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Knowledge and perceptions of plant viral diseases by different stakeholders in Zimbabwe's agricultural sector: Implications for disease management

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Plant viruses are major constraints to crop production worldwide, causing US$60 billion losses annually. This study assessed various agricultural sector stakeholders' knowledge and perceptions of plant viruses in Zimbabwe. Data was collected from six provinces using surveys and participatory rural appraisal methodologies between December 2013 and October 2014. *Maize streak virus*, *Tobacco mosaic virus*, *Cucumber mosaic virus*, *Tomato mosaic virus* and *Groundnut rosette virus* were ranked as the country's five most important plant viruses by agricultural technical staff. Most (72%) technical staff rated *Maize streak virus* as the most important plant virus in Zimbabwe. Over 30% of farmers were self-taught to identify diseases, while only 15.3% were trained by agricultural extension staff. Most (95.8%) technical staff trained people in disease identification through running short courses, use of demonstration plots and field days. The majority (41.9%) of farmers recommended the use of radio/TV/newspaper broadcasts to improve virus awareness. Only 23.7% of farmers and 41.6% of technical staff had heard about TSWV/tospoviruses. While most (97.2%) technical staff rated TSWV/tospoviruses as "fairly important" to "very important" plant pathogens, only 15.7% were able to correctly identify tospoviral vectors. The study showed that there is poor knowledge of plant viruses the stakeholders in the agricultural sector. There is need to train the technical staff in plant virology so that they can disseminate their knowledge to farmers for improved virus disease management.

Key words: Awareness, disease identification, tospoviruses, training.

INTRODUCTION

Zimbabwe has an agro-based economy, with over 70% of the population either directly or indirectly dependent on

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agriculture for a living (Marongwe et al., 2012). The major stakeholders in Zimbabwean agriculture are the farmers, input (seed, pesticide and fertilizer) suppliers, researchers, extension staff, and agricultural teachers and lecturers. All of them play significant roles in ensuring successful agricultural productivity which is seriously constrained by many abiotic and biotic factors. Amongst the biotic factors are plant pathogenic viruses that cause about US$60 billion losses annually worldwide (Wei et al., 2010).

Plant pathogenic viruses cause huge agricultural losses especially in the developing world where most farmers have poor knowledge of these pathogens. This can be attributed to the fact that unlike insects, fungal mycelia and rodents that can be seen with the naked eye, viruses are microscopic entities. In addition, viruses may incite symptoms similar to those by other pathogens, nutritional and/or environmental disorders (Astier et al., 2007). So, farmers tend to apply the wrong control measures in virus-infected plants. Furthermore, plant virus studies require highly specialized equipment and study techniques which are not readily available in most developing countries (Kaitisha, 2003).

Zimbabwe is a developing country reported to have impressive agricultural training, research and extension systems for improved agricultural productivity (Mutambara et al., 2013). A common perception is that stakeholders in Zimbabwe's agricultural sector are highly knowledgeable about all farming aspects, including disease and pest identification and management. However, this may not be the case with plant viral diseases due to the reasons mentioned earlier. Furthermore, changes in Zimbabwe's economy and education system since the year 2000 may have had an impact on knowledge and perceptions of viral diseases by agricultural sector stakeholders. Globally, climate change, trade and genetic mutations have contributed to the emergence of new viruses like begomoviruses, criniviruses, carlaviruses, torradoviruses and tospoviruses in the last 30 years (Navas-Castillo et al., 2012; Pappu et al., 2009). The tospoviruses, in particular, have become very important in tropical and subtropical regions. One tospovirus species, *Tomato spotted wilt virus*, is estimated to cause US$1 billion losses annually for several important food and ornamental crops worldwide (Parrella et al., 2003). This virus has previously been reported infecting weeds, ornamentals, and food and industrial crops in Zimbabwe (Dobson et al., 2002).

In light of these pointers, a survey was conducted to capture the understanding and perceptions of plant viral diseases by key stakeholders within Zimbabwe's agricultural sector. The survey provided a useful way to canvas ideas and opinions of the respondents about plant virus diseases. This would form the basis for identifying potential intervention points in developing viral disease management strategies. Results of the study will also assist policy makers in the Agriculture and Higher Education ministries during policy formulation on curricula development, research and extension services on plant viral diseases.

