are major viral diseases of okra in Ghana [11,12]. Okra leaf curl disease incidence was also observed to be devastating over 50% of farms surveyed by Askira [19] in Lake Alau area of Borno State of Nigeria.

The high prevalence and severity of viral diseases observed in the study areas could partly be attributable to the poor agronomic practices by the farmers, as has been reported [11]. It was also discovered in the study that majority of the farmers practiced mono-cropping, in both major and minor cropping seasons, suggesting that they cropped throughout the year. It has been reported that continuous cultivation of the same crop, especially in tropical and sub-tropical countries, is a potential cause of viral disease epidemics [24]. According to Nayudu [25], increased mono-cropping over vast areas favored vector populations and establishment of viruses, leading to increased severity of diseases. Loebenstein and Lecoq [26] also argued that continuous planting facilitates the establishment and perpetuation of pests and diseases, especially plant viruses and their vectors.

It was revealed in the study that majority of the farmers applied pesticides every two weeks (Fig. 8). This high frequency of pesticides application has also been reported by other scientists [27, 28]. According to Now [29], the pattern and frequency of pesticides used by farmers could play a role in the development of resistance in insect vectors/pests of crops. The pesticides used by the farmers become ineffective leading to high incidence of pests and diseases.

The ineffectiveness of the pesticides used by the respondent farmers could also be due to their misuse or misapplication as has been reported by other scientists [27, 29, 30]. It was observed in our study that most farmers used fungicides such as Mancozeb, Copper hydroxide, Cupric hydroxide, Thiophanate methyl to control viral diseases and their insect vectors such as flea beetles and whiteflies (Table 9). This indicates that the farmers used wrong chemicals in the management of insect vectors and the diseases they transmit. It was further observed that most farmers used insecticides and fungicides, which had not been cleared for use on target vegetable crops or were applying pesticides, which, were not registered for vegetable production. For instance, Aceta Star EC (Bifenthrin + Acetamiprid), Confidor 200SL (Imidacloprid) and Akatemaster (Bifenthrin) are registered only for use in cocoa production, but the farmers were using them for the production of okra and other vegetables. This suggests that such farmers were misusing such pesticides thereby affecting the quality and safety of vegetables as has been argued by Afari-Sefa et al. [28].

The findings of the present study support the reports of Amoako et al. [27] and Afari-Sefa et al. [28] who confirmed that certain banned chemicals such as Endosulfans and DDT and those not recommended for vegetable production including Akatemaster which contains bifenthrin; Confidor which contains imidacloprid and thiamethoxam; and Cocostar which contains bifenthrin and pirimiphosmethyl were being used for vegetable production in parts of Ashanti and Western regions of Ghana. This practice seriously endangers the lives of consumers, and so farmers should be advised to desist from it.

The study revealed that the farmers' educational levels and experience in farming had a significant influence on their awareness and management of the OMD. These findings are consistent with that of Nagaraju et al. [31] who reported that both formal education and experience in farming or number of years in farming can serve as means through which farmers get informed. Most farmers in this study had attained at least Junior High School education with only 16.7% being illiterates (Fig. 1). This explains why the majority of the farmers were aware of the incidence of the viral diseases in their farms.

The study also showed that majority of the farmers adopted measures aimed at managing viral diseases in their okra farms. This could be due to their high awareness of the incidence of diseases in their farms and their effects on the yield and quality of okra. This finding agrees with Lewis and Miller [32] who reported that basic knowledge about the prevalence of a disease is one of the main tools in its management. Most farmers also reported of yield losses ranging from 41% - 50% due to OMD and OLCD, which was a clear evidence of the effect of these diseases on the yield of okra.

The study further has revealed that most vegetable farmers harvest their produce between 2 and 4 days after spraying pesticides thereby exposing consumers to high pesticide residue levels. This finding corroborates reports of Amoako et al. [27], Afari-Sefa et al. [28]. It was revealed in their studies that some vegetable farmers in parts of Ashanti and Western regions do not even observe any waiting period but harvest their produce the same day they apply the pesticides. Judging from the fact that the pre-harvest intervals of the pesticides used by the farmers ranged from 7 to 30 days, it is quite clear that consumers of some vegetables especially okra are being pre-disposed to severe health risk.

