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Incidence and Severity of Viral and Fungal Diseases of Chili Pepper (*Capsicum frutescens*) in Some Districts in Ghana

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To assess the incidence and severity of viral and fungal diseases infecting pepper in some major producing areas in Ghana and to identify farmers' agronomic practices that influence disease incidence and severity.
Study Design: Descriptive survey involving household and field surveys.
Place and Duration of Study: Sekyere South district of the Ashanti Region, Komenda-Edina-Eguafo-Abirem district of Central Region, Kintampo South district of Brong-Ahafo Region and North and South Tongu districts in the Volta Region, between April 2013 and September 2013.
Methodology: Questionnaire with both open ended- and closed ended- questions was administered to 30 pepper farmers purposively selected from each of the selected district in each Region in order to determine the farmers' awareness of the fungal and viral diseases and their

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agronomic practices which could affect the disease spread in their farms. Thirty hot pepper fields from each district were selected randomly and forty (40) plants from each of the fields were observed for disease incidence and severity. Pepper diseases assessed were pepper mosaic, phytophthora leaf blight, cercospora leaf spot, fruit rot and leaf anthracnose.

Results: There were high incidences (up to 86.3%) and severities (11.8-32.1%) of pepper mosaic disease, leaf anthracnose, anthracnose fruit rot, phytophthora blight and cercospora leaf spot in all the fields surveyed. Majority of the farmers use seeds from their own farms (30-60%), practice monocropping (50-73.7%), rotate their pepper crops with tomatoes and garden eggs (43-60%) and manage diseases in their farms using synthetic pesticides (50-70%).

Conclusion: The adoption of poor agronomic practices by the farmers was the major contributing factor for the high incidences and severities of viral and fungal diseases in their farms.

Keywords: Chili pepper; viral diseases; fungal diseases; pepper mosaic disease; anthracnose; phytophthora blight; cercospora leaf spot.

1. INTRODUCTION

Chili pepper (*Capsicum frutescens* L), an herbaceous biennial of the Solanaceae family is one of the most important spices and condiments in the world. It is consumed daily by a quarter of the world population and the rate of consumption is growing. World chili pepper production has grown on average 3.9 percent per year during the last 10 years led by a steady increase of global demand. The main chili pepper producers in the world are China, Mexico, and Turkey, which in total account for more than 70 percent of the world chili pepper production [1]. Ghana ranks 11th place among the leading chili producers in the world, and 2nd as the largest producer in Africa with an estimated total production of 88,000 metric tons in 2011 [2].

In Ghana, chili pepper is produced either as a single crop or as a mixed crop in the Central Region (Komenda, Edina Eguafo-Abirem Municipality and Mfantseman West Districts), Brong Ahafo Region (Kintampo North and South Districts), in the Ashanti Region (Sekyere South), Eastern Region (Kwahu East and South Districts), Volta Region (Tongu, Adidome and Bator areas), the Northern Region, and some areas in Upper East and Upper West Regions. The crop is cultivated widely in Ghana mainly for its fruit's pungent taste and scent. It can be eaten green, ripe or in dry powdered forms.

Pepper production is a source of livelihood of many farmers across the country. The produce also serves as foreign income earner to Ghana due to its high demands in the European countries such as Germany, France and the United Kingdom [1,3]. It has been reported that Ghana is the 5th largest exporter of chilli peppers to the European Union (EU) with an annual export increase of 17 per cent since the year 2000 [1]. Ghanaian chili exports have ranged between 26,000 and 41,000 metric tons over the past five years with corresponding foreign exchange earnings increasing from US$18.2 to US$28.7 million [1].

Notwithstanding the importance of pepper to the economy of Ghana, low yields are constantly being recorded by the local farmers, leading to a decline in production of the crop. The current yield of 6.8 Mt ha^{-1} is far below an achievable yield of 33.4 Mt ha^{-1} [4]. The drop in production has also resulted in the reduction of the volume of pepper for export.

