Research Article

Knowledge and Management Strategies of Farmers to Safeguard Sweet Potato (*Ipomoea batatas* L.) Against Viral Diseases in Benin

Nadia Kèmi Assana Chabi[1], Gildas Codjo Tchemadon[1,2*], Olaïgbé Lydie Hounkpatin[3], Paul Kouété Jimmy[4] and Leonard Antoine Chaffara Afouda[1]

[1]Laboratoire de Phytotechnie, d'Amélioration et de Protection des Plantes (LaPAPP), Université de Parakou (UP), Parakou, Benin; [2]Center for Tropical Agricultural Research and Development (CTARD), Parakou, Benin; [3]Laboratoire de Recherche sur l'Innovation pour le Développement Agricole (LRIDA), Université de Parakou (UP), Parakou, Benin; [4]Department of Agricultural Economics and Rural Sociology, Faculty of Agronomy, University of Parakou, Parakou, Benin.

Abstract | Sweetpotato (*Ipomoea batatas* L.) is a major food crop in the world and is cultivated in many African countries, including Benin. Viral infections contribute significantly in reducing the yield of sweetpotato. Therefore, this study aims to evaluate farmers' knowledge and perception of viral diseases that can affect sweetpotato, as well as the control strategies used to manage them. A semi-structured survey was conducted in March and October 2022 among 156 sweetpotato farmers in 11 townships in agro-ecological zones (AEZ) II, VI and VIII of Benin. Among the respondents, 96.3% do not recognize symptoms of sweetpotato viral diseases, although 81.4% observe these symptoms in their fields with most (76.7%), a low incidence (0 to 25%). Also, 72.3% farmers affirm that the first viral symptoms appear at the flowering stage of sweetpotato plants. They observe the presence of aphids or whiteflies in their fields at 53.3% (AEZ II); 65.0% (AEZ VI) and 75.6% (AEZ VIII). Moreover, 100% (AEZ II); 92.5% (AEZ VI) and 93.0% (AEZ VIII), of farmers do not apply any management strategy for sweetpotato viral diseases. However, 5.0% (AEZ VI) and 7.0% (AEZ VIII) of them use chemical insecticides and 2.5% (AEZ VI), ash to control these diseases. To limit the impacts of these diseases and improve sweetpotato production in Benin, it is necessary to carry out in-depth studies on the distribution and importance of these diseases, set up selection programs focused on resistant varieties to viruses and improve the agricultural practices of farmers.

Received | January 31, 2024; **Accepted** | February 29, 2024; **Published** | March 27, 2024
***Correspondence** | Gildas Codjo Tchemadon, Laboratoire de Phytotechnie, d'Amélioration et de Protection des Plantes (LaPAPP), Université de Parakou (UP), Parakou, Benin ; **Email:** gildast092@yahoo.fr
Citation | Chabi, N.K.A., G.C. Tchemadon, O.L. Hounkpatin, P.K. Jimmy and L.A.C. Afouda. 2024. Knowledge and management strategies of farmers to safeguard sweet potato (*Ipomoea batatas* L.) against viral diseases in Benin. *Hosts and Viruses*, 11: 01-08.
DOI | https://dx.doi.org/10.17582/journal.hv/2024/11.1.8
Keywords: Farmers knowledge, Perception, Virus control, Sweet potato, Benin

Introduction

A herbaceous, creeping plant from the Convolvulaceae family, sweetpotato (*Ipomoea batatas* L.) is a starchy tuber rich in vitamins (A and C), proteins, fiber, and amino acids such as methionine and cysteine (Kim *et al.*, 2018; Neela and Fanta, 2019). It plays various fundamental roles in the global

