

Original Research Article

Prevalence of mosaic and leaf curl diseases of okra (*Abelmoschus esculentus* L. Moench) in the Central region of Ghana

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 find their correlation with soil fertility status of the okra fields.

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 transition zone, between June 2009 and December 2015.

Methodology: Household data were collected using structured questionnaire from 180 respondents (60 farmers per district) using multi-stage procedure, and analysed using descriptive statistics. Incidence (DI) and severity scores (SS) of OMD and OLCD were determined from thirty-six (36) okra fields selected from each of the three districts. Total N, available P, exchangeable K concentrations and pH of soil samples collected from each of the fields were determined and the relationship between soil fertility status and incidence and severity of the viral diseases determined. The field data was subjected to analysis of variance (ANOVA) and the means separated with least significant difference (LSD) method at 5% level of probability.

Results: There were high prevalence of OMD and OLCD in all the districts surveyed. Incidence and severity of OMD did not differ significantly ($P > 0.05$) among the three AEZs. 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 soils surveyed were acidic (pH 5.23-6.17) with low levels of N (0.11%-0.23%), available soil P (5.53-30.55 $\mu\text{g g}^{-1}$) and K (0.11-0.31 cmol kg^{-1}). There were no significant correlations between soil total N (%), available P and exchangeable K and incidence and severity of OMD and OLCD ($P > 0.05$). Also respondent farmers had small farm holdings and practiced monocropping, using farmer saved seeds. Majority of the farmers were aware of the incidences of OMD and OLCD in their farms, and managed them using mainly pesticides.

Conclusion: The prevalence of viral diseases in the farmers' okra farms is at least, 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 and 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 fibre, 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 OLCV causes yield losses of up to 80% [17, 18].

OLCV is transmitted in a persistent manner by the whitefly (*Bemisia tabaci* Gen.); whereas OMV is transmitted by *Podagrica* species [18]. Symptoms of OLCV 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

44 prevalence of the OMD and OLCD [11]. However, the prevalence of these diseases and pest
45 infestation in other parts of the Central Region is not known.

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47 In his review article, Dordas [21] concluded that there are contradictory reports regarding the
48 effect of plant nutrients and diseases. For instance severity of infection due to obligate
49 parasites increases with increasing N concentration while high N concentration lowers
50 severity of infection caused by facultative parasites. High K concentration decreases the
51 susceptibility of host plants up to the optimal level beyond which no further increases in
52 resistance or tolerance was observed. In contrast, the role of P on resistance or tolerance to
53 diseases was found to be variable and seemingly inconsistent. In general, nutrient-pathogen
54 interactions are not well understood, but according to Spann and Schumann [22] two
55 mechanisms may explain the influence of soil nutrients on plants response to pathogens: (i)
56 the formation of mechanical barriers, primarily through the development of thicker cell walls
57 and (ii) the synthesis of natural defense compounds, such as phytoalexins, antioxidants, and
58 flavanoids, that provide protection against pathogens. It has also been reported that the
59 severity of viral diseases is higher in nutrient deficient soils than in fertile soils. Knowledge of
60 the relationship between soil fertility and severity of viral diseases of okra will, therefore, be
61 useful in the development of appropriate management strategies. Furthermore, information
62 on farmers' knowledge level of these viral diseases and agronomic practices which can
63 influence their spread and severity is also important in the development of effective
64 management strategies.

65 This study assessed farmers' perception on the incidence and management of OMD and
66 OLCD in okra fields and the influence of soil fertility on severity of these viral diseases.

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70 2. MATERIAL AND METHODS

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72 2.1 Study area

73 The study was conducted in three ecological zones in the Central region of Ghana:
 74 Komenda-Edina-Eguafo-Abirem (KEEA) district in the coastal savannah zone, Assin North
 75 (AN) district in the forest zone, and Ajumako-Enyan-Essiam (AEE) district in the forest-
 76 coastal savannah transition zone (Table 1) during 2015 cropping season. These districts are
 77 major okra producing centres in the Central region of Ghana.

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

District	Ecological zone	Longitude/Latitude	Temperature °C	Rainfall (mm)
KEEA	Coastal savannah	1° 20' W to 1° 40' W 5° 05' N to 5° 15' N	26 – 30	750 - 1000
AN	Forest	1° 05' E to 1° 25' E 6° 05' N to 6° 04' N	26 – 30	1500 - 2000
AEE	Transition	0° 53' to 1° 08' W	26 – 30	1200 - 1500

79

80 2.2 Research Design

81 The study was a descriptive survey carried out in two parts; the first part involved a
 82 household survey using questionnaire to identify farmers' perception and their management
 83 of the OMD and OLCB of okra in their various farms. The second part involved a field survey
 84 to determine the incidence and severity of the viral diseases of okra in the various districts,
 85 and their relationships with soil fertility status (N, P, K, and pH) of each okra field.

