Assessment of Sweet Potato Virus Disease Under the Presence of a Mulch-material and an Organic Insecticide on Sweet Potato and the Viral Distribution in Kwara State of Nigeria

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ABSTRACT

Assessments of 30 sweet potato farms in three districts of Kwara State of Nigeria were carried out to evaluate the incidence of sweet potato virus disease (SPVD). A serological study by Antigen-coated plate enzyme-linked immunosorbent assay (ACP-ELISA) was set up to assay six viruses on sweet potato samples. A field experiment to appraise the influence of variety, mulch and organic insecticide on virus incidence was performed on two

genetically improved sweet potato varieties. The surveys revealed the occurrence of SPVD in all locations with incidence from 2.6% in Oyun (Kwara Central district) to 39.1% in Agbamu (Kwara South district). The serology test confirmed the predominance of Sweet potato feathery mottle virus (SPFMV) and Sweet potato chlorotic stunt virus (SPCSV) correspondingly as 100% and 30% respectively in the study. The field experiment indicated lower virus disease incidence (15.3%) and increased numbers in storage roots (7.5/plant) and weight of storage roots (32.4 kg/plant) in Orange Fleshed Sweet Potato variety, mulched with organic insecticidal treatment. This is the first authentication of the occurrence and prevalence of sweet potato virus disease in Kwara State, Nigeria. The study recommends Orange Fleshed Sweet Potato variety, mulching with guinea corn stalk and organic insecticide application for sustainable management of SPVD, particularly for resource-poor farmers.

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INTRODUCTION

Sweet potato (*Ipomoea batatas* L) is among the most important food crops

in the world and an extremely important food crop for subsistence farmers in Sub-Saharan Africa (SSA). It is a vegetatively propagated vegetable and ranks as the world's seventh most important crop, with an estimated annual production of approximately 122 million metric tons (Wau and Komolong, 2019). In developing countries, sweet potato is especially valued because it is highly adaptable, and tolerates high temperatures, low fertility soil and drought (Yamakawa and Yoshimoto, 2002).

Practically, most production and consumption of sweet potatoes occur in developing countries. In Africa, sweet potato cultivars commonly have white, cream or yellow flesh; while few are orange-fleshed cultivars. Vitamin A deficiency is especially prevalent in SSA because most available foods contain negligible amounts of β -carotene, a precursor of vitamin A (Yessoufou *et al.*, 2016) whereas white to yellow-fleshed sweet potatoes have been reported to contain little or no Vitamin A; the orange-fleshed sweet potato cultivars contain good quantities of Vitamin A, predominantly as β carotene (Karuppanagounder, 2008).

China is the world's leading producer of sweet potato, accounting for about 80% of the total production worldwide. Nigeria is the most abundant sweet potato producer in Africa and second in world production with an annual output of 3.92 million tons (FAO, 2018). However, production is 44% below the potential capacity of 7 million tons especially in the North Central part of the country due mainly to low-yielding varieties planted by farmers (Nedunchezhiyan *et al.*, 2012). The low-yielding varieties usually cultivated include Kukunduku, Katsina, Dunku and Ex-igbariam (Mwanja *et al.*, 2017). This brings to fore, the need to fast track the evaluation of advanced breeding lines through participatory variety selection and release of superior clones (Onunka *et al.*, 2012). One major limitation in sweet potato production is cultivar decline, mostly due to the cumulative effect of virus infection on this vegetatively propagated crop.

Viral diseases are considered a major limiting factor in sweet potato production worldwide, and particularly in SSA. The other identified problems that have hindered high yield are the use of poor agronomic practices and poor control of pests and

diseases Pests and diseases are the greatest limitations that affect production and reduce yields (Motsa *et al.*, 2015). Viral diseases are the greatest threat to sweet potato production, causing yield losses of up to 80% (Tesfaye *et al.*, 2011; Gibson and Kreuze, 2015). Since early reports of suspected viral diseases of sweet potato in the United State of America (Moyer and Salzer, 1989) and Eastern Africa (Hansford, 1994), at least 30 viruses have been recognized as pathogens of sweet potato worldwide (Mukasa *et al.*, 2003).