Factors which have been reported to militate against vegetable production in Ghana include poor husbandry techniques, pests and diseases, poor extension services, unreliable rainfall, and lack of organized post harvest processing and marketing [5]. However, diseases are major constraints to hot pepper production in sub-Saharan Africa [6] including Ghana. Phytopathogenic fungi, bacteria and viruses having been reported to cause a major yield loss in pepper. However, there is limited information on specific diseases responsible for the decline in yield and production of pepper in Ghana. Such information is very important for the development of effective control strategy for the management of diseases in farmers' fields in order to improve yields. The study was aimed at assessing the incidence and severity of common viral and fungal diseases of pepper and to identify farmers' agronomic practices that influence their spread and severity.

2. MATERIALS AND METHODS

2.1 Study Area

The research was conducted in five districts in Ghana. These are Sekyere South district of the Ashanti Region, Komenda-Edina-Eguafo-Abirem district of Central Region, Kintampo South district of Brong-Ahafo Region, and North and South Tongu districts in the Volta Region. These districts are major pepper producing centres in Ghana.

2.2 Research Design

The study was a descriptive survey carried out in two parts. The first part involved a household survey using questionnaire to identify farmer's agronomic practices that influence incidences of diseases in their pepper farms. The second part involved a field survey to determine the incidence and severity of viral and fungal diseases of pepper in the various districts.

2.2.1 The household survey

Questionnaire with both open ended- and closed ended- questions (Appendix 1) was administered to 30 pepper farmers purposively selected from each of the selected district in each region. The questions were written in English and administered in both English and local languages (Akan). In total, 150 households were surveyed.

2.2.2 Disease assessment

Thirty (30) hot pepper fields from each district were selected randomly and forty (40) plants from each of the fields were observed for disease incidence. Disease assessments were made by observing visual expression of symptoms on representative plants to determine the general presence or absence of diseases using the Asian Vegetable Research and Development Centre (AVRDC) pepper disease compendium [7]. Pepper diseases assessed were pepper mosaic, phytophthora leaf blight, cercospora leaf spot, fruit rot and leaf anthracnose (Table 1).

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, as reported [8]. The disease severity index (DSI) for each disease was calculated according to the formula $DSI = \sum(P \times Q)/ (M \times N)] \times 100$ [8]. Where P = severity score, Q = number of infected plants having the same score; M = Total number of plants observed, N = Maximum rating scale number.

2.3 Data Analysis

The household data were analysed using descriptive statistics comprising means, frequency distributions and percentages, using Statistical Product and Service Solutions (SPSS) programme, version 18. Data on disease incidences and severity indices were transformed using the Arcsine transformation, in order to ensure homogeneity of the variance and normal distribution of the data. The transformed data was subjected to analysis of variance (ANOVA) and means separated by the least significant difference method at 5% level of probability using GenStat Discovery 9th edition [VSN International].

3. RESULTS

3.1 Demographic Characteristics of Farmers

Most farmers in all four regions were in the age range of 30-59 years, implying that pepper farmers comprised of young and middle age people (Table 2). Farmers within the age range of 30-39 years dominate in the North Tongu (46.7%) and South Tongu districts (40%) compared to KEEA (20%), Kintampo South (26.7%) and Sekyere South (23.3%) districts (Table 1). KEEA (33.3%) and Kintampo South (40%) had more farmers within the age range of 40-49 years compared to South Tongu (20%), North Tongu (16.75) and Sekyere South (20%). Sekyere South on the other hand had more farmers within the age range of 50-59 years (36.7%) compared to KEEA (23.3%), South Tongu (16.7%), Noth Tongu (23.3%) and Kintampo South (16.7%). Only few farmers in each district were in the age ranges of 20-29 years (6.7 – 13.3%) and 60 years and above (3.3% - 13.3%).

