Survey of Weed Hosts of Viruses Infecting Sweet Potato (*Ipomoea Batatas L., Lam.*) in Kebbi and Katsina States, Nigeria

Abdulrahman Musa[2], Mathew Dada Alegbejo[1], Boniface David Kashina[1], Busari Yunus Abolore[2], Mustapha Sale Na-Allah[2], Ibrahim Yusuf Jega[2], Peter Abraham[3] and **Ibrahim Umar Mohammed[2]**

[1]Department of Crop Protection, Ahmadu Bello University, Zaria, Nigeria
[2]Department of Crop Science, Kebbi State University of Science and Technology, Aliero, Nigeria
[3]Department of Horticulture, Federal College of Horticulture, Dadin kowa, Gombe State, Nigeria

Correspondence: abdulmusatsoho@gmail.com

Abstract

Weed plants naturally harbor economically important plant viruses and their insect vectors. To effectively manage viruses infecting sweet potatoes, their weed hosts need to be identified and managed. This research was therefore conducted to identify weed hosts of Sweet potato chlorotic fleck virus (SPCFV), Sweet potato mild mottle virus (SPMMV) and Sweet potato virus 2 (SPV2) in Kebbi and Katsina States, Nigeria. A field survey was conducted during the rainy season of 2020 and dry season of 2021. Three sweet potato fields were sampled in each of the three Local Government Areas (LGAs) purposively selected in each state. A total of one hundred and eighty (180) symptomatic and asymptomatic weed leaf samples were collected and tested against SPCFV, SPMMV and SPV2 using double antibody sandwich enzyme-linked immunosorbent assay (DAS-ELISA). The results generated revealed that five weed species within four families were identified as weed hosts of SPCFV, SPMMV, and SPV2 in the two states but with variation (P = 0.05) in incidence and distribution. Ipomoea involucrata P., and Ipomoea cordatotriloba Dennst., were identified as weed hosts of SPCFV, SPMMV and SPV2. Commelina benghalesis L., and Mitracarpus villosus (Sw.) DC., were tested positive of SPMMV. Senna obtusifolia L., tested positive for SPV2. This research established that some weed plants harbored SPCFV, SPMMV, and SPV2 in the study area. Farmers should employ proper weed management to minimize the spread of the viruses and research that will explore more weed hosts of viruses infecting sweet potato is recommended.

Keywords: *DAS-ELISA, incidence, sweet potato viruses, weed-hosts,*

Introduction

Sweet potato (*Ipomoea batatas* L. Lam.) is a dicotyledonous perennial plant but grown as an annual. It belongs to family *Convolvulaceae* commonly known as Morning Glory and the family comprises plants with funnel-shaped flowers (Austin, 1988). In terms of importance as a food crop, sweet potato ranks seventh most important energy food crop after wheat, rice, maize, Irish potato, barley and cassava (Tavva and Nedunchezhiyan, 2012). The storage root of sweet potato is very rich in carbohydrate and is used as a subsidiary food after boiling/or baking and its vines tips are used as vegetables in some countries and they also serve as feed for livestock (Tavva and Nedunchezhiyan, 2012). Sweet potato is a nutritional security promoter particularly in developing countries (e.g. Nigeria) because it is a good source of protein, lipid, calcium and carotene besides carbohydrates (Laurie *et al.*, 2018). Some varieties of sweet potato like orange fleshed variety which contain high vitamin A play an important role in alleviating vitamin A deficiency which is rampant among children in Asia and Sub-Saharan Africa (Laurie *et al.*, 2018).