food system, through meeting food needs, reducing poverty, and increasing food security (El-Sheikha and Ray, 2017). Indeed, in the field of food security, it represents a major source of calories and vitamins such as carotenoids which are essential for the prevention of malnutrition in children (Lebot, 2010; Kismul *et al*., 2014). In terms of annual production, it constitutes in 2022, the eighth largest food production in the world after maize, wheat, rice, potato, soybean, cassava, and barley FAOSAT (2024). According to FAOSAT (2024), global sweetpotato production in 2022 was estimated at 86.4 million tons with China as the world's largest producer (approximately 47 million tons produced in 2022). In Africa, it was around 29.5 million tons and Malawi was the leading producer with 8 million tons. In Benin, it was estimated at 56,590 tons in 2022. But sweetpotato production in these different countries is threatened by various factors including diseases. Indeed, there are at least thirty diseases that negatively impact sweetpotato production around the world (Clark *et al*., 2013; Johnson and Gurr, 2016). Among sweetpotato pathogens, viruses occupy a preponderant place as they cause significant damage. According to Mukasa *et al*. (2003), viral diseases alone can cause sweetpotato yield losses of up to 98%. Farmers can lose up to 100% of the crop yield; losses differ depending on the cultivar, the infecting virus, the stage of infection, and whether the crop is infected with one or more viruses (Valverde *et al*., 2007; Rey *et al*., 2012; Loebenstein, 2015). Propagation material is the principal means of viral spread (Gibson *et al*., 1997; Mbanzibwa *et al*., 2014), though insects such as whiteflies (*Bemisia tabaci*) and aphids (*Aphis gossypii*) can transmit viruses (Clark *et al*., 2012; Byamukama *et al*., 2004). Foliar symptoms of virus infection include leaf distortion, strapping and crinkling, mosaics, vein clearing, brown blotches and general stunting and chlorosis (Mbanzibwa *et al*., 2014). Knowing that improving sweetpotato productivity depends closely, according to Ebregt *et al*. (2004), knowledge of farmers on the pathogens responsible for yield losses and appropriate measures to control these diseases, listing in each sweetpotato producing country, the information available in this sense is essential. However, in Benin, to date, no scientific data is available on the knowledge, perception and control strategies of farmers on sweetpotato viral diseases. The present study therefore aims to investigate the knowledge and perception that farmers have about sweetpotato viral diseases, as well as the methods they adopt in the face of them.

Materials and methods

Study area

The survey was carried out in three (3) main agro-ecological zones (AEZ) of sweetpotato production (AEZ II, VI and VIII) in Benin. According to Gbemavo *et al*. (2014), Chabi *et al*. (2019), and MCVDD (2020), AEZ II brings together the Townships of Banikoara, Gogounou, Kandi, Kerou, Segbana and is characterized by a cultural season, extending from May to September, a tropical ferruginous soil more or less sandy, a rainfall of 900-1000 mm and a temperature varying from 28 to 45°C. Called "bar land zone" because of the characteristics of these soils, AEZ VI is located in the southern part of Benin and includes the Townships of Abomey, Abomey-Calavi, Adjarra, Agbagnizoun, Akpro-Misserete, Allada, Avrankou, Bohicon, Cove, Djakotomey, Dogbo, Houeyogbe, Ifangni, Klouekanme, Kpomasse, Porto-Novo, Sakete, Tori-Bossito, Toviklin, Zagnanado, Za-Kpota and Ze. The climate is subequatorial with two rainy seasons (900 to 1200 mm and 1100 to 1400 mm of water per year, in the West and the East, respectively). The average annual temperature is 26.5°C. The soils in this area are barren land on the continental terminal, deep and easy to work but mostly degraded. AEZ VIII (Fisheries Zone) is geographically the southernmost zone. It occupies the fluvio-lacustrine zone of the Departments of Atlantique, Mono, Oueme and Zou where it covers the Townships of Adjohoun, Aguegues, Athieme, Bonou, Bopa, Come, Cotonou, Dangbo, Grand-Popo, Lokossa, Ouidah, Ouinhi, Seme-Kpodji, and Sô-Ava. This area has a subequatorial climate with two rainy seasons (1000 to 1400 mm of water per year) and thermal differences are low (25 and 30°C). There are alluvial and colluvial soils, sandy soils and lowlands.