The objectives of this study were to: (i) Identify ten plant viruses that agricultural technical staff rank as the most important in Zimbabwe; (ii) Determine farmers' trainers and methods of training for disease identification; (iii) Assess respondents' perceptions of plant viruses; (iv) Gather respondents' opinions on how to improve awareness of plant virus diseases, and (v) Evaluate respondents' knowledge of *Tomato spotted wilt virus* (TSWV)/tospoviruses (TSWV/tospoviruses).

MATERIALS AND METHODS

Study area

The study was carried out in Zimbabwe (latitudes 15°13'S and 22°30'S; longitudes 25°E and 33°E), a country bordered by South Africa to the south, Mozambique to the east, Zambia to the north and Botswana to the west. Zimbabwe has five natural farming regions (NFRs) delineated primarily on the basis of rainfall, soil quality and vegetation (Chiremba and Masters, 2003). The best rainfall and land resources occur in NFR 1, while NFR 5 is very hot and unsuitable for most crops, except traditional small grains and sugarcane. Up to 80% of Zimbabwe's crops are grown in the Mashonaland Provinces, which are mainly in NFR 2. Mid-season dry spells and high temperatures occur in NFR 3 which receives 500 to 750 mm rainfall annually. NFRs 4 and 5 are low-lying, receiving not more than 650 mm rainfall per annum.

Sampling procedure and selection of participants

The study was conducted between December 2013 and October 2014. A multistage sampling process was conducted to select provinces, districts and respondents. Six provinces, namely: Harare, Manicaland, Mashonaland Central, Mashonaland East, Mashonaland West and Masvingo, were selected. From each province, three districts were chosen for surveys. The chosen districts represented the country's NFRs as follows: NFR 1: Nyanga and Chimanimani; NFR 2: Bindura, Chegutu, Chinhoyi Urban, Goromonzi, Harare districts, Mazowe, Mutare, Seke, Shamva and Zvimba; NFR 3: Gutu and Mutoko; NFR 4: Masvingo Urban; and NFR 5: Chiredzi (Figure 1). At each district, the Principal Investigator (PI) engaged the District Agricultural Extension Officer (DAEO) who recommended wards (cluster of villages) for assessments, and agricultural extension staff (Agricultural Extension Officers and Agricultural Extension Workers) who assisted in identifying interviewed farmers. Three wards were selected per district, and fifteen farmers per ward were interviewed with questionnaires.

In addition, ten farmers per district were interviewed in Farmer Group Discussions (FGDs). Respondents from agricultural colleges, high schools, input suppliers, research stations, non-governmental and private organizations involved in agriculture in the study areas were also interviewed. In total, 810 farmers and 214 technical staff (composed of agricultural extension staff, research and training officers, agricultural teachers and lecturers, and input suppliers) were interviewed using questionnaires, and another 180 farmers were interviewed in FGDs. All protocols were followed in regards of research ethics, which included securing government permission to conduct surveys and allowing free choice of participation in the interviews.

