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Farmers' knowledge and perceptions of viral diseases of hot pepper (*Capsicum* sp.) and their management in Rwanda

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ABSTRACT

Hot pepper (*Capsicum* spp.) is an important cash crop in Rwanda however, its productivity can only increase after addressing factors that limit its production. This study aimed at revealing the farmers' knowledge and perceptions of virus diseases and their management in Rwanda. A survey was conducted between February and March 2018 in the main hot pepper growing areas covering low, mid and high-altitude agro-ecological zones (AEZs). Household data were collected using a structured questionnaire from 101 respondents and analysed using descriptive statistics. Majority of farmers (86.1%) indicated that pests and diseases were the main constraints to hot pepper production. Viral diseases were perceived by 71.9% of the farmers as the most serious diseases while 51.4% and 12.9% of them reported that aphids and whiteflies were the major insect pests of hot pepper, respectively. Only 17.8% and 25.7% of the farmers attributed the cause of the viral diseases to insect vectors and the use of infected seeds, respectively. The main method used to control viral diseases was application of synthetic pesticides. About two-thirds of the farmers lacked in knowledge of viral disease symptoms, spread and management across all AEZs. Majority of the farmers (80.2%) did not have access to extension service or training but relied mainly on farmer-interactions for information. Farmers awareness of viral diseases was significantly influenced by training (χ^2 = 29.205; P = <0.001) and age (χ^2 = 10.421; P = 0.005). Therefore, interventions such as farm-level training to raise the farmers' awareness of diseases, especially viral diseases and integrated disease management are needed. This study provides baseline information for the development of sustainable integrated pest management (IPM) strategy for hot pepper viral diseases in Rwanda.

Keywords: *Capsicum* spp., constraints, virus diseases, farmers' perception, pest management

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1 Introduction

Hot pepper (*Capsicum* spp.) is one of the most promising horticultural commodities in Rwanda and is among the crops prioritized by the government for export diversification (MINAGRI, 2014). Hot pepper is mainly cultivated for local consumption, income generation, export and processing industries. In terms of production, Rwanda is the third producer in the East African region and is ranked 19th in Africa producing 5,009 tonnes of green pepper in 2018 (FAO, 2019). In 2017/2018, the crop contributed 4.5% of the total revenue generated from the export of vegetables in Rwanda (NISR, 2014). Over the years, the production of hot pepper in Rwanda has increased from 2,600 tonnes in 2008 to 5,009 tonnes in 2018 (FAO, 2019). Despite the increase in production, farmers have been recording low yield compared to other leading countries in Africa such as Egypt which produced 713, 752 tonnes in 2018 (FAO, 2019). The current average yield of 10 t ha^{-1} in the last five years, is below the country's potential of 15 t ha^{-1} (FAO, 2019; RDB, 2010). Consequently, local production fails to meet the domestic market demand. This gap in yield might be due to several biotic and abiotic constraints. According to Alamerie et al. (2014), identification of sources of risk plays a crucial role in achieving sound and sustainable production of vegetables.

There has been increasing evidence of pests and diseases of hot pepper in the recent (Arogundade et al., 2012). Aphids, whiteflies, thrips, mealybugs, fruit borers among others are the significant insect pests, attacking hot pepper at different stages of growth (Bugti et al., 2014; Djieto-Lordon et al., 2014). Bacterial wilt (*Ralstonia solanacearum*), soft rot (*Erwinia carotovora*), phytophthora root rot, anthracnose (*Colletotrichum capsici*) and viral diseases are among the most challenging diseases in hot pepper production (Asare-Bediako et al., 2015; Mekonen and Chala, 2014). More than 68 virus diseases are associated with hot pepper (Pernezny et al., 2003). The wide range of pests and diseases reported on hot pepper raises concerns and calls for the development of sustainable pest management strategies. The farmers' indigenous knowledge can play a major role in attaining adequate interventions and sustainable management.