86

87 2.2.1 Household survey

88 2.2.1.1 Sampling approach

89 A multi-stage approach to sampling was adopted for the study because okra farmers were
 90 selected from different communities in different districts from the three important okra

91 producing agro-ecological zones. Through interactions with personnel (District Directors and
92 Agricultural Extension Agents) from the regional and district directorates of Ministry of Food
93 and Agriculture (MoFA), information on the most important okra growing areas in the various
94 ecological zones in the region was acquired. Reconnaissance survey was conducted for
95 familiarization of the study area. This led to the selection of the three districts across the
96 three ecological zones in the region for this study.

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

101

102 ***2.2.1.2 Instrumentation and data collection***

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

112

113 **2.2.2 Disease assessment**

114 Twelve okra fields from each district were selected randomly. A transect (25 m²) was made at
115 three different points along the diagonal of each field and all plants within transects were
116 assessed for incidence and severity of OMD and OLCD. The prevalence of the viral

diseases were 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.* [23] with modification as indicated in Table 2.

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

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.* [23].

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

130

131 **2.2.3 Determination of the Relationship between Soil Fertility Status and Severity of**

132 **the Okra Viral Diseases**

133 Soil samples were collected from all the farms surveyed. Surface samples (0 -15 cm)

134 collected from 20 different spots at each site were thoroughly mixed to form a composite

135 sample after all plant debris had been removed. The samples were air-dried and sieved

136 through a 2 mm mesh sieve to obtain the fine earth fraction (< 2 mm) which was used for

137 laboratory analyses.

138

139 **2.2.3.1 Soil Analyses**

140 All the soil samples collected during the study were analyzed at the Soil Science laboratory

141 of the University of Cape Coast using standard laboratory procedure. Soil pH was

142 determined in water (1:2.5; soil:water ratio) according to the method described by Rowell

143 [24]. Total N concentration in the soil was determined using the microKjeldahl method

144 described by Bremner [25]. Available phosphorus was determined using the method of Bray

145 and Kurtz [26]. A soil extract was obtained with 1.0 M NH_4OAc (pH 7.0) and exchangeable K

146 concentration in the extract was determined by flame photometry.

147

148 **2.3 Data analyses**

149 The data from the household survey was analyzed using descriptive statistics (means,

150 frequency distributions, and percentages), and inferential statistics (chi-square test).

151 Microsoft 'EXCEL' and IBM 'Statistical Package for the Service Solutions (SPSS)' Software

152 Package Version 16 were used to process the elicited data. Data on disease incidence was

153 transformed with angular transformations in order to homogenize the variance before being

154 subjected to analysis of variance (ANOVA). The other quantitative data (severity scores of

155 OMD, OLCD) were subjected to ANOVA and the means separated by least significance
156 difference (l.s.d.) at 5% level of probability using GenStat Discovery version 4 (VSN
157 International).Data on soil fertility status (total N, available P, exchangeable K and pH)
158 analyzed were presented as means of three samples with standard deviations. Pearson's
159 correlation coefficients were calculated for the relationships between incidence and severity
160 of OMD and OLCD and soil total N, available P, exchangeable K and pH using GenStat.

161

162

163 **3. RESULTS**

164

165 **3.1 Household and farm characteristics**

166 A total of 180 respondents (58.3% males; 41.7% females) participated in the study (Table 4).
167 Majority of the respondents (71%) were within the age group of 20-29 years and 50-59
168 years. Most respondent farmers (31.1%) were Junior High School graduates, followed by
169 primary school (22.8%), Middle School (21.1%) graduates as indicated in Figure 1. Farmers
170 who had completed Senior High School and tertiary education were 6.1 and 2.2%,
171 respectively of the total respondents, whereas 16.7% were illiterates (Figure 1). Majority of
172 the farmers (53.3%) had farm sizes of less than 0.4 ha followed by those (39.4%) whose
173 farm sizes ranged from 1 to 1.2 ha, whereas only 7.3% had farm sizes greater than 1.2 ha
174 (Table 4).

175 With respect to land tenure system, most farmers (47.7%) farmed on rented land, 27.1%
176 farm on family land, 11.7% acquired their own land; whereas 10.6% practiced share
177 cropping. Only a few of them (2.9%) practiced a combination of the above mentioned land
178 tenure systems (Table 4). Most farmers (42.2%) employed both family and hired labour for
179 farming, 23.8% used only family labour, 22.2% used both self and hired labour, whereas
180 10.6% used only self-labour, only 1.2% of the respondent farmers employed “nnoboa” either
181 alone or in combination with hired labour (Figure 2).