Weeds are considered as a source of new viruses and reservoirs of unidentified economically important viruses but are often neglected as important area of study in Nigeria (Abraham *et al*., 2020). Weeds provide shelter and sources of nutrients for virus insect vectors. Other vegetative structures or contaminated weed seeds may also harbor viruses. Aside from facilitating the spread of disease as alternative source of inoculum, these plants sustain the viability of the virus between cropping seasons (Duffus, 1971). Numerous weeds act as reservoirs for a virus and its vectors (Kahn *et al*., 2005), and certainly those of genus *Ipomoea*, have been found to be important in the epidemiology of certain sweet potato viral diseases (Hobbs *et al*., 2000). The persistent feature of most weeds in nature due to their ability to thrive under a wide range of edaphic and climatic conditions, make them suitable hosts or reservoirs for the survival of plant viruses and possible transmission to field crops (Abraham *et al*., 2021). The first effective management step for

virus diseases in screen house and fields, relied on the accurate detection of these viruses in their principal host crops and weed hosts using serology and molecular techniques (Sastry and Zitter, 2014), as most farmers are not conversant with virus disease symptoms while most of the infected weed hosts expressing no symptoms (Sastry and Zitter, 2014). Some of the symptoms expressed by sweet potato plants infected with viruses are: mottling on leaves, mosaic patterns, vein clearing, leaf curling, and stunted growth. Identification of weed host species of viruses infecting sweet potato within and around sweet potato fields will give a better understanding of the viruses' epidemiology and significant for their effective management. Hitherto, this information remains unexplored in major sweet potato producing states in Nigeria, Kebbi and Katsina States inclusive. In this study, we report the detection of weed species infected with *Sweet potato chlorotic fleck virus* (SPCFV), *Sweet potato mild mottle virus* (SPMMV) and *Sweet potato virus 2* (SPV2) in Kebbi and Katsina States, Nigeria.

Materials and Methods

Field Survey

Field surveys were conducted in August 2020 rainy and January 2021 dry growing seasons. Three sweet potato-growing Local Government Areas (LGAs) each were selected from each of the Kebbi and Katsina States. In each LGA, three sweet potato fields were sampled. The LGAs were selected based on their sweet potato production and the locations were selected at random based on weeds infestation. In each field, 6 weed plants were randomly sampled along two diagonals (X) (that is three from each diagonal) and examined for symptoms of viruses infecting sweet potatoes (Sseruwagi *et al.*, 2004). Weeds were sampled based on their gross morphology, that is, two grasses, two broad-leaves and two sedges. Geographical Positioning System (GPS) co-ordinates (latitude, longitude, and elevation) were also collected from each field (Tables 1).

Table 1: GPS coordinates of locations sampled during the rainy season of 2020

State	LGA	Location	GPS Coordinate
Kebbi	Aliero	Tunga	12.1356 N 4.33345 E
		Faratu	12.21258 N 4.28781 E
		Kashinzama	12.228 N 4.29072 E
	Jega	Allelu	12.11409 N 4.2773 E
		Gindi	12.12517 N 4.21651 E
		Dangamaji	12.13051 N 4.18376 E
	Mayama	Rafinguzuma	12.02681 N 4.21945 E
		Mayalo	12.15062 N 4.16491 E
		Kuberi	12.08680 N 4.1686 E
Katsina	Danja	Rafinkara	11.23083 N 7.32752 E
		Kwanar Daura	11.24684 N 7.30955 E
		Huguma	11.24344 N 7.30983 E
	Funtua	Unguwarwanzamai	11.30661 N 7.18878 E

		School of Basic Remedial Study	11.29210 N 7.18318 E
		Maigamji	11.27170 N 7.17553 E
	Bakori	Karin kudu	11.33122 N 7.25636 E
Katsina	Bakori	Kagadama	11.33281 N 7.25798 E
		Kurami	11.32209 N 7.21749 E

Table 2: GPS coordinates of locations sampled during the dry season of 2021

State	LGA	Location	GPS Coordinate
Kebbi	Aliero	Kashinzama	12.22815 N 4.29105 E
		Sabiyal	12.23148 N 4.27239 E
		Kali	12.16388 N 4.26307 E
	Jega	Gadar sanagi	12.194091 N 4.364071 E
		Akalawa	12.179304 N 4.309304 E
		Allelu	12.12173 N 4.27931 E
	Mayama	Mayalo	12.243001 N 4.283587 E
		Rafinguzuma	12.045652 N 4.366589 E