Several studies on farmers' knowledge and perceptions of diseases and pests, and their management in vegetables have been done in Cameroon, Japan and India (Abang et al., 2014; May Lwin et al., 2012; Nagaraju et al., 2002). Skelton et al. (2018) identified some viruses affecting the production of hot pepper in Rwanda. However, there are no other studies done and documented based on perceived constraints, farmers' perception and knowledge of hot pepper pests and diseases, in particular viral diseases and their management. Building knowledge among farmers is the most important strategy for controlling viral diseases, and the first step in building this knowledge is to understand the current status of farmers' knowledge. The purpose of this study was to assess the farmers' knowledge and perceptions of hot pepper virus diseases, their causes and applied management practices. This information will be important in developing an effective management strategy for hot pepper viral diseases.

2 Materials and Methods

2.1 Study site

The study was conducted in high, mid and low-altitude AEZs covering seven main hot pepper-producing areas in Rwanda (EU, 2015), from February to March 2018 during the long rain season. The geographical location of the surveyed areas in Rwanda is shown in Fig. 1.

2.2 Sampling procedure and interviews

A multiple-stage random sampling technique was used to select the farmers for the study with the AEZs as the strata. In the first stage, the districts to be surveyed within the AEZs were purposively selected based on the intensity of hot pepper production. In the second stage, at least two sectors were purposively selected from each district on the basis of the number of farmers involved in the production of hot pepper. A sector is an administrative entity that is made up of several villages. In the last stage, simple random sampling was used to select 10% of the total farmers involved in hot pepper production in each of the selected sector (Mohammed, 2016). The selection was done in consultation with the sector agronomists. In total, 101 hot pepper farmers were interviewed and distributed as 23 in high, 64 in low and 14 in the mid-altitude AEZ, depending on the proportion of farmers involved in hot pepper production across regions. The low-altitude AEZ has the highest number of farmers involved in pepper production. The interviews were face to face with the individual farmer and was performed in local language by three enumerators.

2.3 Data collection

One questionnaire that consisted of both closed and open-ended questions was designed. The questionnaire was pretested with ten farmers and revised. Printed colour photographs of virus-infected plants and other major diseases of hot pepper were shown to farmers to assist in the identification. The information collected included (i) demographic characteristics of households including gender, age, the experience in hot pepper farming and training; (ii) farm characteristics and production systems including land owned, the area under hot pepper production, varieties grown, input usage, source of planting materials and type of cropping systems; (iii) constraints encountered by farmers' in hot pepper production, and (iv) farmers' perception and knowledge of viral diseases, causes and management practices.

2.4 Data analysis

The data recorded in the questionnaire were coded and entered into an excel spreadsheet and later transferred to statistical product and service solutions (SPSS version 16) program for descriptive and correlation analysis. Cross tabulations were used to determine the relationships among variables in the three