Sampling

As part of this study, agro-ecological zones II, VI and VIII being the three main sweetpotato production zones in Benin, they were chosen for the investigation. Thus, in these zones, with the collaboration of agents from the decentralized structures of the Ministry of Agriculture and Livestock, three to five Townships were chosen by AEZ on the basis of their sweetpotato production. Eleven (11) Townships, three (03) in AEZ II (Banikoara, Gogounou and Kandi), three (03) in AEZ VI (Akpro-Misserete, Houeyogbe and Klouekanme) and five (05) in AEZ VIII (Adjohoun, Bonou, Come, Dangbo and Sô-Ava) were therefore

chosen. In each of these Townships, a random sampling of 10 to 25 sweetpotato farmers using the snowball technique was carried out. This sampling technique uses the recommendations of the first respondents to lead to new respondents (Johnston and Sabin, 2010). It was adopted due to the absence of conclusive data on the number of sweetpotato farmers in the townships considered for the study. In total, 156 sweetpotato farmers were therefore surveyed (respectively 30 in AEZ II, 40 in AEZ VI and 86 in AEZ VIII).

Data collection

Data was collected in March and October 2022 using a semi-structured questionnaire and through visual observations in the field. Face-to-face interviews were conducted with farmers and focused on the socio-demographic characteristics of the respondents, the characteristics of their fields, their general knowledge and perception of sweetpotato viruses and the control methods adopted against these viruses. At the start of each interview, information about the purpose of the study, confidentiality of the data, approximate length of the interview, and contact information for the research team was provided to the respondents. The free and informed consent of each of the respondents was therefore obtained. To avoid confusion and make the study more reliable, color images of sweetpotato plants showing symptoms of viruses were shown to the respondents. Sweetpotato fields were also visited if necessary.

Data analysis

The data collected through the questionnaires were coded, entered into the Microsoft Excel 2016 spreadsheet and then a check for possible aberrant data and the consistency of the data was carried out. These data were then subjected to statistical analyzes (descriptive statistics, and Chi2 contingency tests followed by a Student's t-test) using the R 4.1.1 software.

Results and Discussion

Socio-demographic characteristics of sweetpotato farmers

Farmers surveyed in the three main AEZ of sweetpotato production in Benin were 90.1% men compared to 9.9% women. Young people aged 29 to 39 predominated at 54.1% and the majority of farmers surveyed (75.7%) had no level of education and were not literate either. Most of them (72.3%) planted sweetpotato areas of between 1 and 4 ha. For the production of sweetpotato, they take the majority (68.3%) of the seeds from their previous harvests (Table 1).

Table 1: *Socio-demographic characteristics of the surveyed farmers.*

Characteristics	Percentage of respondents						
	AEZ II (n=30)	AEZ VI (n=40)	AEZ VIII (n=86)	Mean	df	χ^2	P value
Sex of farmers							
Male	96.7	87.5	86.0	90.1	2	2.51	0.286
Female	3.3	12.5	14.0	9.9			
Age of farmers (years)							
29-39	43.3	72.5	46.5	54.1	4	9.54	0.049
40-50	53.4	22.5	47.7	41.2			
51-61	3.3	5.0	5.8	4.7			
Education level							
None	80.0	75.0	72.1	75.7	6	7.77	0.256
Adult education	20.0	22.5	15.1	19.2			
Primary	0.0	0.0	1.2	0.4			
Secondary	0.0	2.5	11.6	4.7			
Size of sweetpotato farm (ha)							
< 1	20.0	10.0	7.0	12.3	6	12.42	0.053
[1 - 4]	80.0	62.5	74.4	72.3			
[4 - 7]	0.0	22.5	16.3	13.0			
[7 - 10]	0.0	5.0	2.3	2.4			
Sources of seed supply							
Market	23.3	5.0	9.3	12.5	4	18.95	0.001
Fellow farmer	13.3	35.0	9.3	19.2			
Previous harvest	63.4	60.0	81.4	68.3			

df= degree of freedom; χ^2= Chi square test, P ≤ 0.05 shows there was a significant difference.

Table 2: *Respondents' knowledge and perception of sweetpotato viral diseases and infection conditions.*