The control of plant virus infections is a challenge due to the lack of therapeutic measures. Therefore, disease management has to focus on indirect measures such as reduction of insect vector populations through chemical or cultural methods and induction of systemic resistance in host plants by exogenous application of biotic/abiotic inducers such as mulching (Prasannath *et al.*, 2014). The understanding of pathogen dynamics and implementing pathogen management strategies require consistent and reliable detection of microorganisms in hosts, reservoirs, and dispersal agents (Haydon *et al.*, 2002).

Mulching is a common practice in rainfed ecosystems in smallholder farming (Ray and Ravi, 2005). The use of mulching is a simple cultural method that requires no specialized equipment (Doring *et al.*, 2006). The occasional use of abrasive mineral dust, natural desiccants like wood ash and various plant materials with repellent or insecticidal properties is well-documented (Golob and Webley, 1980). Sand kaolin, paddy husk ash, wood ash and clays constitute a group of materials that are used commonly by small-scale farmers in the developing world as protectants (Golob *et al.*, 1982). The awareness of the consequences of environmental pollution, the increasing cost of storage insecticides and growing problem of insect resistance has led to pest management specialists reappraising inert dusts. Unlike conventional contact insecticides, inert dusts function through their physical properties and, are generally slower acting (Maciljski and Korunic, 1972). Wood ash is a product of incomplete combustion of wood containing organic and inorganic compounds. It contains a mixture of oxides, hydroxides, carbonates and silicates but usually has very little nitrogen as it gets volatilized during the combustion process (Ozolincius *et al.*, 2005). Food security

remains a huge challenge for millions of Africans who depend on agriculture for their subsistence. Emerging and reemerging pathogens, including many viruses, continue to cause devastating losses of food production. However, there is a widespread lack of basic information and understanding of virus populations throughout Africa, even though such basic information is required to manage the spread and impact of these viral diseases.

Orange-fleshed sweet potato (OFSP) is a special type of biofortified sweet potato that contains high levels of beta-carotene. Beta-Carotene is an organic, red-orange pigment abundant in plants and fruits. Beta-carotene what gives OFSP an orange color and is converted to Vitamin A in the body after consumption to provide additional nutritional benefits. Biofortification enhances the nutritional value of staple food crops by increasing the density of vitamins and minerals in a crop through either conventional plant breeding, agronomic practices or biotechnology (Bechoff *et al.*, 2011). The intensity of orange-coloured flesh in sweet potatoes root indicates the level of beta carotene (Nwankwo *et al.*, 2012). Therefore, these OFSP varieties could be useful to combat the widespread

Vitamin A deficiency that results in blindness and death of 250,000-500,000 African children yearly (Wariboko and Ogidi, 2014). Hence, the evaluation of improved sweet potato varieties is timely, needed.

The objectives of the study, therefore, were (i) to assess the occurrence and distribution of sweet potato virus disease in Kwara State, Nigeria and (ii) to evaluate the effect of mulching and wood ash extract application on incidence of sweet potato virus disease on improved Orange-Fleshed Sweet Potato (OFSP) TIS 2498 and local White-Fleshed Sweet Potato (WFSP) varieties. The results from the study could reveal important information on the status of sweet potato virus diseases in Kwara State, Nigeria and proffer sustainable management initiatives for farmers who have poor resources in a developing country.

MATERIALS AND METHODS

Study Location and Estimation of Virus Incidence

Kwara State is located on longitude 2°6'E and 5°2'E and latitude 7°30'N and 9°40'N. It is situated within

the North Central geopolitical zone of Nigeria. The climate of Kwara State exhibits both wet (rainy) and dry seasons in response to the South West Monsoon wind and the North East continental wind which are the major prevailing winds that blow across the state. The wet or rainy season begins towards the end of April and lasts till October. The dry season begins in November and ends in April. The temperature of the state ranges from 33°C to 35°C from November to January and from 34°C to 37°C from February to April. The total annual rainfall ranges from 990.3 mm to 1318 mm. The rainfall exhibits a double maximal pattern. Relative humidity ranges from 75% to 88% from May to October and 35% to 80% during the dry season (Ajadi and Adeniyi, 2017).