5. CONCLUSIONS

The study has demonstrated high prevalence and severity of OMD and OLCD in the okra farms in the Central region of Ghana. The majority of the respondents knew these viral diseases. The levels of education of the farmers were generally low, with the majority of them being basic school graduates. Majority of the farmers have adopted poor agronomic practices; including the use of non-certified seeds, mono-cropping in both the major and minor cropping seasons and managed viral diseases mainly with synthetic pesticides. The farmers misused pesticides by spraying too frequently; did not observe appropriate pre-harvest intervals; used pesticides not registered or recommended for vegetables and also used wrong pesticides against insect vectors. These practices we believe have led to the high prevalence and severity of OMD and OLCD in some regions of Ghana.

ACKNOWLEDGEMENTS

We wish to acknowledge the Directorate of Research, Innovation, and Consultancy (DRIC), University of Cape Coast, Cape Coast-Ghana for funding this project.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Arapitsas P. Identification and quantification of polyphenolic compounds from okra seeds and skins. Food Chemistry. 2008;110(4):1041–1045.
2. Saifullah M, Rabbani MG., Evaluation and characterization of okra (*Abelmoscus esculentus* L. Moench.) genotypes. SAARC Journal of Agriculture. 2009;7(1): 92–99.
3. Oyolu C. Okra Seeds: Potential Source of High Quality Vegetable Oil. In Proc*. 5th* Annual Conference of Horticulture Society. Nsukka, Nigeria. 1983;23.
4. Schippers RR. African indigenous vegetables: An overview of the cultivated species. Natural Resources Institute/ vACPEU Technical Centre for Agricultural and Rural Cooperation, Chatham, UK. 2000;221.
5. Asawalam EF, Emeasor KC, Adieze O. Influence of some soil amendments on insect pest infestation and damage to okra (*Abelmoschus esculentus* (L.) in Umudike, Abia State. Research Journal of Biological Science. 2007;2(1):108–111.
6. Adebawoo OO, Salau BA, Adeyanju MM, Famodu AA, Osilesi O. Fruits and vegetables moderates blood pressure, Fibrinogen concentration and plasma viscosity in Nigerian hypertensives. African Journal of Food, Agriculture, Nutrition and Development. 2007;7(6):1–13.
7. Echezona BC, Asiegbu JE, Izuabga AA. Flea beetle populations and economic yield of Okra as influenced by Nitrogen and 2, 3-Dihydro-2, 2-Dimethyl Benzofuran. African Crop Science Journal. 2010;18(3):97–105.
8. Norman JC. Tropical vegetable crops. Arthur H. Stockwell Ltd., Devon, UK. 1992;252.
9. Vanlommel S, Duchateau L, Coosemans J. The effect of okra mosaic virus and beetle damage on yield of four okra cultivars. African Crop Science Journal. 1996;4(1):71–77.