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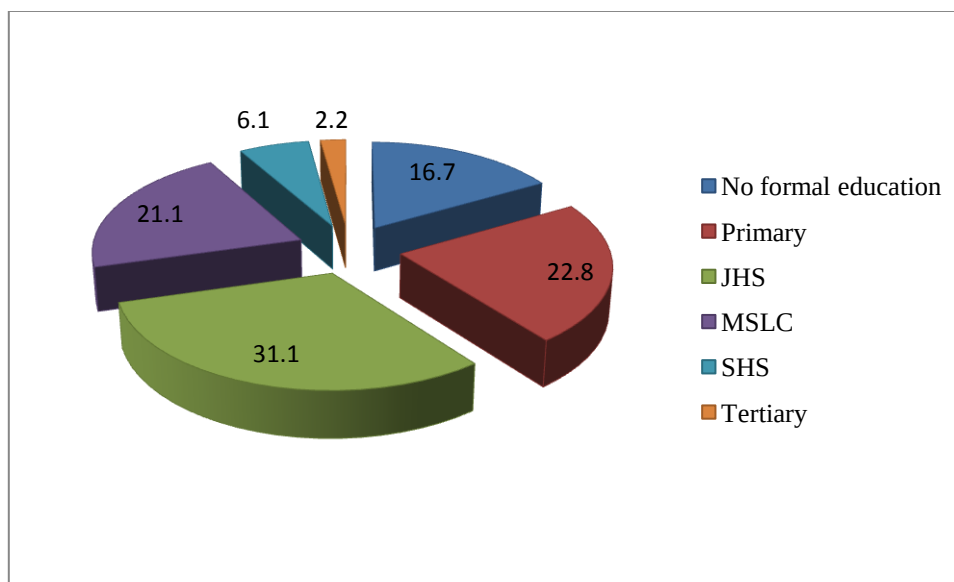
183 **Table 4. Demographic characteristics of respondent Okra farmers in the study area.**

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

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187 **Fig. 1. Level of education of respondent okra farmers**

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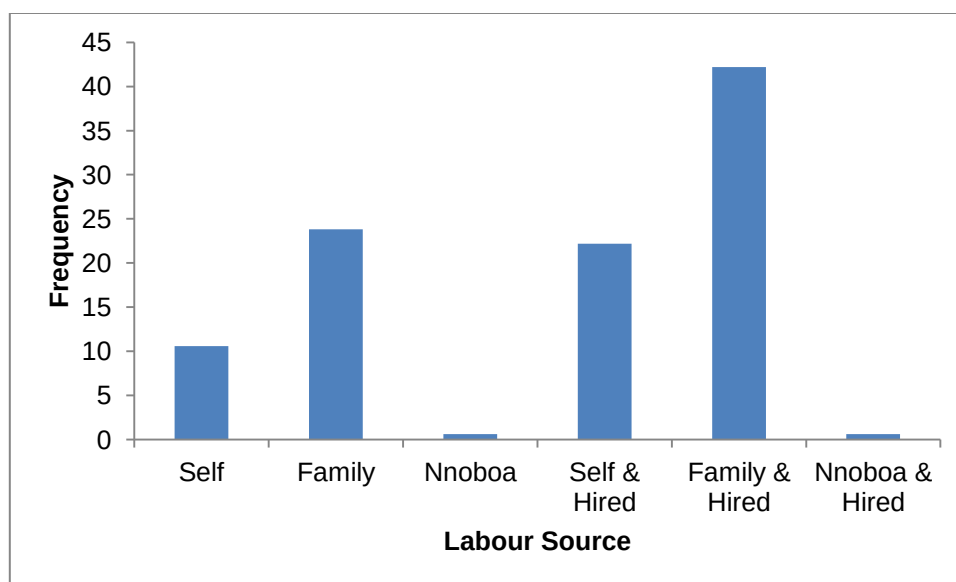


Fig. 2. Source of labour used by the respondent okra farmers

3.2.Farmers' agronomic practices

As for land preparation, most farmers (43.3%) practiced slash and burn, 18.3% practiced, zero tillage, 11.7% used 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, 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%) practiced both major and minor season farming; 11.8% practiced only major season farming; whereas the other 6.7% practiced minor season farming only (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, 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 okra cultivars cultivated 11.2% said 'Asontem', 5.6% indicated 'Avalavi' and 1.7% pointed to 'Nkrankrumba' as shown in Figure 3.

208 **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

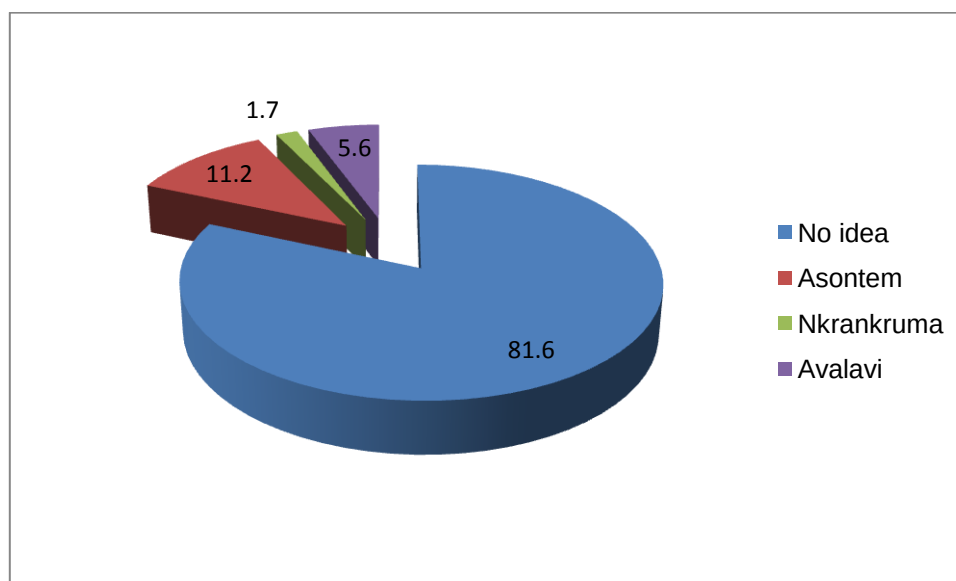


Fig. 3. Names of okra cultivars cultivated by the respondent farmers in the study area.