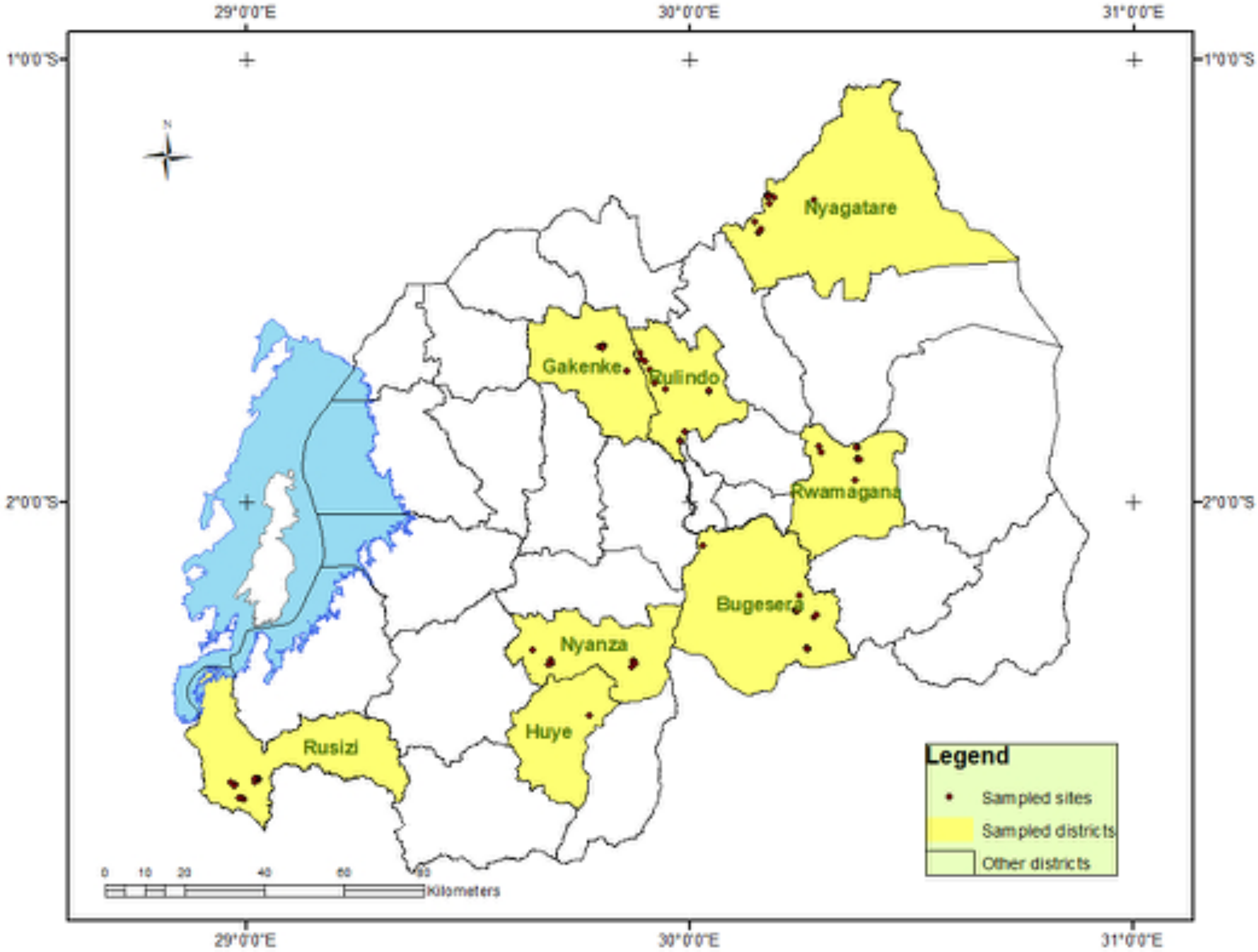

Figure 1. A map of Rwanda showing the geographic location of the areas where the survey was carried out in three agro-ecological zones

AEZs. Pearson chi-square was used to test for differences in variables across the three AEZs. Associations and correlations between farmers' knowledge of viral diseases and variables such as gender, age, farming experience, the area under hot pepper production and training were conducted using Pearson chi-square and Cramer's V test.

3 Results

3.1 Farmers' demographic characteristics

The majority of the interviewed farmers were males with an average of 80.2% while only 19.8% were female (Table 1). A quarter of the farmers were 35 years and below, 72% between 36-65 years while 3% were 66 years and above with an overall mean of 44.7 years. The years of experience in hot pepper farming did not differ significantly (χ^2 = 7.775; P = 0.255) across the AEZs. Majority of the farmers had between 1.1 to 5 years' experience in hot pepper farming. The training on pepper production also differed significantly (χ^2 = 12.671; P = 0.002) among the AEZs with low-altitude AEZ having the highest number of farmers who did not receive any training (Table 1). Only 19% of the farmers from all AEZs had been trained or had access to extension information regarding agronomic practices and pest management from extension officers, exporting companies and school/colleges (Table 1).

3.2 Constraints in hot pepper production

Across all the AEZs, majority (86.1%) of the farmers ranked diseases and insect pests as their number-one problem in hot pepper production followed by lack of technical knowledge (38.6%), unfavourable weather conditions (37.6%), unstable markets (30.7%), lack of credit facilities (16.8%) and high cost of inputs (13.9%) among others (Table 2). However, the importance of these constraints varied across the AEZs (Table 2). In the high-altitude zone, the top five constraints were the diseases and insect pests (73.9%), unpredictable weather (30.4%), inadequate technical knowledge (26.1%), unstable markets (17.3%) and in-

Table 1. Demographic characteristics (%) of the hot pepper farmers interviewed in three agro-ecological zones in Rwanda