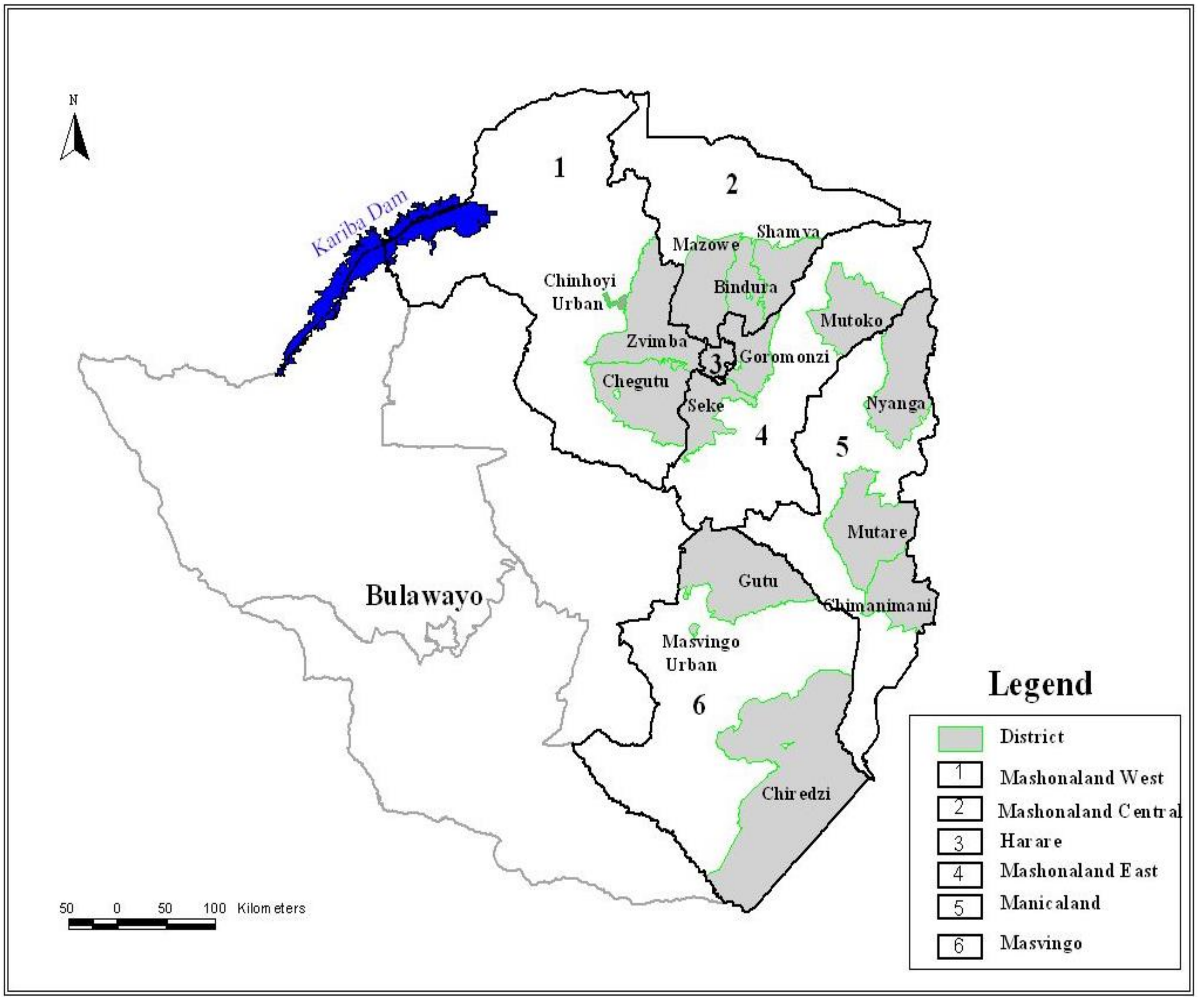

Figure 1. Provinces and districts chosen for the studies on plant virus knowledge and perceptions by stakeholders in Zimbabwean agriculture. The provinces are numbered 1 to 6 while districts are shaded grey.

Data collection

Two questionnaires were designed, one for farmers and another for the technical staff. Both questionnaires were designed in English and had closed and open-ended questions. For illiterate farmers, questionnaires were administered in Shona (a local language) and completed by the PI and his assistants. The questionnaires were pretested with fifteen farmers and eight technical staff, and modified to ensure that meanings were unambiguous. Some interviews and FGDs were recorded on audio tapes and later processed to extract information. To ensure maximum data collection, some probing and interactive sessions outside the formal data collection sessions were carried out. Printed color photographs of virus-infected plants were shown to respondents to assist with disease identification.

The questionnaires captured respondents' general knowledge of plant viruses, including major plant viruses in Zimbabwe, rating of viruses as plant pathogens and methods of improving virus awareness. Perceptions on viruses were captured as categorized variables using a scale of 1 to 5 where, 1 = Not important; 2 = Fairly important; 3 = Important; 4 = Very important and 5 = Don't know. For TSWV/tospoviruses, respondents provided the following information: Virus knowledge source, rating alongside other viruses, vectors and control measures. Respondents' socio-economic characteristics captured on the questionnaires included province, district, gender, age, educational level, marital status, land tenure system and agricultural experience.

Data analysis

Statistical analysis for quantitative survey data was done using the Statistical Package for Social Sciences (SPSS) Version 16.0. Survey data was coded and entered into the SPSS spreadsheet and checked before analysis. Both descriptive statistics and econometric models were used in data analysis. The logistic (logit) regression model was used to assess the respondents' awareness about TSWV/tospoviruses. The logit model is found in random utility theory and built around a latent regression.

$Y^* = \beta x + \varepsilon_i$

Y^*= is an underlying latent variable that indexes respondents' knowledge on TSWV/tospoviruses. β is a column vector of unknown parameters to be estimated. X is a row vector of respondent characteristics and Ɛ is the stochastic error term. The dependent variable that was used for the model is the respondents'

Table 1. Explanatory variables used in assessing farmers' awareness to TSWV/tospoviruses.