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 incidences of OLCD and OMD occurring during the vegetative growth stage, followed by those who said the diseases occurred during the flowering and fruiting stages, only few of them (less than 4%) indicated diseases 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 major season and minor season only 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 (Figure 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 (Figure 5).

Yield loss of 50% due to the OLCD and OMD were reported by the respondents (Figure 7). Most farmers reported of yield losses ranging from 41- 50% due to OLCD (32.6%); and OMD (28.6%) (Figure 6). This was followed by farmers who noted that OLCD (27.5%) and OMD (15.4%) could cause yield losses of over 50%.

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	7	3.9
Seedling Stage		
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

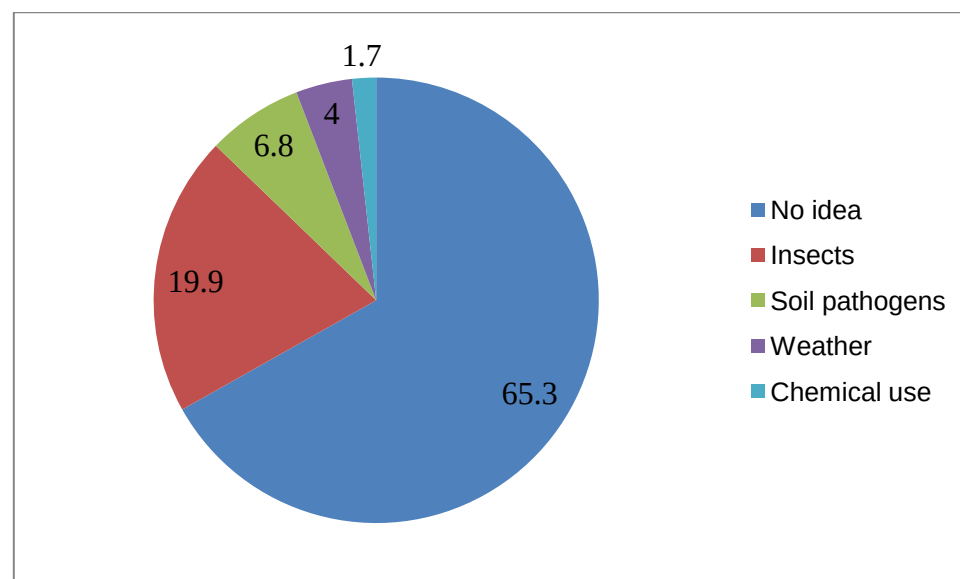
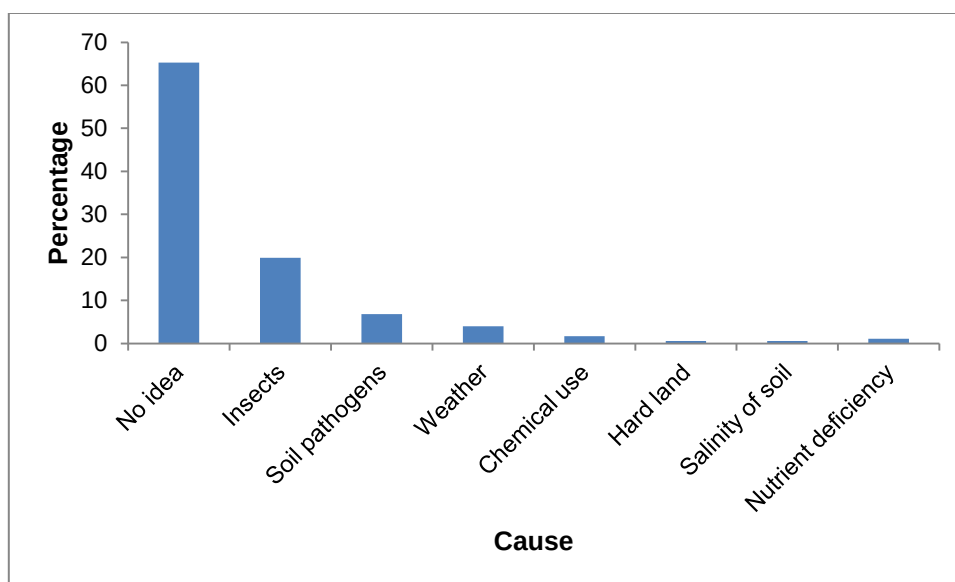