		Mayama	12.4952 N 4.2182 E
Katsina	Bakori	Karin kudu	11.3301 N 7.25541 E
		Hayinrumawa	11.32306 N 7.25203 E
		Hayingada	11.33397 N 7.25848 E
	Danja	UnguwarDanbirni	11.22754 N 7.35552 E
		Unguwarmakaranta	11.24073 N 7.35417 E
		Unguwarshara	11.22928 N 7.34647 E
	Funtua	Yar'tafki	11.26364 N 7.19865 E
		Bakin gada	11.26183 N 7.19592 E
		Zaria road	11.30665 N 7.18871 E

Sample Collection and Preservation

Symptomatic and asymptomatic leaf samples of weed plants were collected, and samples were collected during both survey. The samples collected were preserved separately in bottles containing calcium chloride, and taken to Virology Laboratory, Department of Crop Protection, Ahmadu Bello University, (ABU) Zaria for analysis. Six weed leaf samples were collected per field, one from each of the six weed plants sampled of both symptomatic and asymptomatic. Weeds sampled were two grasses, two broad-leaves and two sedges. In total, one hundred and eighty (180) weed leaf samples were collected.

Weed identification

A clear picture of each weed sampled was taken and herbarium of the full weed plant was also prepared. *Identification of the weed samples was done at the herbarium unit of the Department of Botany, Faculty of Life Sciences, Ahmadu Bello University, Zaria, and as described by Akobundu et al. (2016).*

Virus Incidence

Virus incidence in percentage was calculated using the formula of Hidayat et al. (2020). This was achieved after laboratory analysis of the weed leaf samples.

$$\textit{Virus Incidence (\%)} = \frac{\text{Number of positive samples/field}}{\text{Total number of samples examined/field}} \times 100 \quad (1)$$

Enzyme-Linked Immunosorbent Assay (ELISA) Procedure

ELISA procedure were used for the detection of SPV2, SPMMV and SPCFV. ELISA kits were supplied by DSMZ-German Collection of Microorganisms and Cell Culture GmbH, Braunschweig. Buffers dilution was achieved following manufacturer's procedure. Step-by-step procedure of ELISA as previously stated by Clack and Adams (1977), were followed.

The plates were assessed visually against the controls. Positive samples developed yellow color as the positive control while those that were negative remained colorless. Thereafter, spectrophotometer measurement of absorbance at 405 nm was taken using the ELISA spectrophotometer (BIO RAD Microplate Reader, iMark). An absorbance value twice the values of negative control was rated as positive (Clack and Adams, 1977).

Data Analysis

Data generated were analyzed using SAS software version 20. Means were separated using least significant difference (LSD) to determine variation of means which were considered significant at 5% level of probability as described by Gomez and Gomez (1984).

Results

A total of five (5) weed species within four (4) families (Table 3) were detected as hosts of viruses infecting sweet potato in Kebbi and Katsina States, Nigeria with significant ($P \leq 0.05$) variation in their occurrence and incidence across the LGAs surveyed in the two states. During the rainy growing season, only SPMMV was detected on weed hosts and the virus incidence was same in both states (12.5%). During the dry growing season, all the three viruses infecting sweet potato indexed in this study were detected on some weed hosts from both states. Higher incidence of SPCFV (25%) on weed species was recorded in Kebbi State, while higher incidence of SPMMV and SPV2 (12.5%) and (37.5%), respectively, were recorded in Katsina State (Tables 4 and 5).

In rainy growing season survey, the weed samples tested positive for SPMMV were identified as *Ipomoea involucrata* P., *Ipomoea cordatotriloba* Dennst. and *Commelina benghalesis* L. In dry growing season survey, the weed samples that tested positive for SPCFV were identified as *Ipomoea cordatotriloba* Dennst., *Ipomoea involucrata* P., and *Mitracarpus villosus* (Sw.) DC. The weed sample that tested positive for SPMMV was identified as *Mitracarpus villosus* (Sw.) DC. The weed samples that tested positive for SPV2 were identified as *Ipomoea cordatotriloba* Dennst., *Senna obtusifolia* L. and *Ipomoea involucrata* P. (Table 3).