Variable description	Variable type	Units
Awareness of farmers on tospoviruses	Dummy	1=aware, 0= not aware
Age of farmer	Years	Continuous
Education level	Category	1=None; 2=Primary; 3=Secondary; 3=Post-secondary
Farming experience	Years	Continuous
Tenure system	Category	1=Communal; 2=A1; 3=A2, 4=Large scale commercial; 5=Plot/Nursery; 6=Other
Land area	Continuous	Continuous

awareness of the viruses. This was chosen because the logistic model can be used in binary data; 1 = those who were aware of the viruses and 0 = those who were not aware of the viruses. The explanatory variables for the farmers' questionnaire were age, educational level, farming experience, land tenure system and land area (Table 1). For technical staff, the explanatory variables were age, gender, employer, education level and agricultural experience.

To calculate the odds ratios (which represents the constant effect of the explanatory variables on the likelihood that the respondents were aware of TSWV/tospoviruses), the formula ODDS = e^{a+bX} was used; while the probabilities from the odds ratio were calculated using the formula: $Y=\frac{ODDS}{1+ODDS}$

The analysis used both the odds ratio and probabilities because the odds ratio is a single summary score of the effect and the probabilities are more intuitive.

RESULTS

Socio-economic characteristics of respondents

The proportion of male to female farmers was 60:40. Most (65.1%) farmers were from NRF 2, with only 3.7% from NR 1 and 5.6% from NR 5. The literacy rate amongst the farmers was 97.8%, and 29.6% of them had post-secondary education. All illiterate farmers were females; the literacy rate of female farmers was higher than that of their male counterparts only at primary school level. Most (76.8%) farmers were married, with 10.2% widowed and 12% single. The youngest farmer was 18 years old, while the oldest was 79 years. The largest proportion (37.9%) of farmers was communal, while 18 and 5.4% were A1 and large scale commercial farmers, respectively. Farmers with no more than 10 years' farming experience accounted for 45.9% of the respondents.

For the technical staff, the male to female ratio was 55:45. The government employed 77.1% of the technical staff, while only 20.1% were employed in the private sector. Agricultural extension staff constituted 50.5% of the technical staff. The majority (67.1%) of the agricultural extension workers (AEWs) had diplomas, while 91.4% of the agricultural extension officers (AEOs) had agriculture bachelor's degrees as their highest relevant qualifications. Only 15% of the technical staff had postgraduate degrees, with 1.9% having doctoral degrees. Of the lecturers and teachers, 22.4% had agricultural diplomas as their highest qualification. Most (87.9%) technical staff were married. Those with 2 to 10 years' work experience accounted for 77.1% of the technical staff, while only 3.3% had more than 20 years' experience.

Major plant viruses in Zimbabwe

According to the technical staff, the major plant viruses that occur in Zimbabwe are as shown in Table 2.

MSV was rated as Zimbabwe's most important plant virus by 72% of the technical staff. All agricultural extension staff highlighted the importance of MSV in maize production. TMV and CMV were ranked as the second and third most important plant pathogenic viruses, respectively (Table 2). GRV was reported mainly by extension staff working with smallholder groundnut farmers from NFRs 3 and 4.

Training for disease identification

The majority of farmers were self-taught to identify diseases (Figure 2). Another 20.2% were trained by agrochemical and seed company agents, while only 16% were trained by agricultural extension and research staff (AREX/research officers). Farmers who grew greenhouse flowers hired foreign experts to assist with disease identification and management.

The main methods of farmer training for disease identification used by 51.9% of the technical staff included conducting of short courses, setting of demonstration plots and field days. Lectures/lessons and practicals were mainly used by teachers and lecturers to train students in disease identification.

Respondents' perceptions of plant viruses and methods used in virus disease identification

Close to 29% of farmers did not know about plant pathogenic viruses. Only 3.1% of farmers and 2.8% of

Table 2. Top ten most economically important viruses affecting crops in Zimbabwe.