Characteristics	Percentage of respondents						
	AEZ II (n=30)	AEZ VI (n=40)	AEZ VIII (n=86)	Mean	df	χ^2	P-value
Recognition of viral diseases symptoms							
Yes	0.0	7.5	3.5	3.7	2	2.67	0.263
No	100.0	92.5	96.5	96.3			
Causal agent of viral symptoms							
Fungi	0.0	0.0	2.3	0.8	16	30.95	0.014
Pests	0.0	2.5	4.7	2.4			
Poor transplanting technique	3.3	0.0	0.0	1.1			
Drought	16.7	0.0	1.2	5.9			
Senescence	3.3	0.0	3.5	2.2			
Soil poverty	0.0	0.0	3.5	1.2			
Sun	0.0	0.0	2.3	0.8			
Virus	0.0	7.5	3.5	3.7			
Don't know	76.7	90.0	79.0	81.9			
Viral diseases symptoms in farmer's field							
Observed	66.7	77.5	100.0	81.4	2	28.46	$6.6.10^{-7}$
Not observed	33.3	22.5	0.0	18.6			
Incidence of viral diseases in farmer's field (%)							
No	33.3	22.5	0.0	18.6	4	28.50	$9.9.10^{-6}$
Low (0-25)	63.3	72.5	94.2	76.7			
Medium (25-50)	3.3	5.0	5.8	4.7			
Growth stage with first symptoms							
Pre-flowering	20.0	10.0	7.0	12.3	6	4.46	0.614
Flowering	80.0	62.5	74.4	72.3			
Tuberization	0.0	22.5	16.3	13.0			
Tuber maturity	0.0	5.0	2.3	2.4			

df= degree of freedom; χ^2 = Chi square test, P ≤ 0.05 shows there was a significant difference.

Farmers' knowledge and perception of sweetpotato viral diseases

Almost all (96.3%) of the farmers surveyed don't recognize the symptoms of sweetpotato viral diseases as due to viruses. Of these, 81.9% say they do not know the cause of these symptoms, 5.9% attribute them to drought; 2.4% to insects; 2.2% to plant senescence; 1.2% to soil poverty; 1.1% to poor seedling transplanting technique; 0.8% to fungi; and 0.8% to sun. However, the majority of respondents (81.4%) observed these symptoms in their fields, with the majority (76.7%) having a low incidence (0 to 25%). They largely (72.3%) affirm that the first symptoms appear at the flowering stage of sweetpotato plants (Table 2).

Observation of aphids and whiteflies by farmers in sweetpotato fields

Sweetpotato farmers surveyed respectively in AEZ II, VI and VIII, say 53.3%; 65.0% and 75.6%, observe the presence of aphids or whiteflies in their fields, unlike 46.7%; 35% and 24.4% who did not notice them (Figure 1).

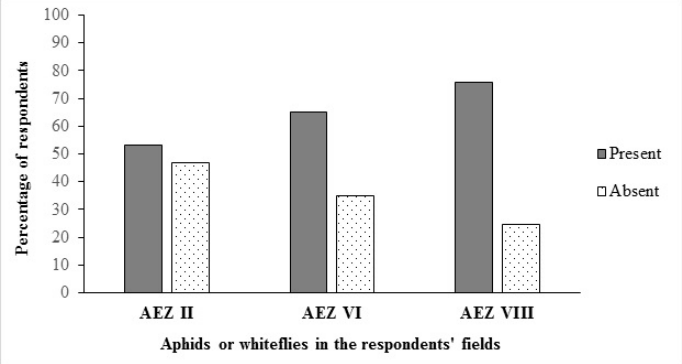

Figure 1: *Observation of aphids and whiteflies by respondents in their fields.*

Viral diseases management by sweetpotato farmers

The farmers surveyed (respectively 100% in AEZ II;

92.5% in AEZ VI; and 93.0% in AEZ VIII) do not apply any method to control sweetpotato viruses. However, 5.0% and 2.5% of respondents in AEZ VI apply chemical insecticides and ash respectively to manage these viruses. In AEZ VIII, chemical insecticides at 7.0% constitute the only products used by the farmers surveyed to control sweetpotato viruses (Figure 2).