Variable	High altitude	Mid altitude	Low altitude	Overall mean	χ^2-test	P-value
Gender						
Male	87	78.6	78.1	80.2	0.858	0.651
Female	13	21.4	21.9	19.8		
Age (year)						
≤ 35	34.8	25	20.7	24.7	2.339	0.674
36-65	60.9	75	75.9	72		
≥ 66	4.3	0	3.4	3.2		
Experience (year)						
≤ 1	50	58.3	23.3	37	7.775	0.255
1.1-5	41.7	33.3	66.7	53.7		
5.1-10	0	8.3	6.7	5.6		
≥ 10.1	8.3	0	3.3	3.7		
Training received						
Yes	43.5	23.1	9.5	19.2	12.671	0.002
No	56.5	76.9	90.5	80.8		

adequate capital or lack of credit facilities (13%). In the mid-altitude AEZ, all respondents reported that pests and diseases were the major constraint followed by the high cost of inputs (42.9%), unstable markets (42.9%), inadequate technical knowledge (35.7%) and lack of quality seeds (28.6%). On the other hand, diseases and insect pests (84.8%), unpredictable weather conditions (45.5%), inadequate technical knowledge (42.4%), unstable market (31.8%) and inadequate capital or lack of credit facilities (19.7%) were the leading constraints in the low-altitude areas.

3.3 Farmers' perceptions of viral diseases

Awareness of viral diseases was at 33% among the hot pepper farmers (Table 3). However, farmers' awareness of viral diseases varied significantly (χ^2 = 20.116; P = <0.001) across the AEZs. The majority of the farmers from the mid-altitude AEZ seemed to be aware of the viral diseases. Viral diseases were regarded as the most serious across the three AEZs by 71.9% of the farmers followed by fungal diseases as reported by 22.8% of the farmer respondents and lastly bacterial diseases by 5.3% (Table 3). Concerning the stage of growth at which farmers observed viral symptoms, about 40% reported flowering and fruiting stage, respectively, followed by vegetative stage (16.5%) and the least was at the seedling stage (3%). These farmer proportions differed (χ^2 = 18.833; P = <0.016) across the AEZs.

3.4 Farmers' knowledge on viral diseases

The farmers' knowledge of perceived sources or causes of the viral diseases varied significantly among the AEZs (χ^2 = 26.896; P = 0.003). About a quarter (25.7%) and slightly below a fifth (17.8%) of the respondents were able to correctly link the viral diseases to infected seed and insect-vectors, respectively (Table 4). In contrast, about a third of the farmers thought that the viral diseases were caused by bad weather and/or poor soils, respectively while (23.8%) did not know the cause at all.

3.5 Farmers' knowledge of causes of viral diseases

Among the arthropod pests infesting hot pepper, the aphids were the most serious insect across the AEZs reported by 51.4% of the farmers (Table 5). The whiteflies were ranked second by 12.9% while the mites and thrips were ranked third by 2% of the farmer respondents. Forty-per cent of the farmers did not know that insects infest hot pepper. Farmers' perceptions of insect pests infesting hot pepper did not vary (χ^2 = 13.641; P = 0.190) across the AEZs but the management of insect pests differed significantly (χ^2 = 16.913; P = <0.001) (Table 5). All the farmers from the mid-altitude AEZ engaged in the management of the insects followed by high-altitude AEZ (65.2%) and the least were farmers from low-altitude AEZ (40.3%). The main method used to control insects by the majority of the farmers (82.5%) was insecticides namely cypermethrin, Thiodan 35 EC (endosulfan) and Rocket 44 EC (profenofos 40% + cypermethrin 4%). A few (8.8%) of the farmers used cultural practices and traditional products to control insect pests. Cultural practices included crop rotation, mulching and the use of border crops such as tobacco and sunflower to control insects from hot pepper plants.