Table 3: Weed species sampled and tested for SPV2, SPMMV and SPCFV

		Wet season 2020			Dry season 2021		
Families of weeds tested	**Scientific name of weeds**	**SPCFV**	**SPMMV**	**SPV2**	**SPCFV**	**SPMMV**	**SPV2**
Convolvulaceae	*Ipomoea involucrata* P.	_	+	_	+	+	+
Leguminosae	*Senna obtusifolia* L.	_	_	_	_	_	+
Amaranthaceae	*Amaranthus spinosus* L.	_	_	_	_	_	_
Commelinaceae	*Commelina benghalesis* L.	+	_	_	_	_	_
Acanthaceae	*Monechma ciliatum*	_	_	_	_	_	_
Urticaceae	*Laportea aestuans*Linn.	_	_	_	_	_	_
Rubiaceae	*Mitracarpus villosus*(Sw.) DC.	_	_	_	+	_	+
Amaranthaceae	*Celosia leptostachyya* Benth	_	_	_	_	_	_
Convolvulaceae	*Ipomoea cordatotriloba* Dennst.	_	_	_	+	+	+
Solanaceae	*Solanum nigrum* L.	_	_	_	_	_	_
Asteraceae	*Acanthospermum hispidum* DC.	_	_	_	_	_	_
Aizoaceae	*Triantheman portulacastrum* Linn.	_	_	_	_	_	_
Malvaceae	*Sida cardifolia* Linn.	_	_	_	_	_	_
Nyctaginaceae	*Boerhavia erecta*L.	_	_	_	_	_	_

SPCFV = *Sweet potato chlorotic fleck virus*,
SPMMV = *Sweet potato mild mottle virus*,
SPV2 = *Sweet potato virus*.

Table 4: Incidence of SPCFV, SPMMV, and SPV2 on weed hosts for two seasons in Kebbi and Katsina States.

Virus	Kebbi State		Katsina State	
	Incidence in rainy season (%)	Incidence in dry season (%)	Incidence in rainy season (%)	Incidence in dry season (%)
SPCFV	0.00[b]	25.00[a]	0.00[b]	20.00[b]
SPMMV	12.50[a]	6.25[c]	12.50[a]	12.50[c]
SPV2	0.00[b]	12.50[b]	0.00[b]	37.50[a]
LSD	**1.7302**	**4.6586**	**0.5767**	**5.8248**

SPCFV = *Sweet potato chlorotic fleck virus,*
SPMMV = *Sweet potato mild mottle virus,*
SPV2 = *Sweet potato virus 2,*
LSD = least significant difference.

Table 5: Sweet potato viruses detected from some weed species during both seasons.

Weed species	Viruses species
Ipomoea cordatotriloba Dennst.	SPCFV, SPMMV, and SPV2
Ipomoea involucrata P.	SPCFV, SPMMV, and SPV2
Mitracarpus villosus (Sw.) DC	SPCFV and SPV2
Commelina benghalesis L.	SPCFV
Senna obtusifolia L.	SPV2

SPCFV = *Sweet potato chlorotic fleck virus,*
SPMMV = *Sweet potato mild mottle virus,*
SPV2 = *Sweet potato virus 2.*