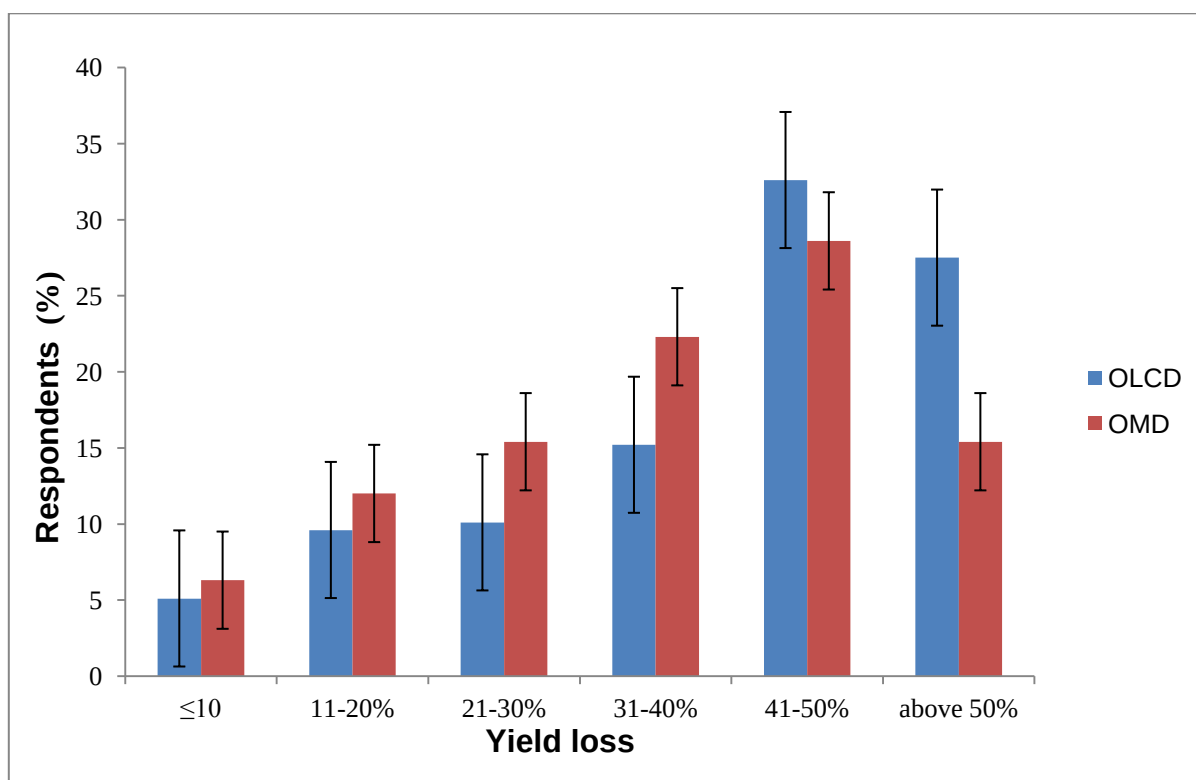
Fig. 4. Farmers' perception on the causes of okra leaf curl disease (OLCD) in the study area.



240

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

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243

244 **Fig. 6. Yield losses of okra by the respondent farmers due to okra mosaic disease**

245 **(OMD) and okra leaf curl disease (OLCD) in the study area. (Error bars = SED)**

246 3.4 Disease management practices

247 Majority of the farmers (80%) managed diseases on their okra farms by using only synthetic
 248 pesticides, with only 0.6% using botanicals (Table 7). About 10.5% of the farmers used
 249 pesticides and also practiced roguing; 1.7% practiced only rogueing but 7.2% did not apply
 250 disease management method (Table 7). Majority of the farmers (97.7%) relied on agro input
 251 shops for the pesticides; whereas only 1.2% relied on agricultural extension agents.
 252 However, there were few farmers who relied on neighbours (0.6%) and pesticides peddlers
 253 (0.6%) for recommendation on the types of pesticides they use (Table 8). Majority of the
 254 farmers (59.1%) used the same chemicals season after season but 40.9% of the farmers
 255 varied them from time to time (Table 7).

256
 257 Majority of the respondents (62.7%) applied pesticides fortnightly; 25.9% applied the
 258 chemicals weekly; whereas 11.4% of the respondents applied the pesticides over 2 weeks
 259 intervals (Figure 7). Many respondents (39.8%) observed pre-harvesting intervals (PHI) of 3
 260 days, followed by 39.3% (PHI of 4 days), 17.2% (4 days); whereas 3.7% (PHI of 2 days). In
 261 response to the question of whether the pesticides they applied was effective in managing
 262 the target pest and diseases, majority of the respondents (85.7%) said the pesticides were
 263 not effective whereas the rest (14.3%) said they were effective (Table 7).