Table 2. Farmers' perception (%) of constraints to hot pepper production in three agro-ecological zones in Rwanda

Constraints †	High altitude	Mid altitude	Low altitude	Overall mean
Pests and diseases	73.9	100	84.8	86.1
Inadequate technical knowledge	26.1	35.7	42.4	38.6
Unpredictable weather conditions	30.4	7.1	45.5	37.6
Unstable market	17.3	42.9	31.8	30.7
Inadequate capital/lack of credit facilities	13	7.1	19.7	16.8
High cost of inputs	8.7	42.9	9.1	13.9
Price fluctuations	0	14.2	16.7	12.9
Lack of quality seeds	8.7	28.6	4.5	8.9
Lack of postharvest facilities	0	0	12.1	7.9
Shortage of land	4.3	0	9.1	6.9
Delayed payment by exporting companies	0	7.1	9.1	6.9
Expensive irrigation facilities	4.3	0	7.6	5.9
Low yields of local varieties	4.3	7.1	1.5	3
Poor soil conditions	0	7.1	0	1
Lack of extension services	0	7.1	0	1
Difficulties in irrigation due to land topography	0	0	1.5	1

† Multiple responses

Table 3. Farmers' perception (%) of viral diseases in hot pepper in Rwanda

Variable	High altitude	Mid altitude	Low altitude	Overall mean	χ^2-test	P-value
Farmers awareness of viral diseases						
Yes	43.5	83.3	19.4	33	20.116	<0.001
No	56.5	16.7	80.6	67		
Perceived diseases by farmers †						
Fungal diseases	21.7	21.4	28.1	22.8	1.694	0.792
Bacterial diseases	13	7.1	3.1	5.3		
Viral diseases	78.3	85.7	81.3	71.9		
Growth stage at which symptoms of viral disease are seen						
Seedling	5.9	0	2.2	3	18.833	0.016
Vegetative	11.8	80	11.1	16.5		
Flowering	52.9	20	37.8	40.3		
Fruiting	29.4	0	48.9	40.3		

† Multiple responses

Table 4. Farmers' knowledge (%) of perceived sources or causes of viral infections of hot pepper in three agro-ecological zones in Rwanda

Sources or causes of infection †	High altitude	Mid altitude	Low altitude	Overall mean	χ^2-test	P-value
Infected seed	30.4	42.9	19.7	25.7	26.896	0.003
Insect vectors	30.4	7.1	15.2	17.8		
Bad weather	30.4	7.1	42.4	35.6		
Poor soils	21.7	50.0	33.3	33.7		
Do not know	30.4	0.0	25.8	23.8		

† Multiple responses

Table 5. Farmers' knowledge (%) of insect pests associated with hot pepper and their management in three agro-ecological zones in Rwanda

Variable	High altitude	Mid altitude	Low altitude	Overall mean	χ^2-test	P-value
Insects observed in fields						
Aphids	56.5	78.6	43.8	51.4	13.641	0.190
Whiteflies	13	35.7	7.8	12.9		
Broad mites	4.3	7.1	0	2		
Thrips	0	7.1	1.6	2		
Do not know	34.8	7.1	50	40.6		
Do you control insects						
Yes	65.2	100	40.3	54.1	16.913	<0.001
No	34.8	0	63.3	45.9		
Type of control used for insects						
Insecticides	60.9	92.9	32.8	82.5	6.488	0.166
Cultural practices	4.3	0	4.7	8.8		
Traditional products	4.3	0	6.3	8.8		

3.6 Farmers' perception of yield loss

Most of the farmers (95.3%) were aware that viral diseases could cause yield losses. The farmer perceptions of yield losses across the three AEZs did not vary significantly (χ^2 = 4.406; P = 0.110). About one-fifth of the farmers estimated yield losses of less than 25% while 39.2%, 17.7% and 22.8% of the farmers estimated 25-50%, 50-75% and more than 75% yield losses, respectively (Table 6).

3.7 Farmers-based management options

The management options used by farmers varied widely (χ^2 = 35.135; P = <0.001) across the AEZs. The farmers relied mainly on synthetic pesticides to control viral diseases (Table 7). Application of pesticides was markedly higher in the mid-altitude AEZ compared to other zones while rouging of virus-infected plants was mainly practised in the low-altitude areas. Overall, the most common method used to control viral diseases was spraying pesticides (fungicides and insecticides) reported by 36.6% of the farmers. The commonly used fungicides were Copper oxychloride 50% WP and Ridomil Gold (4% w/w metalaxyl-M and 64% w/w mancozeb). Other methods included cultural control practices such as rouging of diseased plants used by 24.8% of the farmers, field sanitation by 8.9%, crop rotation by 2%, the use of quality seeds by 2% and the least was planting of different varieties of hot pepper by 1% of the farmers.