A virus-disease-survey of 30 sweet potato farms across three districts of Kwara State was carried out at the vegetative growth stage of the plants grown between 2018 and 2019. The surveyed locations and the Global Positioning System (GPS) coordinates are shown in Table 1. The farms selected had an area not less than 10,000 m². The incidence of viruses was estimated based on 100 sweet potato plants per field and by visual inspection

of virus disease symptoms on the plants such as mosaic, chlorosis, mottling, stunting, mottling, necrosis, leaf deformation and bunching (James, 1974). The plants were identified by walking in a “W” shaped pattern method of sampling with 10 plants per side spaced at an equal distance of 0.5 m from each other (Olawale *et al.*, 2015). The percentage incidence of virus disease on the field was calculated based on the formula:

$$= \frac{\text{Number of infected plants (symptomatic plants)}}{100 \text{ (number of total plants inspected)}} \times 100$$

A total of 20 sweet potato vine cuttings and leaves (sourced from WFSP and OFSP varieties) from each farm were randomly collected, tagged, put in plastic containers and stored in iced packs prior to virus testing using antigen-coated plate enzyme-linked immunosorbent assay.

Virus Detection by Enzyme-Linked Immunosorbent Assay (ELISA)

Antigen-coated plate enzyme-linked immunosorbent assay (ACP-ELISA) was the protocol used in confirming the presence of 6 viruses using monoclonal antibodies. The antibodies were specific to Sweet potato feathery mottle virus (SPFMV), Potato

virus X (PVX), Potato virus Y (PVY), Sweet potato chlorotic stunt virus (SPCSV), Soybean mosaic virus (SBMV) and Cowpea mild mottle virus (CPMMV). An initial antibody dilution

of 1:100 was made followed by double-fold serial dilution to 1:51,200. Antibody dilutions were made in phosphate-buffered saline containing 0.05% v/v Tween20 (PBS-T).

Table 1: Survey-locations and percentage incidence of viruses on sweet potato in Kwara State

S/N	Location	District	Latitude	Longitude	Virus Incidence
1	Suku	Kwara North	8.72817	5.75762	16.7
2	Kusegi	Kwara North	8.71667	5.93333	13.2
3	Koro	Kwara North	8.55001	5.95002	11.6
4	Yagbagi	Kwara North	8.72851	5.75561	17.4
5	Gbagufa	Kwara North	9.10816	3.11222	19.2
6	Gwanara	Kwara North	9.55073	3.22805	21.6
7	Tsoho	Kwara North	9.56083	3.228049	16.9
8	Lafiagi	Kwara North	7.21041	5.0028	23.4
9	Teshe	Kwara North	8.76736	5.0028	27.4
10	Kuhiaro	Kwara North	8.61662	4.45211	13.2
11	Afon	Kwara Central	8.45111	4.3332	11.1
12	Fufu	Kwara Central	8.44811	4.72111	9.6
13	Egbejila	Kwara Central	8.53201	4.54621	6.3
14	Ile-Apa	Kwara Central	8.6166	4.3833	11.1
15	Badi	Kwara Central	8.47821	4.70611	14.3
16	Oke-oyi	Kwara Central	8.58333	4.71666	7.6
17	Woru	Kwara Central	8.71663	4.90002	3.8
18	Lajiki	Kwara Central	8.50002	4.71544	4.1
19	Oyun	Kwara Central	8.19921	4.63163	2.6
20	Afeyin	Kwara Central	8.43211	4.70311	4.9
21	Ilemona	Kwara South	8.11664	4.66665	36.3
22	Ira	Kwara South	8.08342	4.60621	28.8
23	Ilofa	Kwara South	8.11112	5.15463	33.3
24	Etan	Kwara South	8.03333	5.21667	29.1
25	Oke-opin	Kwara South	8.06667	5.23333	26.4
26	Agbamu	Kwara South	8.11876	4.87012	39.1
27	Offa	Kwara South	8.14913	4.72076	28.6
28	Kajola	Kwara South	8.34663	5.16843	21.4
29	Ibobo	Kwara South	8.36664	4.40001	26.1
30	Idofian	Kwara South	8.38332	4.71665	31.3