3.2 Farmers Agronomic Practices

Majority of the farmers in all the districts surveyed used seeds from their own farms (30-60%), local markets (16.7-26.7%) and friends (6.7-26.7%) (Table 3). Only few farmers (10-23.3%) obtain seeds from agro-chemical stores, indicating that most of the farmers obtain seeds from uncertified sources. In terms of their cropping pattern most of the farmers practice monocropping (53.3-73.7%), while others practice mixed cropping (26.7-46.7%).

When the farmers were asked about their previous crop before pepper was cultivated, majority said they cultivated tomatoes or garden eggs (43.3-60%) whereas others rotated pepper with either maize, okra, cassava or watermelon (0 - 20%). On the other hand, up to 20% of the farmers practice land fallowing. Majority of the farmers (50-70%) across the districts use synthetic pesticides in the management of pests and diseases in their farms. Only few of the farmers use botanicals (0-6.7%), rogue diseased plants (13.3 -26.7%) and control weeds regularly (6.7-16.7%) in the management of diseases in their pepper farms (Table 3).

Table 1. Disease rating scales used in scoring observed diseases in the fields

Disease	Rating scale	Description	Reference
Cercospora leaf spot	0	No disease symptom	[8]
	1	10% of canopy showing diseased symptoms	
	3	10-20% of canopy showing disease symptoms	
	5	25-50% of the canopy showing disease symptoms	
	7	50-75% of canopy showing disease symptoms	
	9	>75% of canopy showing disease symptoms	
	0	Symptomless/healthy plant	Modified
	1	Leaf yellowing and no stem necrosis	[9]
	2	Leaf yellowing, small lesions on lower leaves/minor stem necrosis	
	3	Lesions on lower and middle leaves, leaf drop and shallow stem necrosis	
	4	Lesions on most leaves, extensive leaf drop and deep stem lesions	
	5	Extensive leaf and stem necrosis cum dead plant	
Leaf anthracnose (*Colletotrichum* spp*)*	0	Healthy	[10]
	1	1-5% of mature leaves with necrotic and chlorotic symptoms	
	2	6-15% of mature leaves with necrotic and chlorotic symptoms	
	3	15-50% of young shoots and stems water soaked lesions and minor die back	
	4	51-95% of water-soaked lesions with abundance mycelia growth and fructification, and extensive shoot dieback	
	5	Dead plant	
Fruit rot	0	Healthy fruit on entire plant	
	1	Sunken, light-coloured lesions on exposed fruits lesion can enlarge that may extend to sides	
	2	Dark leathery spot on blossom-end Raised, wart-like brown lesion + Small pale halos- “ghost spots”	[11]
	3	Water-soaked, dull green spots covered with cream mould growth	
	4	Water-soaked sunken lesions that expand Cloudy, yellow blotches directly below skin	
	5	Pods soften and quickly collapse	
Viral disease	0	Health, asymptomatic plant	Modified
	1	mild mosaic, mottle or chlorosis on leaves	[12]
	2	moderate chlorosis, mottle or mild mosaic without significant leaf distortion	
	3	Score 1or 2 plus leaf malformation	
	4	Severe chlorosis, mottle or mosaic plus stunting or dwarfing of the whole plant	
	5	Score 4 plus leaf drop and dying	

Table 2. Background information of respondents

Characteristics	Districts (Regions)				
	KEEA (CR)	South Tongu (VR)	North Tongu (VR)	Kintampo South (BAR)	Sekyere South (AR)
	Frequency	Frequency	Frequency	Frequency	Frequency
Age (years)					
20 – 29	3 (10.0)	2 (6.7)	3 (10.0)	4 (13.3)	3 (10.0)
30 – 39	6 (20.0)	14 (46.7)	12 (40.0)	8 (26.7)	7 (23.3)
40 – 49	10 (33.3)	6 (20.0)	5 (16.7)	12 (40.0)	6 (20.0)
50 – 59	7 (23.3)	5 (16.7)	7 (23.3)	5 (16.7)	11 (36.7)
60 and above	4 (13.3)	3 (10.0)	3 (10.0)	1 (3.3)	3 (10.0)
Educational level					
No formal education	6 (20.0)	13 (43.3)	12 (40.0)	12 (40.0)	9 (30.0)
Primary	2 (6.7)	7 (23.3)	9 (30.0)	7 (23.3)	4 (13.3)
J.H.S/Middle school	18 (60.0)	8 (26.7)	5 (16.7)	5 (16.7)	10 (33.3)
S.H.S	2 (6.7)	2 (6.7)	3 (10.0)	4 (13.3)	6 (20.0)
Tertiary	2 (6.7)	0 (0.0)	1 (3.3)	2 (6.7)	1 (3.3)