Discussion

Many weed species either introduced or native have been found to serve as hosts of plant viruses and play a very significant role in the spread and epidemiology of viruses in crop fields worldwide (Papayiannis *et al*., 2011). High incidences of plant viral diseases are influenced by weed hosts of their causative agents (Asala *et al*., 2014). This study revealed that SPCFV, SPMMV, and SPV2 are naturally infecting weed species in Kebbi and Katsina States, Nigeria. The serological detection of SPCFV, SPMMV, and SPV2

from weed species revealed that majority of weed species tested positive belong to the same family (that is *Convolvulaceae*) with sweet potato. *Ipomoea involucrata* P. and *Ipomoea cordatotriloba* Dennst. were tested positive of all the three viruses (that is SPCFV, SPMMV, and SPV2), *Mitracarpus villosus* (Sw.) DC. was tested positive of SPCFV and SPV2, *Commelina benghalesis* L. was tested positive of only SPCFV, *Senna obtusifolia* L. was tested positive of only SPV2. A relatively weed-free of some sweet potato fields surveyed and some symptomless weed leaf samples tested might be some of the factors responsible for low positive weed samples reported in this research. All the symptomatic weed leaf samples analyzed were tested positive of one or more of the three viruses indexed in this work. While, only very few of the asymptomatic leaf samples were tested positive. Number of positive samples does not correlate with the number of samples showing typical symptoms of viruses infecting sweet potato. Mottling, vein clearing, and purpling were the symptoms observed on some weed species sampled and collected. Kwak *et al.* (2014); Mohammed, (2018); Ndunguru *et al.* (2009); Sivparsad and Gubba (2013) and Wasswa (2012) reported these symptoms to be induced by viruses infecting sweet potato.

Only SPMMV was detected from leaf samples collected during rainy season survey. The detection of only SPMMV during the rainy season might be as a result of small number of whitefly (that is vector of SPMMV) observed infesting sweet potato and some weed species in the course of field survey as compared with aphids (that is vector of SPV2) that were not observed. SPV2 was detected in both states during dry season survey with higher incidence. The higher incidence of SPV2 recorded during the dry season in both states compared to rainy season can probably be attributed to its dependence on transmission by aphid (*Myzus persicae*) which was not observed during the rainy season survey in both states and was observed during dry season survey. The presence of whitefly and aphids as observed in large number infesting sweet potato and some weed species during dry season

survey might also contribute to the large extent the higher incidence of SPMMV and SPV2 in the two states.

This work reported *Senna obtusifolia* L., *Ipomoea involucrata* P., *Mitracarpus villosus* (Sw.) DC, and *Ipomoea cordatotriloba* Dennst. as the weed hosts of SPV2 in Kebbi and Katsina States while, Mohammed (2018) reported *Ipomoea eriocarpa* as the weed host of SPV2 in Kaduna State, Nigeria. This work also reported *Mitracarpus villosus* (Sw.) DC., *Ipomoea involucrata* P., and *Ipomoea cordatotriloba* Dennst. as weed hosts of SPCFV. While, Tugume *et al.* (2016), reported *H. sublobata*, *L. owariensis* and 15 species of the 26 *Ipomoea* species tested as the wild plants of SPCFV in Uganda. This study reported five weed species within four families as weed hosts of SPCFV, SPMMV, and SPV2 in Kebbi and Katsina States.

The prevalence of these weed species as weed hosts of SPCFV, SPMMV, and SPV2 could be attributed to their occurrence in high population and proximity with sweet potato crop; ability to thrive during both the cultivation and crop-free periods; naturally found to be infected with the virus and associated with its vector; farmers' unawareness about viral diseases; poor management of weed species within and around the sweet potato fields. The high frequency of the three viruses tested observed in *Ipomoea involucrata* P. and *Ipomoea cordatotriloba* Dennst. might be because of their frequency in sweet potato fields surveyed, being members of *Convolvulaceae* family, and suggests it to be the most stable and preferred weed hosts for the three viruses and their vectors in the region. Further studies are needed for the detection of virus(es) responsible for the symptoms of viruses infecting sweet potato observed on weeds in farmers' fields which were tested negative of the three viruses tested in this study.