The sap (200 µl) obtained by grinding infected leaf tissues and healthy yam leaves in grinding buffer (PBS-T containing 0.5 mM polyvinyl pyrrolidone (PVP)-40 and 79.4 mM Na₂SO₃) were loaded in duplicate wells for each antibody dilution. The initial antibody dilution of 1:500 was followed by a two-fold serial dilution to 1:256,000. Antibody dilutions were made in conjugate buffer (half strength phosphate-buffered saline-PBS containing 0.05% (v/v) Tween-20, 0.02% (w/v) egg albumin, 0.005 mM PVP-40). Wells of microtitre plates were coated with 100 µl of sap obtained by grinding infected leaf tissues and healthy leaves in 0.05 M sodium carbonate buffer (pH 9.6) containing 0.5 mM PVP-40 and 79.4 mM Na₂SO₃. After a skimmed milk blocking step, 100 µl of each antibody dilution was loaded into duplicate wells pre-coated with diseased and healthy sap. Goat anti-rabbit alkaline phosphatase (Sigma, UK) diluted with 1:40,000 in conjugate buffer were added to each well, followed by addition of 200 µl p-nitrophenylphosphate substrate (pNPP) (1 mg ml⁻¹ in 10% diethanolamine, pH 9.8) into each of the wells to detect the antigen-antibody reactions. The optical density (OD) values were measured after 1 hour at absorbance of A405 using a Bio Tek

ELx800, Universal Micro plate Reader. An optical density value greater than three times the mean of the negative controls i.e. virus – free plants, was considered as positive (Resende *et al.*, 2000).

Field Experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replicates. The total plot size was 33 m x 10 m with each replication having a plot size of 11 m x 2 m. The intra and inter-row spacing was 30 cm and 90 cm, respectively. Rows of each variety were separated by a 1 m boundary and replications were separated by 2 m boundaries. The vines of each variety were planted in triplicate rows containing 6 plants each with a total of 18 plants per block. The sweet potato cuttings measuring at least 30 cm in length with at least 4 nodes were planted on top of the ridges with cuttings facing the right-side-up (Esan and Omilani, 2018). The Sweet potato varieties used for the field trial were the improved variety Orange Fleshed Sweet Potato (OFSP) TIS 2498 and local White Fleshed Sweet Potato (WFSP) variety Iwo. The two varieties are more preferred and highly promoted in Nigeria to fight with

hunger and malnutrition because of high levels of beta-carotene content.

The treatments were mulching with guinea corn straw (7.5 cm thickness) applied on the ridge at 1 week after planting and wood ash extract applied as a foliar spray at weekly intervals until 12 WAP at the rate of 3 L/ 25 m². The materials are cost-effective as conventional control and can be easily sourced locally and applied. The extract was prepared by dissolving 5 kg of sieved wood ash in 40 L of water, stirred properly every day for 7 days and filtered using a clean white cloth (Moyin-jesu, 2010). The combination treatments were: (i) OFSP x mulched (ii) OFSP x insecticide (iii) OFSP x mulched x insecticide (iv) OFSP control (no mulching, no insecticide) (v) WFSP x mulched (vi) WFSP x insecticide (vii) WFSP x mulched x insecticide (viii) WFSP control (no mulching, no insecticide).

Data Collection and Statistical Analysis

Data were collected from 8th to 16th week after planting (WAP) for parameters such as plant height, number of leaves, and number of leaves with virus disease symptoms. The

symptoms were visually identified (Figure 1) based on typical virus symptoms manifested by the plants and with the aid of disease diagnosis manuals (Chen *et al.*, 2010; Samarakoon *et al.*, 2012). The virus disease incidence was measured by the number of infected plants relative to the total number of plants inspected (100) and expressed as a percentage. At harvest, the number of storage roots per plant and the weights were measured. The data collected were subjected to analysis of variance (ANOVA) using the Statistical Package for the Social Sciences SPSS version 15.0. The significantly different means were separated using New Duncan Multiple Range Test at 5% level of probability.