Values in parenthesis are percentages of the frequencies
AR-Ashanti Region, BAR-Brong Ahafo Region, CR-Central Region, VR-Volta Region,

3.3 Mean Incidence of Viral and Fungal Diseases

Results revealed varying levels of incidences of pepper mosaic, anthracnose, cercospora leaf spot, phythophtora blight and fruit rot diseases of chili pepper fields at various districts surveyed (Table 4). Incidences of anthracnose, fruit rot and pepper mosaic diseases were significantly higher in KEEA districts than at the other districts ($P < 0.05$). Incidence of anthracnose in Sekyere South district was not significantly different from that of North and South Tongu districts but significantly higher than that of Kintampo South district ($P<0.05$). Incidences of cercospora leaf spot and phytophtora blight at KEEA were not significant different ($P > 0.05$) from that of North Tongu but significantly higher ($P < 0.05$) than that of South Tongu, Kintampo South and Sekyere South districts. Incidences of cercospora leaf spot and phytophtora blight at North Tongu districts were not significantly different from that of South Tongu district but significantly higher than those of Sekyere South and Kintampo South districts ($P < 0.05$).

3.4 Mean Severity of Fungal and Viral Diseases of Pepper in Ghana

Analysis of variance showed significant differences ($P < 0.05$) in the various diseases among the five districts surveyed (Table 5). Anthracnose disease was significantly more severe in KEEA than in the other districts ($P < 0.05$). Severity indices of anthracnose disease recorded at Kintampo South (17.4±1.1%) was not significantly different from that of Sekyere South (17.0±1.1%) but significantly higher than that of North Tongu (13.1±1.1%) and South Tongu districts (13.1±1.1%).

The severity index of cercospora leaf spot recorded at KEEA (17.1±0.9%) was not significantly different from that of North Tongu district (15.2±1.0%) but significantly higher than that of Kintampo South (12.5±1.0%), South Tongu (13.5±1.2%) and Sekyere South (9.4±1.0%) districts.

KEEA district recorded the highest severity index of phytophthora blight (25.6±1.3%) which was not significantly different ($P > 0.05$) from those recorded at North Tongu district (21.6±1.4%) but significantly higher ($P < 0.05$) than those recorded at South Tongu (19.8±1.7%), Sekyere South (16.0±1.4%) and Kintampo South (13.9±1.4%) districts.

Fruit rot was significantly more severe in KEEA (26.7±1.2%) than in the other districts ($P < 0.05$). The severity index of fruit rot disease in Sekyere South (17.3±1.3%) was not significantly higher than that of North Tongu (17.3±1.3%) and Kintampo South (13.9±1.3%) but significantly higher than that of South Tongu district (11.8±1.5%).