Conclusion and Recommendation

This study established that SPCFV, SPMMV, and SPV2 naturally infect five (5) weed species within four (4) families out of which

two (2) species belong to the same family with sweet potato. The nature of the virus, characteristics, farmer's awareness about the virus as well as its vector, weed hosts, and their management are factors that influence the incidence and spread of the virus in the studied areas. The findings of this study will give a further understanding of the epidemiology of the virus for its effective management. Exploring more weed hosts of these viruses and molecular characterization of the virus in the host weeds for the possible evolution of novel strain(s) in the region is recommended.

Acknowledgements
We sincerely appreciate the technical assistance rendered by Mr. Z. Abdulmalik, Mr. Jonathan O. Sedi and Mrs. H. J. Wakawa of the Plant Virology Laboratory, Crop Protection Department Ahmadu Bello University, Zaria in the course of this research. We also appreciate *Nafiu Abubakar Gwandu of* Department of Crop Science, Kebbi State University of Science and Technology, Aliero, Nigeria *for their support during field surveys.*

Plate I: Weed host that tested positive of SPCFV, SPMMV, and SPV2.
A= Commelina benghalesis.
B = Ipomoea involucrate,
C = Mitracarpus villosus, and
D = Senna obtusifolia

Source: Taken in the course of field survey (2020 and 2021)

References

Abraham, P., Banwo, O. O., Kashina, B. D., & Alegbejo, M. D. (2020). Occurrence, Distribution and Alternative Hosts of Wheat Streak Mosaic Virus Infecting Ginger In Kaduna State, Nigeria. Journal of Agriculture and Rural Development in Tropics and Subtropics (Jarts), 121(1), 127-133. Https://Doi.Org/10.17170/Kobra-2020052811300

Abraham, P., Banwo, O. O., Kashina, B. D. & Alegbejo, M. D. (2021). Identification of Weed Hosts of Tomato Yellow Leaf Curl Virus in Field-Grown Tomato in Sudan Savanna, Nigeria. International Journal of Horticultural Science and Technology 8(3). 235-246. Https://Doi.Org/10.22059/Ijhst.2021.306752.381

Akobundu, I. O., Ekeleme, F., Agyakwa, C. W. & Ogazie, C. A. (2016). A Handbook of West African Weeds (3rd Ed.). International Institute of Tropical Agriculture (Iita), Nigeria. 379 P.+

Austin, D. F. (1988). The Taxonomy, Evolution and Genetic Diversity of Sweet Potatoes and Related Wild Species. In P. Gregory (Ed.), Exploration, Maintenance, And Utilization of Sweet Potato Genetic Resources (Pp. 27-60). Lima, Peru: International Potato Center.

Asala, S., Alegbejo, M. D., Kashina, B. D., Banwo, O. O. & Shinggu, C. P. (2014). Viruses in Weeds in Dioscorea Yam Fields in Nigeria. African Crop Science Journal 22 (2), 109 - 115. Eissn: 2072-6589

Clark, M. F., & Adams, A. N. (1977). Characteristics of The Microplate Method of Enzyme-Linked Immunosorbent Assay for The Detection of Plant Viruses. Journal of General Virology 34: 475-483.

Duffus, J. (1971). Role of Weeds in The Incidence of Virus Diseases. Annual Review of Phytopathology, 9: 319-340.

Gomez, K. A. & Gomez, A. A. (1984). Statistical Procedure for Agricultural Research (2nd Ed.). Wiley, 680 P.

Hidayat, S., Mutaqin, K., Soekarno, B., and Wahyuno, D. (2020). Incidence and Severity of Mottle Disease in Black Pepper Plants (Piper Nigrum) In Sukamulya Research Station, Sukabumi Regency, West Java. Paper Presented at The Iop Conference Series: Earth and Environmental Science.