3.8 Characteristics of the farms

Hot pepper farming is dominated (96%) by small-scale farmers who owned 1 acre to 2 ha of land

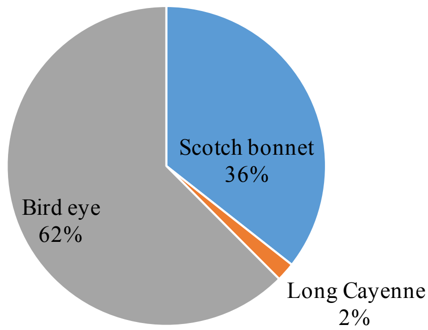

Figure 2. Major hot pepper varieties grown by the farmers in the surveyed agro-ecological zones.

under pepper production while a few (4%) owned 2.1 to 5 ha (Table 8). The cropping systems (χ^2 = 20.235; P = <0.001) and source of planting materials (χ^2 = 20.032; P = 0.010) varied across the AEZs. Intercropping was practised by 55% while mono-cropping was done by 45% of the farmers. The main crops intercropped with hot pepper included banana (*Musa* spp.), coffee (*Coffea arabica*) and arrowroots (*Colocasia esculenta*). Commonly grown varieties of hot pepper included hybrids of the Bird-eye (62%), Scotch bonnet (36%) and Long cayenne (2%) (Fig. 2). Slightly over a half (56%) of the farmers obtained their seeds from export companies that contracted them and about a third (34%) got from their neighbours (Table 8). A small percentage of the farmers sourced seeds from their farms (6%), agro-dealers (3%) and local markets (1%).

Table 6. Yield losses (%) due to virus-induced diseases as reported by farmers in three agro-ecological zones in Rwanda

Variable	High altitude	Mid altitude	Low altitude	Overall mean	χ^2-test	P-value
Do you expect to lose yields due to viral diseases						
Yes	94.4	84.6	98.2	95.3	4.406	0.110
No	45.6	15.4	1.8	4.7		
Expected yield losses by farmers						
<25 %	12.5	36.4	19.2	20.3	11.846	0.065
25-50 %	43.8	9.1	44.2	39.2		
50-75 %	31.2	36.4	9.6	17.7		
>75 %	12.5	18.2	26.9	22.8		

Table 7. Farmer-based management options for viral diseases in three agro-ecological zones in Rwanda (%)

Control strategy †	High altitude	Mid altitude	Low altitude	Overall mean	χ^2-test	P-value
Spraying pesticides	47.8	92.9	20.3	36.6	35.135	<0.001
Rouging of infected plants	0	21.4	34.4	24.8		
Crop rotation	0	0	3.1	2		
Field sanitation	4.3	7.1	10.9	8.9		
Use of quality seeds	0	7.1	1.6	2		
Use of different varieties	0	7.1	0	1		
Did nothing	47.8	7.1	48.4	42.6		

† Multiple responses

Table 8. Characteristics of the hot pepper farm in three agro-ecological zones in Rwanda (%)

Variable	High altitude	Mid altitude	Low altitude	Overall mean	χ^2-test	P-value
Area under hot pepper (ha)						
0.001-2.0	100	85.7	96.9	96	4.99	0.820
2.1-5.0	0	14.3	3.1	4		
Cropping systems						
Mono-cropping	34.8	100	35.9	44.6	20.235	<0.001
Intercropping	65.2	0	64.1	55.4		
Source of seeds						
Own field	18.2	0.0	3.1	6	20.032	0.010
Neighbour	36.4	57.1	28.1	34		
Local markets	0.0	0.0	1.6	1.0		
Agro-dealer	9.1	7.1	0.0	3.0		
Export companies	36.4	57.1	67.2	56		

Table 9. Factors influencing farmers' knowledge and perceptions of viral diseases in hot pepper in Rwanda

Variable	χ^2-test	P-value	Cramer V test
Age of farmer	10.421	0.005	0.340
Gender	1.159	0.282	0.109
Area under hot pepper	3.331	0.068	0.185
Training	29.205	<0.001	0.552
Farmer experience	0.982	0.806	0.136