Table 3. Agronomic practices of the respondent pepper farmers

Agronomic practices	Districts (Regions)				
	KEEA (CR)	South Tongu (VR)	North Tongu (VR)	Kintampo South (BAR)	Sekyere South (AR)
	Frequency	Frequency	Frequency	Frequency	Frequency
Sources of planting materials					
Agro chemical shop	4 (13.3)	3 (10.0)	4 (13.3)	7 (23.3)	7 (23.3)
Local market	5 (16.7)	7 (23.3)	6 (20.0)	5 (16.7)	8 (26.7)
Farmers' own fields	17 (56.7)	18 (60.0)	16 (53.3)	10 (33.3)	9 (30.0)
Friends' farm	4 (13.3)	2 (6.7)	4 (13.3)	8 (26.7)	6 (20.0)
Cropping pattern					
Mono cropping	19 (63.3)	17 (56.7)	15 (53.3)	22 (73.7)	17 (56.7)
Mixed cropping	11 (36.7)	13 (43.3)	14 (46.7)	8 (26.7)	13 (43.3)
Previous crop					
None (Fallow)	0 (0.0)	8 (26.7)	3 (10.0)	4 (13.3)	6 (20.0)
Tomato, garden eggs	13 (43.3)	18 (60.0)	12 (40.0)	17 (56.7)	18 (60.0)
Cassava	6 (20.0)	2 (6.7)	6 (20.0)	3 (10.0)	4 (13.3)
Okra	4 (13.3)	0 (0.0)	4 (13.3)	0 (0.0)	0 (0.0)
Maize	3 (10.0)	2 (6.7)	5 (16.7)	6 (20.0)	2 (6.7)
Watermelon	4 (13.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Total	30	30	30	30	30
Disease management practice					
Synthetic pesticides	19 (63.3)	20 (66.7)	18 (60.0)	15 (50.0)	21 (70.0)
Botanicals	2 (6.7)	0 (0.0)	1 (3.3)	2 (6.7)	1 (3.3)
Roguing of diseased plants	7 (23.3)	6 (20.0)	7 (23.3)	8 (26.7)	4 (13.3)
Regular weeding	2 (6.7)	4 (13.3)	4 (13.3)	5 (16.7)	4 (13.3)

Values in parenthesis are percentages of the frequencies
AR-Ashanti Region, BAR-Brong Ahafo Region, CR-Central Region, VR-Volta Region.

Table 4. Mean incidence of viral and fungal diseases of hot pepper in some major growing districts in Ghana

District (Region)	Mean disease incidence (%) ± standard error (s. e.)				
	Leaf anthracnose	Cercospora	Phythophthora blight	Pepper mosaic	Fruit rot
KEEA (CR)	85.6±2.8a	76.4±2.9a	79.2±3.0a	84.3±2.6a	86.3±3.0a
Kintampo South (BAR)	47.5±3.0c	42.6±3.2c	35.4±3.2d	45.7±2.8c	41.5±3.2d
North Tongu (VR)	45.1±3.0c	70.4±3.2ab	71.0±3.2ab	73.8±2.8b	59.4±3.2b
South Tongu (VR)	50.2±3.7bc	62.9±3.9b	64.5±3.9b	68.6±3.4b	45.4±3.9c
Sekyere South (AR)	55.7±3.0 b	47.5±3.2c	49.7±3.2c	52.4±2.8c	51.5±3.2bc
Mean	56.8±3.1	60.0±3.3	60.0±3.3	65.0±2.9	56.8±3.3
Lsd (0.05)	8.8	9.2	9.3	8.1	9.3

Means in the same column having the same letters are not significantly different from each other (P <0.05). AR-Ashanti Region, BAR-Brong Ahafo Region, CR-Central Region, VR-Volta Region
KEEA-Komenda-Edina-Eguafo-Abirem district

The severity index of pepper mosaic disease recorded at KEEA (32.1±1.4%) was not significantly different from that of North Tongu district (27.8±1.6%) but significantly higher (P < 0.05) than those recorded at South Tongu (20.5±1.9%) and Kintampo South (18.5±1.6%).

Sekyere South recorded the lowest severity index of pepper mosaic disease (16.4±1.6%) but it was not significantly different from that of Kintampo South but significantly lower than that of South Tongu district.