Hobbs, H. A., Eastburn, D. M., Arcy, C. J. D., Kindhart, J. D., Masiunas, J. B. & Voegtlin, D. J. (2000). Solanaceous Weeds as Possible Sources of Cucumber Mosaic Virus in Southern Illinois For Aphid Transmission to Pepper. Journal of Plant Disease, 84:1221-1224. Https://Doi.Org/10.1094/Pdis.2000.84.11.1221

Kahn, N. D., Walgenbach, J. F. & Kennedy, G. C. (2005). Summer Weeds as Hosts for Frankliniella Occidentalis And Frankliniella Fusca (Thysanoptera: Thripidae) As Reservoirs for Tomato Spotted Wilt Tospovirus In North Carolina. Journal of Economic Entomology, 98:1810-1815. Https://Doi.Org/10.1093/Jee/98.6.1810

Kwak, H.-R., Kim, M.-K., Shin, J.-C., Lee, Y.-J., Seo, J.-K., Lee, H.-U., . . . Choi, H.-S. (2014). The Current Incidence of Viral Disease In Korean Sweet Potatoes And Development Of Multiplex Rt-Pcr Assays For Simultaneous Detection Of Eight Sweet Potato Viruses. The Plant Pathology Journal, 30(4), 416. Doi:10.5423/Ppj.Oa.04.2014.0029

Laurie, S. M., Faber, M., & Claasen, N. (2018). Incorporating Orange-Fleshed Sweet Potato into The Food System as A Strategy for Improved Nutrition: The Context of South Africa. Journal of Food Research International, 104, 77-85. Https://Doi.Org/10.1016/J.Foodres.2017.09.016

Mohammed, R. N. (2018). Occurrence, Distribution and Alternative Hosts of Viruses Infecting Sweet Potato (Ipomoea Batatas L.) In Kaduna State, Nigeria. [Unpublished M.Sc. Dissertation]. Ahmadu Bello University, Zaria, Nigeria.

Ndunguru, J., Kapinga, R., Sseruwagi, P., Sayi, B., Mwanga, R., Tumwegamire, S., and Rugutu, C. (2009). Assessing the Sweet Potato Virus Disease And Its Associated Vectors In

Northwestern Tanzania And Central Uganda. African Journal of Agricultural Research, 4(4), 334-343.

Papayiannis, L.C., Katis, N. I., Idris, A. M. & Brown, J. K. (2011). Identification of Weed Hosts of Tomato Yellow Leaf Curl Virus in Cyprus. Plant Disease. 95(2):120-5. Https://Doi.Org/10.1094/Pdis-05-10-0346

Sastry, K. S. & Zitter, T. A. (2014). Plant Virus and Viroid Diseases in The Tropics: Epidemiology and Management. Vol. 2. Springer. 489pp. Isbn: 978-94-007-7819-1

Sivparsad, B. J., and Gubba, A. (2013). Identification and Distribution of Viruses Infecting Sweet Potato (Ipomoea Batatas L.) In Kwazulu-Natal Province, South Africa. South African Journal of Plant Soil, 30(3), 179-190. Https://Hdl.Handle.Net/10520/Ejc144017

Sseruwagi, P., Sserubombwe, W., Legg, J., Ndunguru, J., & Thresh, J. (2004). Methods of Surveying the Incidence and Severity of Cassava Mosaic Disease and Whitefly Vector Populations on Cassava In Africa: A Review. Journal of Virus Research, 100(1), 129-142. Www.Elsevier.Com/Locate/Viruses

Tavva, S., & Nedunchezhiyan, M. (2012). Global Status of Sweet Potato Cultivation. Fruit, Vegetable and Cereal Science and Biotechnology, 6(Si 1), 143-147.

Tugume, A. K., Mukasa, S. B., & Valkonen, J. P. (2016). Mixed Infections of Four Viruses, The Incidence and Phylogenetic Relationships of Sweet Potato Chlorotic Fleck Virus (Betaflexiviridae) Isolates In Wild Species And Sweetpotatoes In Uganda And Evidence Of Distinct Isolates In East Africa. Plos One, 11(12), 1-27. Doi:10.1371/Journal.Pone.0167769

Wasswa, P. (2012). *Sweet potato viruses in Uganda: identification of a new virus, a mild strain of an old virus and reversion.* (Unpublished Doctoral Dissertation), University of Greenwich,