RESULTS

Survey on the Incidence of Viruses on Sweet Potato

The result of the survey on the incidence of viruses on sweet potato in 3 districts of Kwara state (Table 1) showed that the highest virus incidence was in Kwara South district. The locations were Agbamu (39.1%), Ilemona (36.3%), Ilofa (33.3%), Idofian (31.3%), Etan (29.1%), Ira (28.8%) and Offa (28.6%). The lowest virus

incidences were however in Oyun (2.6%), Woru (3.8%), Lajiki (4.1%), Egbejila (6.3%), Fufu (9.6%), Ile Apa (11.1%) and Afon (11.1%) in Kwara Central district. The survey revealed 100% presence of virus disease on sweet potato in all the districts of Kwara State. However, the incidence varied among survey areas with a range of 2.6% in Oyun (Kwara Central district) to 39.1% in Agbamu (Kwara South district). The average virus incidence was between 7.5% in Kwara Central district and 30% in Kwara South district.

ELISA Identification

The ACP-ELISA detected an infection of SPFMV and SPCSV in 100% and 30% of the surveyed locations, respectively. These were either a single viral infection or in mixtures of the two viruses (Table 2). Further scrutiny of the results revealed the presence of mixed sweet potato virus disease on samples from Kusegi, Gwanara, (Kwara North district); Fufu, Ile-Apa, (Kwara Central district); Ilemona, Ira, Offa, Kajola and Idofian (Kwara South district).

Figure 1. Symptoms observed during the field survey: (a) vein clearing with intense mosaic patterns, (b) reddening leaves with a leathery feel, (c) leaf purpling and narrowing along the leaf veins and (d) leaf deformation, yellowing and bunching of leaves.

Table 2. Virus detection on sweet potato plants optical density with ACP-ELISA

S/ N	Location	District	Viruses (OD values in ELISA units)					
			SPFMV	PVY	PVX	SPCSV	SBMV	CPMMV
1	Suku	North	++0.734	--	--	--	--	--
2	Kusegi	North	++0.925	--	--	++0.686	--	--
3	Koro	North	++1.998	--	--	--	--	--
4	Yagbagi	North	++2.111	--	--	--	--	--
5	Gbagufa	North	++1.874	--	--	--	--	--
6	Gwanara	North	++1.624	--	--	++0.695	--	--
7	Tsoho	North	++1.887	--	--	--	--	--
8	Lafiagi	North	++0.767	--	--	--	--	--
9	Teshe	North	++2.222	--	--	--	--	--
10	Kuhiaro	North	++1.775	--	--	--	--	--
11	Afon	Central	++0.896	--	--	--	--	--
12	Fufu	Central	++1.232	--	--	++0.708	--	--
13	Egbejila	Central	++0.791	--	--	--	--	--
14	Ile-Apa	Central	++1.861	--	--	++0.852	--	--
15	Badi	Central	++1.127	--	--	--	--	--
16	Oke-oyi	Central	++1.654	--	--	--	--	--
17	Woru	Central	++1.773	--	--	--	--	--
18	Lajiki	Central	++1.225	--	--	--	--	--
19	Oyun	Central	++1.49	--	--	--	--	--
20	Afeyin	Central	++1.776	--	--	--	--	--
21	Ilemona	South	++1.434	--	--	++0.642	--	--
22	Ira	South	++1.696	--	--	++0.854	--	--
23	Ilofa	South	++0.896	--	--	--	--	--
24	Etan	South	++0.941	--	--	--	--	--
25	Oke-opin	South	++1.116	--	--	--	--	--
26	Agbamu	South	++0.987	--	--	--	--	--
27	Offa	South	++0.816	--	--	++0.569	--	--
28	Kajola	South	++1.187	--	--	++0.896	--	--
29	Ibobo	South	++1.996	--	--	--	--	--
30	Idofian	South	++1.736	--	--	++0.702	--	--
Positive			2.1222	4.042				
Negative			0.133	0.321				
Buffer			0.122	0.313				

Key: SPFMV = Sweet potato feathery mottle virus, PVY = Potato virus Y, PVX = Potato virus X, SPCSV = Sweet potato chlorotic stunt virus, SBMV = Soybean mosaic virus, CPMMV = Cowpea mild mottle virus. ++ denotes presence of virus, -- denotes absence of virus. Figures in parentheses are OD values of positive samples.