4. DISCUSSION

The study has shown high prevalence and severity of one viral and four fungal diseases of chili pepper in the five districts surveyed. The diseases were phythophthora leaf blight, cercospora leaf spot, leaf anthracnose, fruit rot

and pepper mosaic. The above diseases together with pepper wilt disease have also been identified on pepper fields in Uganda [6], thus confirming the predominance of these diseases in pepper fields in sub-Saharan Africa including Ghana. This finding could partly account for the low yield of pepper recorded in Ghana, and hence diseases are a major threat to pepper production in the country. Viral [13] and fungal [14] diseases have been reported to cause up to 100% losses of marketable pepper fruits.

The poor agronomic practices adopted by the pepper farmers could account for the observed high incidences of diseases in the study area. This agrees with the finding of another researcher [15] where agronomic practices adopted by farmers on their fields had an influence on the incidence and severity of pests and diseases of the crops cultivated on those fields. The household survey revealed that majority of the farmers acquires their planting materials from uncertified sources including farmers' own farm, friends' farm and local markets. However, the practice of using planting materials from previous crop contributes to the spread of most of the primary fungal diseases [16] and viral diseases [17,18] that are seedborne. Phythophthora blight, anthracnose, cercospora leaf spot and pepper mosaic are known seedborne pathogens [16-19]. When infected seeds are planted every year by farmers, disease infections continue in every growing season and cause damage to crops until control measures are adopted [20]. Majority of seedlings grown from virus contaminated planting materials will be diseased and can serve as inoculum source for other healthy plants which can aid viral spread if vectors are present [17].

The poor agronomic practice adopted by the farmers could partly be due to high illiteracy among the respondents. Majority of the respondent farmers have no formal education and only few of them have primary, secondary or tertiary education (Table 2). The knowledge about the management of a disease is very important in the incidence and control of that particular disease [21]. The low educational level of most of the farmers in the district could be a disadvantage in adopting improved agronomic practices such as roguing of diseased plants, destruction of crop residues and the elimination of living plants that carry pathogens [13]. Again, due to ignorance, farmers may undertake certain practices that may result in the spread of diseases. For instance, some may uproot and throw diseased plants and other infected crop residues on the field which can result in the spread of propagules of pepper diseases. It has also been reported that the widespread and severity of fungal and viral diseases of hot pepper may be due to poor disease management practices adopted by farmers [22].

The majority of the farmers were practising monocropping whilst others were practising mixed-cropping. Monocropping might have contributed to the wide spread and severe pepper mosaic, fruit rot and phythophtora blight diseases recorded on hot pepper in the districts. Growing pepper as a monocrop influences the incidence of diseases such as leaf anthracnose and pests of the crop particularly aphids and thrips [23]. Monocropping is also characterized by dense populations with genetic homogeneity and as a result, once a disease becomes established, it can rapidly spread to epidemic proportions [18,24]. It has also been reported [25] that, monoculture of hot pepper usually induces the outbreak of pest particularly vectors of viral diseases such as thrips and aphids and other diseases.

Although majority of the farmers in the district are using chemical pesticides to control diseases, high incidences and severities of the diseases were observed in the study. This could be due to the fact that the over-reliance of pesticides might have resulted in the development of resistance in targeted pests and pathogens [26]. The pattern and frequency of insecticide used by farmers could play a role in the development of resistance in insect vectors/pests of crops [27]. The use of broad spectrum pesticides by the farmers might have also resulted in killing some beneficial organisms which would normally feed on other pests and vectors of viral diseases and keep them under the economic threshold level [15,28].This may explain why pepper mosaic was the most prevalent (Table 4, mean of 65%) and severe disease (Table 5) across the districts surveyed. Viral diseases have also been identified together with cercospora leaf spot as most predominant and severe diseases of pepper in Uganda [6].