Rank	Acronym	Virus name	Genus
1	MSV	*Maize streak virus*	*Mastrevirus*
2	TMV	*Tobacco mosaic virus*	*Tobamovirus*
3	CMV	*Cucumber mosaic virus*	*Cucucmovirus*
4	ToMV	*Tomato mosaic virus*	*Tobamovirus*
5	GRV	*Groundnut rosette virus*	*Umbravirus*
6	PVY	*Potato virus Y*	*Potyvirus*
7	TBTV	*Tobacco bushy top virus*	*Umbravirus*
8	CTV	*Citrus tristeza virus*	*Closterovirus*
9	PVX	*Potato virus X*	*Potexvirus*
10	BCMV	*Bean common mosaic virus*	*Potyvirus*

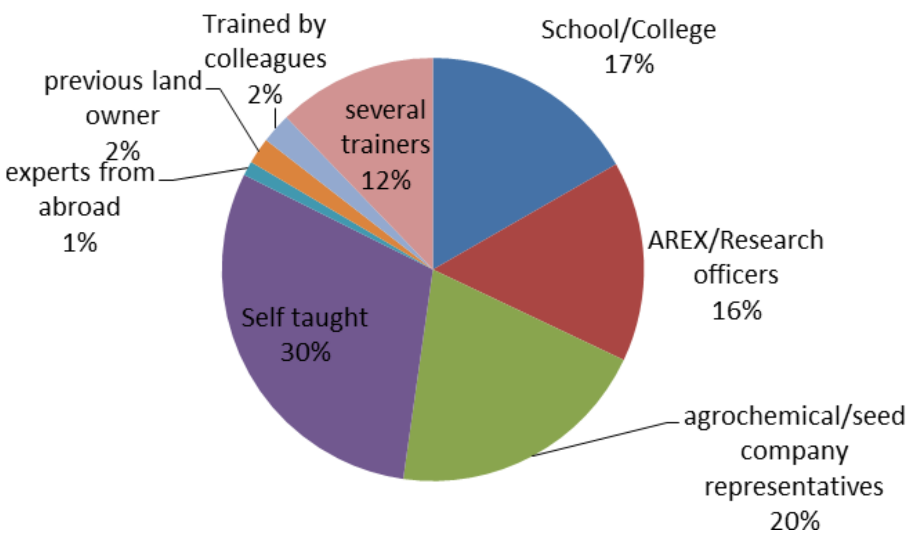

Figure 2. Farmers' trainers for disease identification.

the technical staff rated viruses as "not important", while 22.7% of farmers and 41.1% of the technical staff rated them as "very important."

The majority (85%) of farmers who were able to identify viruses relied on field symptom assessments only. Only 5.2% of farmers sent samples to plant clinics for disease diagnosis (Figure 3).

Opinions on improving virus diseases awareness

To improve virus disease awareness, 41.9% of farmers proposed the use of radio/TV/newspaper broadcasts, while 48.1% of the technical staff recommended farmer training. Another 22.3% of farmers were of the opinion that agricultural extension staff should train farmers, while 11.4% of farmers proposed distribution of color pamphlets of virus-infected plants as a method of improving virus awareness. About 6.5% of the technical staff proposed extension staff training through workshops and short courses as methods of improving virus diseases awareness (Figure 4).

Knowledge of TSWV/tospoviruses by respondents

Education level (p=0.000), farmer age (p=0.011) and agricultural experience (p=0.020) had significant effects on respondents' knowledge of TSWV/tospoviruses (Tables 3 and 4). There were 1.042 chances that older farmers were aware of TSWV/tospoviruses, and only 0.124 chances that educated farmers were aware of the viruses (Table 3). There were 0.522 chances that technical staff respondents were aware of the viruses, and 0.541 more chances that experienced staff were aware of the viruses (Table 4). Only 23.7% of farmers and 41.6% of technical staff had heard about TSWV/tospoviruses, mainly from school/college. The