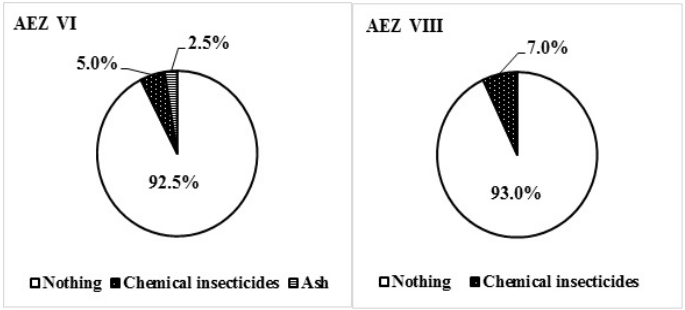

Figure 2: *Management strategies against sweetpotato viral diseases.*

Almost all (96.3%) of the farmers surveyed do not recognize the symptoms of sweetpotato viral diseases as due to viruses. Of these, 81.9% say they do not know the cause of these symptoms, 5.9% attribute them to drought; 2.4% to insects; 2.2% to plant senescence; 1.2% to soil poverty; 1.1% to poor seedling transplanting technique; 0.8% to fungi; and 0.8% to sun. These results corroborate those of various authors who have made the point. Indeed, Temfack *et al.* (2021) have reported in Cameroon that 80.87% of the respondents have never heard of potato viruses and farmers tend to confuse all the symptoms of the different viruses with those caused by other pathogens, especially fungi (late blight) and bacteria (bacterial wilt). Echodu *et al.* (2019), through this work in four East African countries (Kenya, Rwanda, Tanzania and Uganda) highlighted that sweetpotato farmers were unable to associate symptoms such as wilting, curling and yellowing of leaves due to viral, fungal or bacterial diseases. Additionally, Adera *et al.* (2021) revealed that 73% of sweetpotato farmers in the Rangwe region of Eastern Kenya were unable to identify sweetpotato diseases in their fields. Similarly, Adam *et al.* (2015) have noted that 97.9% of farmers surveyed in Tanzania were unable to recognize viruses as responsible for viral symptoms on sweetpotato. As for Schreinemachers *et al.* (2015), they noticed through their work in India, Thailand and Vietnam, that most vegetable crop farmers are unable to associate typical symptoms with viruses. Finally, in Benin, Tchemadon *et al.* (2021) on soybean bacterial leaf pustule, then Toure *et al.* (2023) on Kersting's groundnut diseases noted the lack of knowledge among farmers about plant diseases, their symptoms and the causative agents. This difficulty that farmers experience in recognizing sweetpotato viral diseases as well as their symptoms could be explained by the fact that the viral diseases symptoms such as leaf streaks, distortion, stunted growth, vein release, mosaic and mottling, may resemble in appearance those caused by abiotic stresses, herbicide injury or variation in nutritional levels (van den Bosch *et al.*, 2007; Jones, 2014). In our study, previous harvests (60.0%), fellow farmers (35.0%) and market (5.0%) were the sources of seed supply for sweetpotato farmers. These results confirm those of Bashaasha *et al.* (1995) who reported that sweetpotato farmers in Uganda take their seeds from their previous crop, obtain cuttings from their neighbors by donation, or buy them at the market. Likewise, according to the results of Temfack *et al.* (2021) work in Cameroon, 60.87% of farmers acquired their seeds from individual conservation from previous seasons to be used for the upcoming season; 54.35% from the markets and 16.96% from farmer-to-farmer exchange. The collection of seeds from previous harvests, which was the main source of seed supply, could constitute an important factor favoring the development of sweetpotato viral diseases in Benin. Indeed, according to Adane (2010), vegetative propagation of sweetpotato remains the most important mechanism for the propagation, survival and transmission of sweetpotato viruses from generation to generation. Also, this technique contributes to the accumulation of viruses each season (Karyeija *et al.*, 1998) and increases the risks of spreading viruses over larger areas (Wokorach *et al.*, 2018). The majority of respondents from the three agro-ecological zones concerned by our study observed the symptoms of viral diseases in their fields, thus testifying to the presence of viruses on sweetpotato in Benin. These results are in agreement with those of various authors. Indeed, Mbewe *et al.* (2021) in Malawi, Adera *et al.* (2021) in Kenya, Kwak *et al.* (2014) in South Korea, also reported the presence of several viral diseases on sweetpotato. Sweetpotato farmers surveyed respectively in AEZ II, VI and VIII, say 53.3%; 65.0% and 75.6%, observe the presence of aphids or whiteflies in their fields. This situation could favor the transmission and spread of sweetpotato viral diseases in these different production areas. Indeed, aphids (Byamukama *et al.*, 2004; Loebenstein, 2015) and whiteflies (Gamarra *et al.*, 2010; Trenado *et al.*, 2011) are among the main insect vectors of sweetpotato viral diseases worldwide. The farmers