10. Alegbejo M, Ogulana M, Banwo O. Survey for incidence of Okra mosaic virus in northern Nigeria. Spanish Journal of Agricultural Research. 2008;6(3):408–411.
11. Asare-Bediako E, van der Puije GC, Taah KJ., Abole EA, Baidoo A. Prevalence of okra mosaic and leaf curl diseases and *Podagrica* spp . damage of okra (*Abelmoschus esculentus*) Plant. International Journal of Current Research and Academic Review. 2014;2(6):260–271.
12. Obeng-Ofori D. Sackey J. 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. 2003;26(2):145–150.
13. Iqbal J, Hasan M, Ashafaq , Sahi ST, Ali A. Screening of Okra genotypes against Jassid, amrasca biguttula biguttula (Ishida) (Homoptera: Cicadellidae). Pakistan Journal Agricultural Science. 2008;45(4): 448–451.
14. Alao FO, Adebayo TA, Olaniran OA, Akanbi WB. Preliminary evaluation of the insecticidal potential of organic compost extracts against insect pests of okra (*Abemoschus esculentus* (L.) Moench). Asian Journal of Plant Science and Research. 2011;1(3):123–130.
15. Brunt A, Crabtree K, Gibbs AJ. Viruses of tropical plants. CAB International, Wallingford, UK. 1990;707.
16. Swanson MM, Harrison BD. Serological relationships and epitope profile of an isolate of okra leaves curl geminivirus from Africa and Middle East. Biochemie. 1993; 75(8):707–711.
17. Brown JK. Bird J. Whitefly transmitted geminiviruses and associated disorders in the Americas and the Caribbean Basin. Plant Diseases. 1992;76(348):220–226.
18. Brunt AA, Crabtree K, Dallwitz MJ, Gibbs AJ, Watson L, Viruses of plants. Descriptions and lists from the VIDE database. CAB International, Wallingford, UK. 1996;1484.
19. Askira AB. A survey on the incidence of okra leaf curl virus on okra in Lake Alau Area of Borno State, Nigeria. International Journal of Agriculture. 2012;4(1):1–6.
20. Krishnareddy M, Jalali S, Samuel DK. Fruit distortion mosaic disease of okra in India. Division of plant pathology. Indian Institute of Horticultural Research. 2003;87(11): 1395.
21. Alegbejo MD, Evaluation of okra genotype for resistance to okra mosaic virus. In Abstract of papers delivered at the 15th Annual conference of the Horticultural society of Nigeria held at the National Horticultural Research Institute. Ibadan, Nigeria. 1997;60.
22. Ghanem GAM. Okra leaf curl virus: A monopartite begomovirus infecting okra crop in Saudi Arabia. Arab Journal of Biotechnology. 2003;6(1):139–152.
23. Ukoima HN, Okah A, Use of some biopesticides in controlling pests and diseases of okra (*Abelmoschus esculentus)* in the field. Environment and Ecology. 2006;24(4):773–776.
24. Sumbali G, Mehrotra RS. Principle of microbiology. Tata McGraw-Hill Publishing Inc., New Delhi, India. 2009;924.
25. Nayudu MV. Plant Viruses. Tata McGraw-Hill Publishing Inc., New Delhi, India. 2008;1249.
26. Loebenstein G, Lecoq H. Viruses and virus disease of vegetables in the Mediterranean Basin. In Advances in Virus Research. Elsevier Inc, Oxford, UK; 2012.
27. Amoako PK, Kumah P, Appiah F. Pesticides usage in cabbage (Brassica oleracea) cultivation in the Ejisu-Juaben municipality of the Ashanti Region of Ghana. International Journal of Research in Chemistry and Environment. 2012;2: 26–31.
28. Afari-Sefa V, Asare-Bediako E, Kenyon L, Micah JA. Pesticide use practices and perceptions of vegetable farmers in the cocoa belts of the Ashanti and Western Regions of Ghana. Advances in Crop Science and Technology. 2015;3:174.
    DOI: 10.4172/2329-8863.1000174
29. Ntow WJ. Organochlorine pesticides in water, sediment, crops, and human fluids in a farming community in Ghana. Archives of Environmental Contamination and Toxicology. 2001;40(4):557–563.
30. Ntow WJ, Gijzen HJ, Kelderman P, Drechsel P. Farmer perceptions and pesticide use practices in vegetable production in Ghana. Pest Management Science. 2006;62(4):356–365.
31. Nagaraju N, Venkatesh HM, Warburton H, Muniyappa V. Chancellor TCB, Covin J.

Farmers' perceptions and practices for managing Tomato leaf curl virus disease in Southern India. International Journal of Pest Management. 2002;48(4):333–338.

32. Lewis ILM Miller AS. Anthracnose fruit rot of pepper. In Extension Fact sheet, Plant Pathology. The Ohio State University, Columbus, Ohio, USA; 2004.

© 2018 Asare-Bediako et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/23236