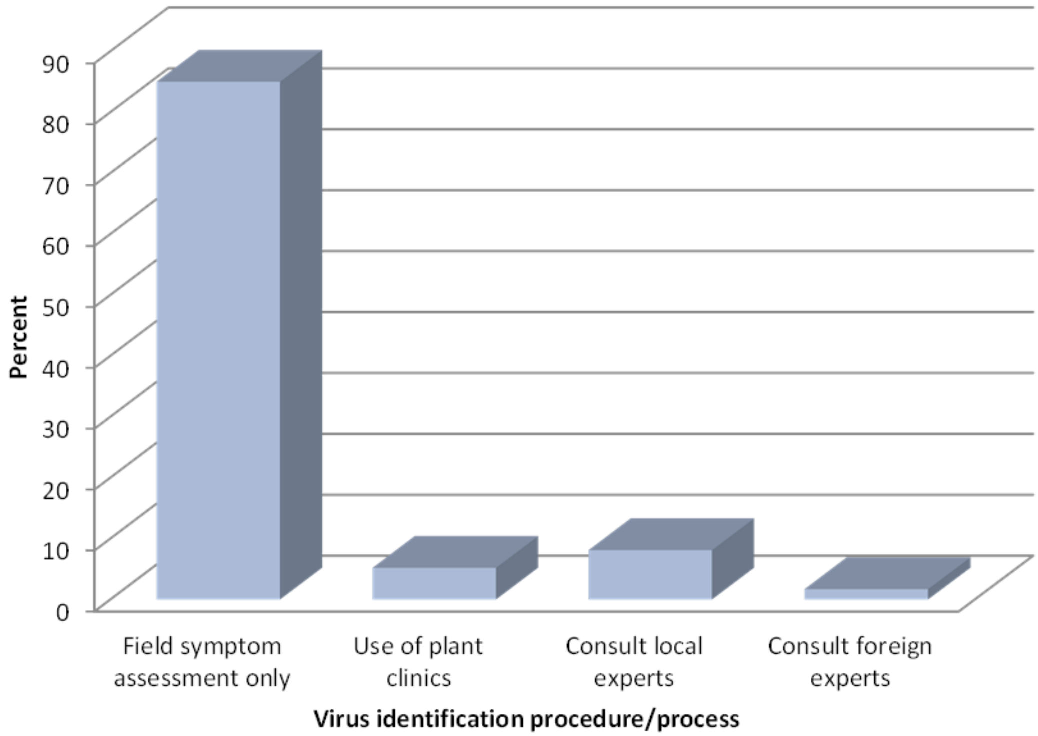

Figure 3. Methods of identifying virus diseases by farmers.