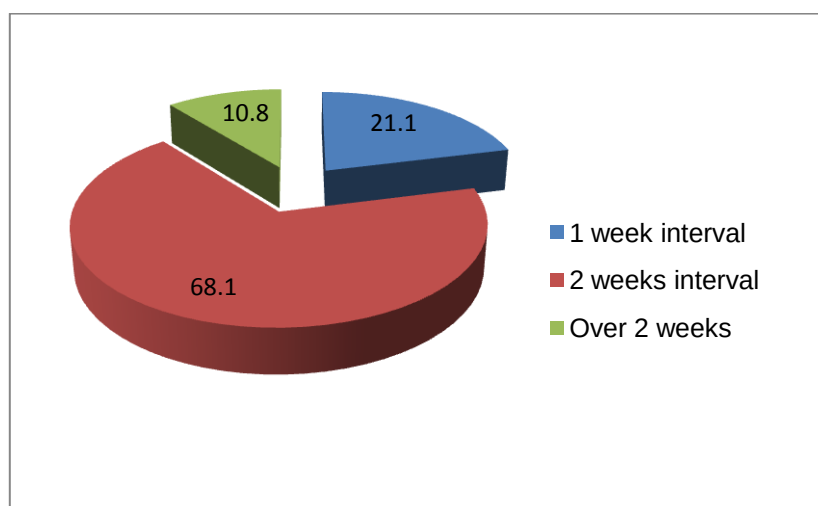
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265 **Table 7. Management of OMD and OLCD by the okra farmers in the study area**

Variable	Frequency	Percentage
Disease management method		
Chemical	144	80
Cultural (Roguing)	3	1.7
Botanical	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 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

266



267

Fig. 7. Frequency of pesticide application by the farmers in the study area.

3.5 Gender, educational level and farming experience

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

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

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

Table 8. Effect of farmers' sex, educational level and farming experience on their perception and management of OMD and 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

289

290 **3.6 Pesticides applied**

291 A total of 18 pesticides were used for okra farming in the study area for the management of
 292 viral diseases. The pesticides consisted of 14 insecticides and 4 fungicides (Table 9).The
 293 classification of these pesticides by the category of pests they control, active ingredient,
 294 chemical group and the World Health Organization (WHO) Hazard category is presented in
 295 Table 9.Two out of 12 insecticides used by the farmers are not registered by the Ghana
 296 Environmental Protection Agency. Generally, most farmers used insecticides and fungicides
 297 which had not been cleared for use on specific vegetable crops or were applying pesticides
 298 not registered for vegetable production by the Environmental Protection Agency (EPA). For
 299 instance, Aceta Star EC (Bifenthrin+Acetamiprid), Confidor 200SL (Imidachloprid) and
 300 Akatemaster (Bifenthrin) are registered only for use in cocoa production, but the farmers are

301 using them for okra and other vegetable production. Besides, some of the farmers used DDT
 302 which is a banned chemical in Ghana.
 303 Furthermore, farmers used fungicides (Mancozeb, Copper hydroxide, Cupric hydroxide,
 304 Thiophanate methyl) to control viral diseases and their insect vectors (flea beetle and
 305 whitefly) as shown in Table 9. This indicated that the farmers were using wrong chemicals in
 306 the management of insect vectors and the diseases they transmit.

307

308 **Table 9.Types of pesticides used by farmers in managing OMVD, OLCVD and their**
 309 **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
	Thiopsin 70 WP	Thiophanate methyl	III	1	Crops

* Banned; nk – not known

3.7 Prevalence of okra mosaic disease (OMD) and okra leaf curl disease (OLCD)

Incidences of 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 on the incidence of OMD in okra fields in the three zones showed no significant differences among them ($F = 2.15$; $df = 24$; $P = 0.139$) (Table 10). This suggests that the different ecological zones did not have significant influence on the incidence of the OMD in the region. However, the highest incidence (76.2%) occurred in the forest zone, followed by the transitional zone (75%) whereas the coastal savannah had the lowest (67.6%).

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
<i>P</i> 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

ANOVA showed highly significant differences among the three agro-ecological zones with respect to their mean OLCD severity scores ($F = 18.15$; $df = 24$; $P < 0.001$). The highest mean severity score was recorded for the coastal savannah (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. This was followed by the transitional zone with mean severity score of 1.93, whereas the coastal savannah had the lowest (1.60) (Table 11).

Table 11: Severity of OLCD and 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	-
<i>P</i> value	<0.001	0.259

NS-not significant ($P > 0.05$).

KEEA-Komenda-Edina-Eguafo-Abirem, AEE- Ajumako-Enyan-Essiam

342

343 **3.8 Relationship between Soil fertility and incidence and severity of viral**
 344 **diseases**

345 The total N concentrations in the soils were found to be adequate ($>0.13\%$) in the
 346 Nkrafuom, Kwekukwaa, Denkyira, Nsawir, FosuOdumase, Atwereboanda, Akonfudi soils but
 347 low in the rest of the soils (Table 12). Available P and exchangeable K concentrations were
 348 low in all the soils except at EnyanAbaasa only ($30.35\text{ }\mu\text{g g}^{-1}$) and Nsawir (0.56 cmol kg^{-1}),
 349 respectively. Soil pH in all the soils was greater than 5.5 (ranged from 5.63 to 6.0) except in
 350 the Dompim soil (5.37), which also showed the least available P concentration ($5.33\text{ }\mu\text{g g}^{-1}$).
 351 $^{-1}$).

352 The laboratory analytical data indicated that all the soil samples collected from the different
 353 farms had low inherent fertility status; their total N concentrations were low or barely
 354 adequate, and available P and exchangeable K concentrations were low in all the soils
 355 except in the Enyan Abasa and Nsawir soils, respectively (Table 12).