The result showed the predominance of sweet potato virus disease in Kwara South district. The other viruses namely: PVX, PVY, SBMV and CPMMV were not found infecting any samples and therefore deemed not occurring on sweet potato in the study area

Effects of Mulching and Wood Ash Extract Application on Virus Incidence

The effects of mulching with guinea corn husk and wood ash extract as an insecticide on the incidence of virus infection on sweet potato are shown in Table 3. The result indicated that irrespective of the sweet potato variety, mulching with guinea corn husk and wood ash extract as insecticide triggered a significant reduction in virus incidence. The result indicated the significantly lowest virus infection at 8 WAP (12.4%), 12 WAP (14.8%) and 16 WAP (15.3%) in the mulched and wood ash treatment. Contrariwise, the control plants without mulching and wood ash had the significantly highest virus incidence at 8 WAP (50.2%), 12 WAP (53.7%) and 16 WAP (56.4%).

Effect of Mulching and Insecticidal Application on the Yield of Sweet Potato

The effect of treatments on yield parameters such as the number of storage roots and weight of storage roots indicated that there were significant differences in the values obtained (Table 4). There is an indication that the action of combining mulching with wood ash extract application was more prolific compared to the other treatments. The highest average number of storage roots per plant (7.5) and weight of storage roots per plant (32.4 Kg) were obtained in the improved OFSP variety mulched with guinea corn husk and wood treatment.

DISCUSSION

The symptoms observed on the field were consistent with those reported by Ndunguru and Kapinga (2007). The survey study detected the distribution and occurrence of 2 viruses namely SPFMV and SPCSV in the study area. The climate influences the incidence as well as temporal and spatial distribution of plant virus diseases (Fabre *et al.*, 2011). Climate affects all life stages of the pathogen

and host and clearly poses a challenge to many pathosystems.

This study is the first report of viruses infecting sweet potato varieties

Table 3. Effect of treatments on percentage virus disease incidence

Treatment	Virus disease incidence (%)		
	8 WAP	12 WAP	16 WAP
OFSP x mulched	25.2 ^b	26.6 ^b	27.1 ^d
OFSP x insecticide	18.0 ^d	19.1 ^d	19.9 ^f
OFSP x mulched x insecticide	12.4 ^f	14.8 ^f	15.3 ^g
OFSP x control	49.5 ^a	52.9 ^a	55.2 ^b
WFSP x mulched	25.5 ^b	28.3 ^b	30.1 ^c
WFSP x insecticide	23.7 ^c	24.8 ^c	25.3 ^e
WFSP x mulched x insecticide	14.1 ^e	16.3 ^e	16.9 ^g
WFSP x control	50.2 ^a	53.7 ^a	56.4 ^a
Standard error of mean (S.E.M)	1.249	1.525	1.547

Means within a column followed by the same letter(s) are not significantly different using New Duncan Multiple Range Test at ($p < 0.05$).

Table 4. Effect of treatments on yield parameters

Treatment	Number of storage roots/plant	Weight of storage roots/plant (kg)
OFSP x mulched	3.8 ^e	25.6 ^c
OFSP x insecticide	5.2 ^c	28.5 ^b
OFSP x mulched x insecticide	7.5 ^a	32.4 ^a
OFSP x control	1.1 ^f	12.4 ^d
WFSP x mulched	3.7 ^e	25.5 ^c
WFSP x insecticide	4.2 ^d	28.2 ^b
WFSP x mulched x insecticide	6.4 ^b	31.8 ^a
WFSP x control	0.9 ^f	10.3 ^e
Standard error of mean	0.384	1.249

Means within a column followed by the same letter(s) are not significantly different using New Duncan Multiple Range Test at ($p < 0.05$).

in the Kwara State of Nigeria with the incidence between 2.6% to 39.1%. This report validates Olabiyi *et al.* (2017), who assessed the climatic dynamics on the incidence and severity of plant diseases for climate prediction purposes in Nigeria and revealed virus disease range of 16.0% to 97.0%. This indicates that favorable climate conditions enhanced disease development, resulting in higher incidence and severity.