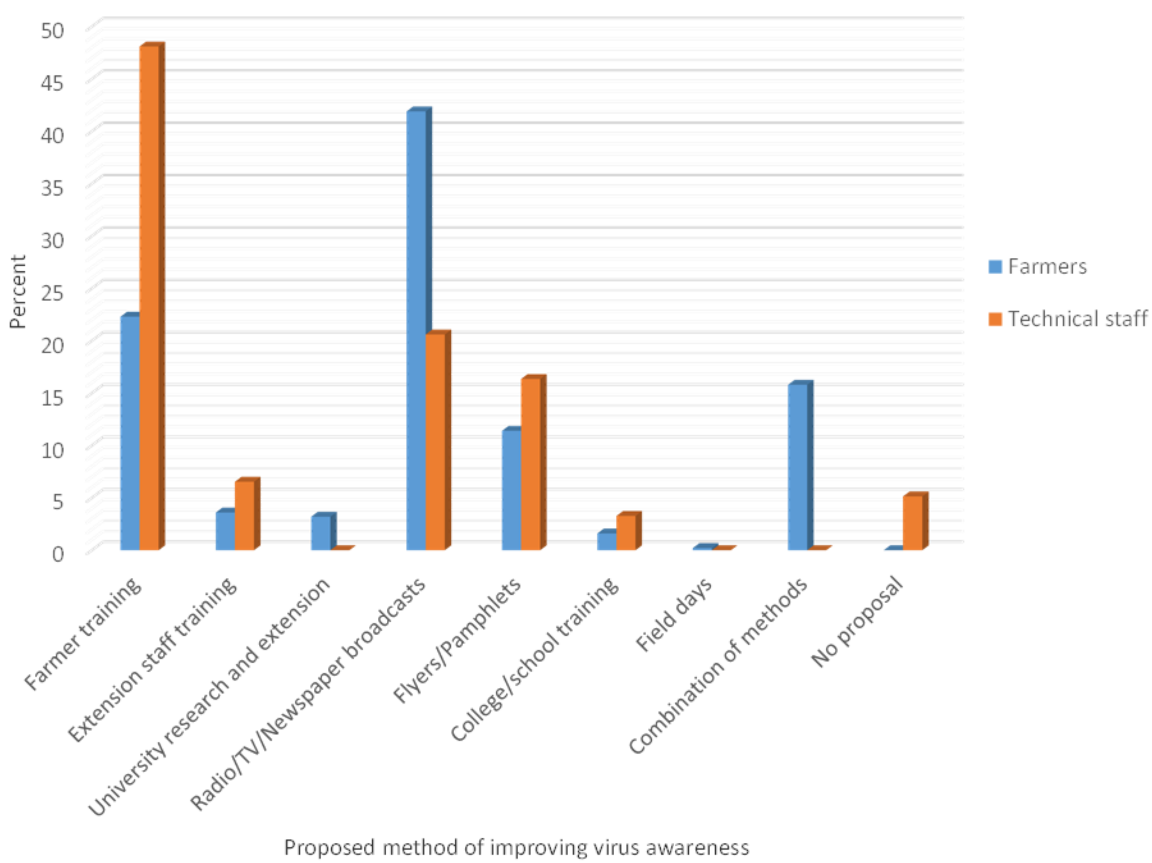

Figure 4. Respondents' opinions on how to improve virus diseases awareness.

Table 3. Logit regression results on factors influencing farmers' knowledge of TSWV/tospoviruses.

Variable	B	S.E.	Wald	DF	Sig.	Exp(B)
Educational level	-2.085	0.179	136.235	1	0.000	0.124
Marital status	-0.116	0.214	0.297	1	0.586	0.890
Farm experience	-0.031	0.020	2.294	1	0.130	0.970
Farm type	-0.101	0.062	2.673	1	0.102	0.904
Age	0.041	0.016	6.487	1	0.011	1.042
Constant	5.286	0.633	69.662	1	0.000	197.611

Table 4. Logit regression results on factors influencing technical staff's knowledge of TSWV/tospoviruses.

Variable	B	S.E.	Wald	DF	Sig.	Exp(B)
Educational level	-0.649	180	12.964	1	0.000	0.552
Agricultural Experience	-0.615	0.265	5.374	1	0.020	0.541
Age	0.064	0.035	1.692	1	0.093	1.047
Gender	0.529	0.308	2.951	1	0.086	1.696
Employer	0.342	0.321	1.135	1	0.287	1.407
Constant	1.025	1.124	0.831	1	0.362	2.787

majority (70.8%) of farmers that had heard about TSWV/tospoviruses had post-secondary education. Only 2.2% of the technical staff mentioned the electronic media as an information source for these viruses. Of those who had heard about TSWV/tospoviruses, 43.8% of farmers and 70.8% of technical staff were able to correctly identify three plant hosts to the viruses, while 39.5% farmers and 18% technical staff could only identify the tomato as a host. Close to 7% of farmers and 11% of technical staff rated TSWV/tospoviruses as "not important," while 33.2% of farmers and 31.5% of technical staff rated them as "very important." Only 14.2% of farmers and 15.7% of technical staff were able to correctly name the TSWV/tospoviruses vectors. None of the respondents were able to name tospoviral species other than TSWV.

For TSWV/tospoviruses control, insecticide use was recommended by 68.9% of farmers and 40.7% of the technical staff. The use of certified seeds and fumigation were proposed by 5.8% of farmers and 14.8% of the technical staff. To improve TSWV/tospoviruses awareness, 27.1% of the technical staff recommended "college/university/school training," while 19.2% recommended "workshops/short courses for research/technical staff" and 20.6% proposed "print and electronic media campaigns."

DISCUSSION

There were more male than female farmer respondents because males, as household heads, were generally more willing to come forward and give information to the researchers. This is despite the fact that women constitute the majority of workers on most farms. Similar findings were reported by Khan et al. (2014). Also, the higher literacy rate among males meant that they could confidently participate during the surveys.

There were fewer female than male agricultural technical staff respondents because fewer females graduate with agricultural professional qualifications in Zimbabwe. Historically, fewer female students study science-oriented subjects in high school and this translates to a smaller number of females who enroll for professional agricultural courses. In addition, agricultural extension is generally considered a masculine profession (Mutambara et al., 2013).

The study confirmed the changes in land demographics brought about by the country's land reform program that started in the year AD2000. The large scale commercial farming sector, previously the backbone of Zimbabwe's agriculture, has been decimated and replaced mainly by A1 and A2 farms. The fact that most farmers had no more than 10 years farming experience shows that they ventured into farming after the land reform program. Most such farmers either did not receive formal agricultural training or were poorly trained, and so are likely to be poorly knowledgeable about plant viruses, their effects and management.