356

357 **Table 12. Soil pH, total N (%), available P ($\mu\text{g g}^{-1}$) and exchangeable K concentration**
 358 **(cmol kg^{-1}) in the soils surveyed.**

District	Community	% N		Available P		Exchangeable		pH
				(μgg ⁻¹)		K (cmolkg ⁻¹)		
AEE	Enyan Abaasa	0.11	(0.04)	30.35	(0.19)	0.28	(0.06)	5.93
AEE	Atwereboanda	0.16	(0.02)	11.55	(0.04)	0.25	(0.06)	5.73
AEE	Enyan Denkyira	0.13	(0.04)	14.49	(0.04)	0.17	(0.02)	5.93
AEE	Kwekukwaa	0.23	(0.07)	9.72	(0.15)	0.31	(0.06)	5.63
Assin North	Akonfudi	0.16	(0.02)	13.74	(0.13)	0.25	(0.05)	6.17
Assin North	Fosu Odumase	0.20	(0.05)	19.02	(0.02)	0.17	(0.08)	5.67
Assin North	Dompim	0.12	(0.06)	13.09	(0.03)	0.11	(0.00)	5.80

Assin North	Nkrafuom	0.15	(0.01)	7.53	(0.04)	0.12	(0.06)	5.87
KEEA	Antado	0.13	(0.03)	10.44	(0.04)	0.23	(0.06)	5.77
KEEA	Nsadwir	0.17	(0.03)	8.82	(0.05)	0.56	(0.17)	6.00
KEEA	Dompoase	0.11	(0.02)	5.33	(0.08)	0.14	(0.05)	5.37
KEEA	Nkontrodo	0.10	(0.01)	5.77	(0.06)	0.19	(0.06)	5.60

The values in brackets represent $\pm$ standard deviation

KEEA: Komenda-Edina-Eguafo-Abirem; AEE: Ajumako-Enyan-Essiam

Pearson's correlation coefficients were calculated in order to ascertain the relationships between soil fertility status and incidence and severity of OLCD and OMD infection (Table 13). Results revealed no significant correlations between soil N, P and K and incidence and severity of OMD and OLCD of okra leaves ($P>0.05$). Soil pH significantly and negatively correlated with incidence of OMD ($r = -0.3877$; $df = 36$; $P = 0.0195$) but did not significantly correlate with incidence and severity of OLCD and severity of OMD ($P> 0.05$). (Table 13)

Table 13: Correlations between soil N, P, K and pH and incidence and severity of OLCD and OMD

Variables	Incidence		Severity	
	OMD	OLCD	OMD	OLCD
%N	0.0886	-0.0490	-0.1479	0.0969
%P	0.0169	0.0926	0.1525	0.1380
%K	-0.1438	0.0893	-0.1636	0.0959
Soil pH	-0.3877*	-0.230	-0.1274	-0.1664

* Significant ($P= 0.05$).

4. DISCUSSION

376 The study has shown high prevalence and severity of okra mosaic disease (OMD) and okra
 377 leaf curl diseases (OLCD) in the three agro-ecological zones in the Central region of Ghana
 378 (Tables 6, 10 11). This is consistent with the research findings where high prevalence of
 379 these viral diseases were recorded at farmers' okra fields in KEEA [11] and other parts of the
 380 country [12, 11]. Incidence of viral diseases in okra had also been reported in several other
 381 countries [9, 10, 19, 27, 28,]. The farms surveyed were seriously devastated by the OMD
 382 and OLCD, as was reported by Asare-Bediako *et al.* [11] in a survey on the incidence and
 383 severity of OMD and OLCD of okra farms in the KEEA district of the Central region of
 384 Ghana. These findings thus support the assertion that OLCD and OMD are major viral
 385 diseases of okra in Ghana [12, 11]. OLCD incidence was also observed to be devastating
 386 over 50% of farms surveyed by Askira [19] in Lake Alau area of Borno State of Nigeria.

387

388 The high prevalence and severity of viral diseases observed in the study areas could partly
 389 be attributable to the poor agronomic practices by the farmers, as was also reported by [11].
 390 It was revealed in the current study that majority (80.6%) of the farmers relied on local
 391 uncertified seeds from their own farms for propagation. However the practice of using farmer
 392 saved seed contributes to the spread of viral diseases [29, 30]. It has also been reported that
 393 majority of seedlings grown from virus contaminated planting materials will be diseased and
 394 can serve as a source of inoculum for other healthy plants, which can aid the spread of the
 395 virus if vectors are present [29].It was also discovered in the study that majority of the
 396 farmers practiced monocropping in the major and minor cropping seasons, suggesting that
 397 they cropped throughout the year. It has been reported that continuous cultivation of the
 398 same crop, especially in tropical and sub-tropical countries, is a potential cause of viral
 399 disease epidemics [31]. According to Nayudu [32], increased monocropping over vast areas
 400 favour vector populations and establishment of viruses, leading to increased severity of
 401 diseases. Loebenstein and Lecoq [33] also argued that continuous planting also 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 the pesticides every two weeks (Figure 7). This high frequency of pesticides application has also been reported by other scientists [34, 35]. According to Ntow [36], the pattern and frequency of insecticide 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 have been reported by other scientists [34, 35, 37]. It was observed in our study that most farmers used fungicides (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 they are applying pesticides which are not registered for vegetable production. For instance, Aceta Star EC (Bifenthrin+Acetamiprid), Confidor 200SL (Imidachloprid) 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 are misusing such pesticides thereby affecting the quality and safety of vegetables for consumption as has been argued by Afari-Sefa *et al.* [35].