Though majority of the respondent farmers grow pepper as a single crop, most of them use fields previously cultivated with solanaceous crops like tomato and garden eggs for the new pepper farm. This practice might have at least been

Table 5. Mean severity of viral and fungal diseases of hot pepper in some major growing districts in Ghana

Districts (Region)	Mean disease severity index (%) ± standard error (s. e.)				
	Leaf anthracnose	Cercospora leaf spot	Phythophthora blight	Pepper mosaic	Fruit rot
KEEA (CR)	27.7±1.1a	17.1±0.9a	25.6±1.3a	32.1±1.4a	26.7±1.2a
Kintampo South (BAR)	17.4±1.1b	12.5±1.0b	13.9±1.4d	18.5±1.6bc	13.9±1.3bc
North Tongu (VR)	13.1±1.1c	15.2±1.0ab	21.6±1.4ab	27.8±1.6a	17.2±1.3b
South Tongu (VR)	14.1±1.4c	13.5±1.2b	19.8±1.7bc	20.5±1.9b	11.8±1.5c
Sekyere South (AR)	17.0±1.1b	9.4±1.0c	16.0±1.4cd	16.4±1.6c	17.3±1.3b
Mean	17.9±1.2	13.5±1.0	19.4±1.4	23.1±1.6	17.4±1.3
lsd (0.05)	3.3	2.9	4.0	4.5	3.7

Means in the same column having the same letters are not significantly different from each other
AR-Ashanti Region, BAR-Brong Ahafo Region, CR-Central Region, VR-Volta Region KEEA-Komenda-Edina-Eguafo-Abirem district

partly responsible for the wide spread and severe infections of the fungal and viral diseases recorded in the study, as has been reported by other workers [22]. Pathogens of most of these diseases like pepper mosaic, anthracnose, cercospora, remain on residues, the soil and the seeds of the previous harvest [29]. This is because pathogens of most of these infections linger on residue and seeds of previously harvested crops from the same family [16,29].

In view of the above findings it is recommended that the Ministry of Food and Agriculture should educate farmers on good agronomic practices in pepper production in order to minimize disease spread in their pepper fields.

5. CONCLUSION

There is high prevalence and severity of phythophthora leaf blight, cercospora leaf spot, leaf anthracnose, fruit rot (all fungal diseases) and pepper mosaic (viral disease) in the study area. Most farmers in this area are illiterates who obtain seeds from uncertified sources, rotate pepper with tomatoes and pepper (all solanaceous crops), practice both monocropping and mixed cropping and manage diseases with synthetic pesticides.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX 1

Questionnaire on farm operations and farmers' level of awareness of diseases situation in surveyed pepper fields