3.9 Factors influencing farmers' knowledge of virus diseases in hot pepper

Five factors which are gender, age of the farmer, the area under hot pepper production, the experience of the farmer and training were tested and shown to vary in association with farmer awareness of hot pepper viral diseases (Table 9). Farmers awareness of viral diseases was significantly influenced by training (χ^2 = 29.205; P = <0.001) and age (χ^2 = 10.421; P = 0.005). Cramer's V test showed a strong positive association (0.552) between training and farmers awareness of viral diseases in hot pepper. Conversely, the other three factors namely gender (χ^2 = 1.159; Cramer's V = 0.109), the area under hot pepper production (χ^2 = 3.331; Cramer's V = 0.185) and the farmer experience (χ^2 = 0.982; Cramer's V = 0.136) correlated positively with farmers' awareness of viral diseases. However, the relationships were not significant (P > 0.05).

4 Discussion

The results revealed that the diseases and pests are the major challenges faced by hot pepper producers in Rwanda. One of the reasons for the increased disease and pest pressure could be climate change (Nwaerema, 2020). Moist and warm climates favour the development of most pests and diseases (Abang et al., 2014). Another reason is the poor pest management due to inadequate farmers' technical knowhow and the high cost of inputs. Poor understanding and management of pests leads to increased incidences of diseases and pests. Indeed, inadequate technical know-how and high cost of inputs were among the top five major constraints mentioned by the farmers. A similar survey conducted by Musebe et al. (2017) showed that insect pests and diseases, coupled with lack of high-quality seeds and the high cost of inputs were the main challenges that led to low and unstable yields in the production of vegetables in Rwanda. Diseases and pests remain a major challenge in hot pepper production not only in Rwanda but also in other producing countries such as Nigeria and Ghana (Mohammed, 2016; Orobiyi et al., 2013). The pests and diseases cause economic problems to the farmers and therefore, there is a need to develop sustainable management strategies.

Among the diseases, virus-induced diseases are serious hindrances to hot pepper farming as perceived by farmers. Two-fifths of the farmers used uncertified planting materials from own fields, neighbours and local markets. Locally, the seed system is informal and the exchange of planting materials is uncontrolled. These might have a role to play in the spread of the viral diseases (RADA, 2002; HCA, 2012). Besides, aphids, whiteflies and thrips were the most recurrent insect pests across the three AEZs (Ekenma et al., 2018; Orobiyi et al., 2013). These insect pests are vectors of devastating viruses (Jeevanandham et al., 2018; Meyer, 2003) and therefore, contribute to the widespread of most of the viral diseases. A previous study by Schreinemachers et al. (2015) reported virus diseases as the major constraint to pepper production in Tamil Nadu, India. The perceived yield losses due to viral diseases estimated to range from 25 to >75% by the interviewed farmers is important and reveal the necessity to implement effective viral diseases management program in hot pepper fields of Rwanda.

Even though the farmers could identify virus symptoms based on leaf crinkling and curling, only a minority knew the role of insect vectors and infected seed in the spread of hot pepper viruses. This might be attributed to the inaccessibility of accurate information. As reported in this study and the work of Abang et al. (2014), the majority of the farmers relied mainly on farmer-interactions for information. Besides, four-fifths of the farmers had not received formal agricultural training leading to limited knowledge of pathogens involved, spread and management of the diseases across the AEZs. The findings are similar to the results of a survey carried out by Schreinemachers et al. (2015) and Nagaraju et al. (2002) who reported knowledge of the cause, spread and management of virus diseases was limited among farmers. For instance, only 8% and 18% of the interviewed farmers could identify the cause of virus diseases symptoms in chilli from Thailand and Vietnam, respectively (Schreinemachers et al., 2015). Also, majority of the farmers had less than 5 years' of experience in hot pepper farming. According to Nagaraju et al. (2002), vast experience in farming can also serve as a means through which farmers get informed. The farmers from the mid-altitude region generally had more knowledge of plant viruses than those from the high and the low-altitude AEZs, depending on how extension services and contractual companies for export had paid attention to this issue.