The findings of the present study support the reports of Amoako *et al.* [34] and Afari-Sefa *et al.* [35] who confirmed that certain banned chemicals (i.e. Endosulfans and DDT) and those not recommended for vegetables (i.e. Akatemaster which contains bifenthrin, Confidor which

429 contains imidacloprid and thiamethoxam and Cocostar which contains bifenthrin and
430 pirimiphosmethyl) were being used for vegetable production in parts of Ashanti and Western
431 regions of Ghana. This practice seriously endangers the lives of consumers, and so farmers
432 should be advised to desist from it.

433

434 The study revealed that the farmers' educational levels and experience in farming had
435 significant influence on their awareness and management of the OMD. These findings are
436 consistent with that of Nagaraju *et al.* [38] who reported that both formal education and
437 experience in farming or number of years in farming can serve as means through which
438 farmers get informed. Most farmers attained at least Junior High School education with only
439 16.7% being illiterates (Figure 1). This explains why majority of farmers were aware of the
440 incidence of the viral diseases in their farms.

441

442 The study also showed that majority of farmers adopted measures at diseases in their okra
443 farms. This could be due to their high awareness of the incidence of diseases in their farms
444 and their effect on the yield and quality of okra. This finding agrees with Lewis and Miller [39]
445 who reported that basic knowledge about prevalence of a disease is one of the main tools in
446 its management. Most farmers also reported of yield loss ranging from 41% - 50% due to
447 OMD and OLCB, which is a clear evidence of the effect of these diseases on the yield of
448 okra.

449

450 The study further has revealed that most vegetable farmers harvest their produce between 2
451 and 4 days after spraying pesticides thereby exposing consumers to high pesticide residue
452 levels. This finding corroborates reports of Amoako *et al.* [34] And Afari-Sefa *et al.* [35]. It
453 was revealed in their studies that vegetable farmers in parts of Ashanti and Western regions
454 do not even observe any waiting period but harvest their produce the same day as they
455 apply the pesticides. Judging from the fact that the pre-harvest intervals of the pesticides

456 used by the farmers range from 7 to 30 days, it is quite clear that consumers are being pre-
457 disposed to severe health risk.

458

459 Furthermore, the study has revealed that the soils surveyed had low inherent fertility status,
460 in that their total N concentrations, available P and exchangeable K concentrations were all
461 generally low (Table 12). The critical limits of total N, available P and exchangeable K
462 recommended by the Council for Scientific and Industrial Research (CSIR) are 0.13%, 20 μg
463 g^{-1} , 0.47 cmol kg^{-1} for total N, available P and exchangeable K, respectively Yeboah *et al.*
464 [40] The low nutrient content of the soil is attributable to the highly weathered nature of the
465 parent material, which would have been exacerbated by continuous cropping as argued by
466 Juo *et al.* [41]. In addition, the soils surveyed were found to be slightly acidic, in that the soil
467 pH ranged between 5.63 and 6.17 (Table 12). The low soil pH could be attributable to
468 continuous cropping [42] and leaching of soil basic cations. It has been reported Garcia-Gill
469 *et al.* [43] that soil pH is one of the deciding factors affecting plant nutrient uptake and
470 movement and many soil attributes and reactions. This suggests that soil pH plays a
471 significant role in the overall health status of plants. This could explain the significantly
472 negative correlation between soil pH and incidence and severity of OMD and OLCD
473 observed in the present study (Table 13). However, there were no significant correlations
474 between soil total N, available P and exchangeable K and incidence and severity of OMD
475 and OLCD of okra leaves (Table 13). This suggests that the degrees of incidence of these
476 viral diseases were independent of the levels of soil total N, available P and exchangeable K
477 in the okra farms surveyed. The generally inherent low soil fertility status of the okra farms
478 predisposed the crops to diseases. On fertile soils, plants grow vigorously and are better
479 adapted to resist pest and disease attacks.

480

481 **5. CONCLUSIONS**

482
483 The study has demonstrated high prevalence and severity of OMD and OLCD in the okra
484 farms in the Central region of Ghana. Soil fertility status of the farms was inherently low and
485 acidic. Majority of the farmers had low educational levels and were adopting poor agronomic
486 practices by using farmer saved seed, practiced monocropping and managed diseases
487 mainly with synthetic pesticides. Majority of farmers were misusing the pesticides by
488 spraying every two weeks, did not observe appropriate pre-harvest intervals, used
489 insecticides not registered for vegetables and wrongly used fungicides against insects and
490 viral diseases.

491

492

493

494 **COMPETING INTERESTS**

495

496 Authors have declared that no competing interests exist.

497

498

499

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