A. FARMERS' PERSONAL DATA

1. Farm Number ……..
2. Age …….
3. Sex …….
4. Level of education ……

B. ON FARM INFORMATION

1. Farm location ……..
2. Soil type

   Sand ☐ Loam ☐ Sandy loam ☐ Clay loam ☐ Clay ☐

3. Farm Size

   Subsistent/backyard ☐ medium Scale ☐ large scale ☐

4. Type of ownership

   Solely owned ☐ Family farm ☐ Co-operative farm ☐ Partnership ☐

5. Cultivars / Varieties used ……..
6. Source of seed/ seedlings ……

C. INFORMATION ON CULTURAL PRACTICES ADOPTED

1. Method of Land preparation

   With Weedicides ☐ Ploughing only ☐ Ploughing and harrowing ☐

   Cutlass /Hoes ☐

2. The crop was sown/planted on

   Ridges ☐ Raised Beds ☐ Sunken Beds ☐ Level land ☐

3. Did you nurse the seeds yourself? Yes ☐ No ☐
4. If yes, for how long were they on the nursery?

   Three weeks ☐ Four Weeks ☐ Five Weeks ☐ More than Five Weeks ☐

5. Was there any fumigation of nursery against fungi and Nematodes?

   Yes ☐ No ☐

6. If yes, what kind of fumigant(s) did you use? ……

7. Did you observe any disease signs on the seedlings before obtaining/transplanting them?

   Yes ☐ No ☐

8. What is the previous crop on this field? Specify ……..…….
9. What kind of weed control method do you mostly practice?

   Cutlass and hoe ☐ Chemical method ☐ Others, specify ……

10. What type of chemicals do you use for weed control [if any, Name them]

……

11. How often do you control weeds?

    Weekly ☐ Fortnightly ☐ As the Need Arises ☐

12. Is there any irrigation system?

    Yes ☐ No ☐

13. If yes, what is the source of the irrigation water?

    Streams ☐ Wells ☐ Pipe borne water ☐

14. How often do you apply water?

    Weekly ☐ Fortnightly ☐ As the Need arises ☐ Daily ☐

15. This irrigation is done by/with:

    Watering can ☐ Drip system ☐ Sprinkler system ☐ Subsurface ☐

16. Which fertilizer (s) did you apply?

    Organic fertilizers ☐ Compound Granular fertilizers ☐ Foliar chemical fertilizers ☐

17. How often do you apply fertilizers?

    Once ☐ Weekly ☐ Fortnightly ☐ As the Need arises ☐

18. What type of farming system are you practicing?

    Mono-cropping ☐ Mixed cropping ☐ Intercropping ☐

19. If mixed or intercropped, name the intercrop(s)

    ……

D. **FAMERS' KNOWLEDGE OF DISEASES AND THEIR EFFECTS ON YIELD**

1. Do you know some of the signs that indicate the appearance of diseases?

   Yes ☐ No ☐

2. What are some symptoms of pepper diseases you have observed on this farm?
   ……, ……., ……., ……., ……., ……., ……., ……,
3. If yes, what are the major diseases that you identify on this farm?

   Fruit drop ☐ Leaf Spot ☐ Wilt ☐ Leaf chlorosis ☐ Dwarfing of plant ☐

4. How many of the following do you to prevent these /this disease(s)?

   Choose cultivars carefully. ☐

   Plant on raised Ridges ☐

   Purchase high-quality seeds or transplants ☐

5. How many of these other things do you to prevent these /this disease(s)?

   Rouging the diseased crops ☐

   Burying of rotting fruits ☐

   Hand picking of insects and flies ☐

6. How many of these other things do you to prevent these /this disease(s)?

   Select the best field possible ☐

   Plant on raised beds ☐

   Control perennial weeds regularly ☐

7. What are some major pests (bad animals) observed on your farm?
   ……, ……., ……., ……..…,
8. What is the distance between rows on field?

   Not regular ☐ Specify if regular ……

9. What is the distance between plants within rows

   Not regular ☐ Specify if regular ……

10. Do the pepper fruits drop prematurely?

    Yes ☐ No ☐

11. When fruits drop, what is the percent yield loss?

    Up to 10% ☐ up to 30% ☐ 50% ☐ More than 50% ☐

12. Are you aware of any botanical(s) (plant materials) used to prevent pests and diseases?

    Yes ☐ No ☐

13. If yes, name them……, ……, ……

14. What do you usually do to control various diseases?

Weeding ☐ Spraying with chemicals ☐ Spraying with Plant extracts ☐

15. What do you usually do to control various pests?

Weeding ☐ Spraying with chemicals ☐ Spraying with Plant extracts ☐

E. RESEARCHER'S PERSONAL ASSESSMENT OF THE FIELD

1. What is the crop season as the time of visit?

……..

2. What is the crop growth stage?

Before flowering ☐ At flowering and early fruiting stage ☐ At maturity stage ☐

3. General on-farm sanitation is:

Very Good ☐ Good ☐ Bad ☐ Very Bad ☐

4. How spacious is the farm belt?

Less Than One Foot ☐ Up To One Meter ☐ More Than One Meter ☐

5. Is the surrounding environment bushy/weedy?

Yes ☐ No ☐

6. What is the soil moisture level at the time of visit?

Soggy ☐ Adequate ☐ Dry ☐

7. Is the farm weedy at the time of visit?

Yes ☐ No ☐

8. What was the level of interest of the farmer(s) in the research/activities?

Very keen ☐ Interested ☐ Somehow Interested ☐ Not Interested ☐

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