Two-fifths of the farmers relied on pesticides for management of viral diseases. They mixed various pesticides including fungicides and insecticides in single sprays, which indicated inadequate farmers' knowledge of plant viruses and the need for training. The findings are similar to Schreinemachers et al. (2015) who found that most of the chilli farmers use fungicides for viral diseases control. Pesticide use in pepper production was markedly lower in the low-altitude zone compared to the mid and the high-altitude zones. This was driven by the international market demands, as the majority of farmers from the low-altitude AEZ had been restricted from using pesticides by the contractual companies. The second commonly used management option was roguing of infected plants and burying especially in the low-altitude areas. Hoque et al. (2003) demonstrated effectiveness of roguing in the management of Jute leaf mosaic disease. Other cultural options used included field sanitation by regularly weeding, the use of quality seeds, crop rotation with unrelated crops and planting of different varieties in order of importance. These cultural practices are effective in reducing the initial level of inoculum and the rate of spread of the diseases and therefore, farmers should be encouraged to make use of them in combination with other management options (Dale and Ogle, 1997; Thresh, 2004).

The management of insect pests was mainly by the use of insecticides. However, continuous use of the insecticides leads to the development of resistance by the insects in addition to health and environment risks (Kenyon et al., 2014). This calls for a need to develop alternative methods that are sustainable and environmentally safe, given the threats posed by pesticide residue to the environment and human health. Utilization of synthetic pesticides by farmers as one of the main technique for pest management in vegetables is also reported in West Africa (Abang et al., 2014). Apart from insecticides application, farmers also used cultural practices to control insects such as crop rotation, mulching and the use of border crops e.g. tobacco and sunflower. Some of these practices are documented, for example, the use of crop borders in potato field was effective in the control of aphid infestation (Olubayo et al., 2009). Bearing in mind the risks related to the use of insecticides, farmers should be encouraged to integrate these cultural practices with other safe pest-suppression methods to sustainably manage insect pests.

Slightly above half of the hot pepper farmers interviewed practised intercropping with the aim of maximizing land use. Besides, the majority of farmers especially from the low-altitude areas intercropped with perennial crops such as banana and coffee to provide shade for hot pepper crop during the dry season. Apart from maximising land use, intercropping has other benefits such as improving soil fertility and control of diseases and pests (Ramert, 2002). Intercropping is effective in the control of non-persistent viruses and associated vectors in several crops (Damicone et al., 2007; Degri and Ayuba, 2016; Fajinmi and Fajinmi, 2010). For example, intercropping hot pepper with maize (*Zea mays*), cassava (*Manihot* sp.) and plantain (*Musa* sp.) reduced the incidence of *Pepper veinal mottle virus* by 76.2%, 88.1% and 80.2%, respectively (Fajinmi and Fajinmi, 2010). The findings from the studies imply that intercropping could be used as a tool for pest and disease suppression in hot pepper production. However, farmers require training since the majority do not understand the principle behind using intercropping as a practice for diseases and pests' management.

Hot pepper farming is dominated by small-scale farmers of which the majority are men. This is probably because hot pepper is more of a cash crop than food security crop and like in many of the African countries, men dominate in the production of cash crops (WB, 2009). Also, due to the fact that in most African cultures, where men are available, they come forward and volunteer to provide information. Slightly above two-thirds of the farmers were in their active age and thus, can participate actively in the farming activities and at the same time are expected to adopt innovations more readily than older farmers (Asare-Bediako et al., 2015). The majority of the farmers had less than 5 years' of experience an indication that most of them ventured in farming after hot pepper was set as a priority crop for export diversification by the government in 2014 (MINAGRI, 2014). Through the sensitization from the government, more farmers engaged in the production of hot pepper.

5 Conclusions

The findings revealed that diseases and pests are important constraints to hot pepper production in Rwanda. The farmers lack accurate information on the cause, spread and management of the diseases. They have no effective management strategy for the pests and diseases. Majority of the farmers rely mainly on farmer-interactions for information. Thus, the government should strengthen extension services such as the farmer field schools, farmer promoters and plant health clinics which are already in place to help in improving farmers' knowledge of diseases and pests' management. The presence of viral symptoms in the three agro-ecological zones calls for a need to identify the pathogens responsible for the diseases and the mode of spread. This will help in the development of efficient and sustainable control strategies. This study provides baseline information that is important in designing appropriate intervention programmes for the management of virus-like diseases in hot pepper production being promoted for export diversification.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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