Most respondents rated MSV as the most important plant virus in Zimbabwe. MSV is endemic to Zimbabwe and the sub-Saharan Africa region (Shepherd et al., 2010; Karavina, 2014). Therefore, most maize breeding and extension programs incorporate MSV researches and knowledge dissemination, respectively.

Some farmers either did not know about plant viruses or the different groups of plant pathogens that attack crops. During the FGDs, farmers talked more about insect pests and fungal diseases than plant viruses. This observation was similar to results reported by Sibiya et al. (2013) who found that plant diseases were lowly ranked by farmers in KwaZulu-Natal, South Africa. The major contributory factor, it appears, is poor education and training about plant viruses since even the technical staff had poor knowledge of plant viruses. While most technical staff were sufficiently trained to assist farmers to improve agricultural productivity, most could not distinguish viruses from other pathogens. A major reason for this was that most of them had diplomas as their highest relevant qualifications and so were not adequately trained in plant pathology. Even amongst the technical staff with degrees, viral diseases appreciation was poor probably because as students, most of them were poorly trained in plant pathology. The lack of qualified lecturers and training facilities in the last decade, and the “Open Distance Learning” system now in operation in the country compromised agricultural training.

The majority of respondents relied on visual symptoms assessment for disease diagnosis. This is not totally reliable, as symptom expression is influenced by the environment, host species, plant nutritional status, season, and pathogen strain (Sevik and Arli-Sokmen, 2012). It was noted that wherever maize is grown, most respondents attributed almost all mosaics, streaking and chlorosis to MSV, yet pathogens that cause similar symptoms like *Maize dwarf mosaic virus, Sugarcane mosaic virus, Maize stripe tenuivirus* and *Maize chlorotic mottle virus,* occur in Zimbabwe (Bonga and Cole, 1997). This highlights the need to employ several diagnostic tests to confirm pathogen identity. Where farmers sent diseased samples to plant clinics, the absence of qualified virologists and well-resourced laboratories also compromised viral disease diagnosis and ultimately, virus disease control.

Amongst the four major plant pathogen groups, viruses were the least appreciated by AEWs. This means the AEWs are less likely to talk about plant viruses to farmers than the other pathogens. Therefore, viruses will remain largely unknown to farmers. To remedy this situation, AEWs ought to be trained in plant virology so that they can disseminate correct information about pathogen biology, epidemiology and control. To achieve that, the agricultural training curricula must incorporate a significantly bigger section on plant virology in which virus diseases are taught.

Of the respondents who said they knew TSWV/tospoviruses, the large proportions of those who only knew tomato as a host crop and those who could not name any other tospoviruses besides TSWV, raise suspicions as to whether they really knew the pathogens. It also questions the seriousness accorded to the plant virology discipline in the country given that tospoviruses are an emerging problem worldwide (Scholthof et al., 2011). Currently, there are at least 28 tospovirus species causing serious yield losses worldwide (Margaria et al., 2014). The fact that wrong vectors were named and wrong control methods recommended showed that respondents had poor knowledge of pathogen biology and epidemiology. This means wrong control measures are likely to be implemented against the pathogens. According to Mehle and Trdan (2012), correct vector diagnosis is the first key step in tospovirus management. The observation that most respondents recommended insecticide use to control TSWV/tospoviruses reinforces an observation by Nagaraju et al. (2002) that there is a “pesticide culture” that has been created by agrochemical companies through their extension programs and aggressive product promotion.

Only a small proportion of the technical staff mentioned the electronic media as a source of information for TSWV/tospoviruses, showing that traditional media platforms still dominate information dissemination in agricultural extension, research and training in Zimbabwe. While the country has an Information and Communication Technology (ICT) Policy that promotes the use of modern ICT tools, the agriculture sector has not adequately embraced it.

Most AEWs lacked ICT resources to enable them to do their work effectively. The majority of research and tertiary education institutions have internet connectivity challenges that further limit internet use by students, academics and researchers.

In conclusion, the study showed that plant viral diseases are poorly appreciated by stakeholders in Zimbabwe’s agricultural sector. Besides MSV, other viral disease remains largely unknown by most people. This is worrying given the fact that there are currently many emerging and re-emerging plant viruses worldwide that are causing significant crop yield losses. The survey revealed the need for concerted and multifaceted approaches to increase knowledge of plant viruses in Zimbabwe through training of all stakeholders and conveyance of information by the media. This will then enable better plant viral disease management.

Conflict of Interests

The authors have not declared any conflict of interests.

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