In many parts of the world, climate variability is already having serious impacts especially on the environment and agriculture (Onu and Ikehi, 2016; Olubanjo and Adebolu, 2018). Interestingly, studies are reported viruses having varying, but significant impacts on yields (Paprotka *et al.*, 2010). However, until only recently there had been no reports on their impact on African sweet potato varieties (Mulabisana *et al.*, 2019). The two viruses detected in the study are considered the most damaging viruses of sweet potato due to their ability to induce synergistic viral diseases with several other viruses (Opiyo *et al.*, 2010). In a synergistic interaction, the virus titer of both, one or neither virus may be enhanced and, as a consequence, the rate of disease spread may be affected.

It is the opinion of Zhang *et al.* (2001) that many virus diseases of plants are caused by a synergistic interaction between viruses within the host plant.

The mixed infection of SPFMV and SPCSV has been reported to constitute Sweet potato virus disease (SPVD) with higher yield reductions compared to SPFMV and SPCSV (Gutierrez *et al.*, 2003). This is an indication that the viruses can be a limiting factor to achieving sustainable and high-yielding sweet potato crop varieties and this is in agreement with Mulabisana *et al.* (2019). In the present study, SPFMV was observed in all samples while SPCSV in 30 % of locations. The disparity in the incidence of viruses across the 3 districts of the State has been studied by Gibson and Kreuze (2015) and was thought to be a result of the specific virus strains and/or varieties planted by the farmers. It could also be the result of limitations in sampling as symptoms may not always be an adequate indicator of virus presence as symptoms disappear over time, making such plants difficult to identify. Symptoms may also be caused by other pathogens, environment, pest and nutrition that could be mistaken for virus infection (Mukasa *et al.*, 2003).

The non-detection of PVX, PVY, SBMV and CPMMV on sweet potato in the study area does not however preclude the absence of these viruses in the study area. In general, most viruses have a limited host range and the inability of interaction between such host factor and virus leads to resistance on the part of the host. The non-detection of the viruses could be the result of the existence of incompatible interactions restricting virus replication (Jaubert *et al.*, 2011). It is yet possible that the viruses can be confirmed using more sensitive virus diagnostic techniques such as Polymerase Chain Reaction (PCR) and sequencing of genomes (Wau and Komolong, 2019). Although in developing countries, this might prove quite cumbersome and expensive for routine implementation.

The field experiment revealed the capability of the treatments to lessen virus incidence with improved crop growth and yield. There have been reports on mulching reducing the incidence of virus diseases in vegetables (Vani *et al.*, 1989). The general trend is that straw mulches have positive effects on the crop and soil moisture (Saeed and Ahmad, 2009). It is assumed that changes in the microclimate within the growing plants

induced increased growth and production (Awal and Sultana, 2006). In addition, it has also been agreed by Alcantara *et al.* (2007) that mulches reduce aphid-borne viruses and whiteflies with resultant higher overall yields.

As revealed in this study, straw mulching, which is less common in sweet potato cultivation can thus be of encouraging effect in improving plant health and suppressing virus infection. The improvement is prompted by the rapid decomposition of the mulch, enhanced soil microorganisms status, aeration and water conservation. Mineral nutrients are essential for the growth and development of plants and microorganisms. They are important factors in plant-disease interactions and also affect the formation of mechanical barriers in plant tissue and play a role in disease resistance (Amtmann *et al.*, 2008).

The doses of wood ash applied as insecticide may also have increased the amount of chlorophyll and total carotenoids, since changes in pigment concentration are linked with more photosynthetic activity (Parekh *et al.*, 1990; Adekayode and Olojugba, 2011). It is also feasible that wood ash extract

contributed immensely in the reduction of activities of insects associated with virus epidemiology. The increase in the population of insect vectors is positively correlated with the spread of virus diseases. Hence, lower virus incidence observed in the mulched and insecticidal plots is connected to a lower abundance of vectors (Awodoyin and Ogunyemi, 2005; Prasannat, 2014). Similar conclusions were made by Ayoade (1977) on the effectiveness of wood ash in the control of pests and insect vectors of viruses.

CONCLUSIONS

The research showed the diverse occurrence and prevalence of sweet potato virus disease in all districts of Kwara State, Nigeria. There is a need therefore to put in place adequate management to curtail the spread of the disease for increased production and food security. The field experimentation endorses the use of the two sweet potato varieties, mulched with guinea corn stalk and wood ash extract applied as an organic insecticide in the management of SPVD especially in sub-Saharan Africa with subsistence agricultural practice.

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