surveyed (respectively 100% in AEZ II; 92.5% in AEZ VI; and 93.0% in AEZ VIII) do not apply any method to control sweetpotato viruses. However, 5.0% (AEZ VI) and 7.0% (AEZ VIII) of respondents apply chemical insecticides and 2.5% (AEZ VI), ash, to manage sweetpotato viruses. This state of affairs could be explained by the lack of knowledge of the farmers surveyed on the methods of managing sweetpotato viral diseases, which pushes them to adopt unsuitable and dangerous control strategies. Indeed, this situation not only leads farmers to significant economic losses due to the application of inappropriate pesticides (Rehman *et al*., 2013), but also constitutes a major cause of environmental pollution, as these chemicals are very dangerous for their environment (Islam *et al*., 2016, 2017). The present study, which is among the first on sweetpotato viral diseases in Benin, should serve as a basis for future research work. Indeed, to better understand the situational status of sweetpotato viral diseases in Benin and avoid their spread, it is necessary to carry out in-depth studies on the distribution and importance of these diseases in Benin, to set up breeding programs focused on virus-resistant varieties and improving farmers' agricultural practices.

Conclusions and Recommendations

Effective control of plant diseases requires farmers' ability to correctly identify these diseases and their symptoms. This study revealed that sweetpotato farmers in AEZ II, VI and VIII of Benin present a significant lack of information on the identification of sweetpotato viral diseases, the symptoms they induce and especially the appropriate control strategies to manage them. Given this situation, it will be necessary to raise awareness and train sweetpotato farmers on the danger posed by these diseases and the control methods to be implemented to manage them effectively.

Acknowledgements

The authors are grateful to sweetpotato farmers of AEZ II, VI and VIII for their contribution to this study.

Novelty Statement

The present study provided basic information on farmers' knowledge of sweetpotato viral diseases and the management strategies adopted by them. Our results indicating a significant lack of knowledge among farmers about these diseases. Sweetpotato production in Benin could risk a decline if active measures are not taken and implemented.

Author's Contribution

NKAC, GCT and LACA designed the research. NKAC and GCT collected and analyzed the data then wrote and edited the manuscript. All authors read and approved the final manuscript.

Conflict of interest

The authors have declared no conflict of interest.

References

Adam, R.I., Sindi, K. and Badstue, L., 2015. Farmers' knowledge, perceptions and management of diseases affecting sweet potatoes in the Lake Victoria Zone region, Tanzania. Crop Prot., 72: 97-107. https://doi.org/10.1016/j.cropro.2015.02.010

Adane, A., 2010. Associated viruses threatening sweet potato improvement and production in Ethiopia. Afr. Crop Sci. J., 18(4): 207-213. https://doi.org/10.4314/acsj.v18i4.68649

Adera, A.N., Onyango, O.B., Nyunja, R. and Ogolla, O.F., 2021. Sweet potato leaf spot diseases and farmer's indigenous knowledge in parts of western Kenya. Int. J. Res. Stud. Agric. Sci., 7(10): 16-26.

Bashaasha, B., Mwanga, R.O.M, Ocitti p'Obwoya, C. and Ewell, P.T., 1995. Sweet potato in the farming and food systems of Uganda: A farm survey report. International Potato Center (CIP), Nairobi, Kenya and National Agricultural Research Organization (NARO), Kampala, Uganda, pp. 63.

Byamukama, E., Gibson, R.W., Aritua, V. and Adipala, E., 2004. Within-crop spread of sweet potato virus disease and the population dynamics of its whitefly and aphid vectors. Crop Prot., 23(2): 109-116. https://doi.org/10.1016/j.cropro.2003.07.003

Chabi, F.O., Dagbenonbakin, G.D., Agbangba, C.E., Oussou, B., Amadji, G.L., Ahoton, E.L. and Saïdou, A., 2019. Soil fertility level and cropping practices determining soybean yield in northern east and center of Benin. Int. J. Plant Soil Sci., 30(6): 1-10. https://doi.org/10.9734/

ijpss/2019/v30i630191

Clark, C.A., Ferrin, D.M., Smith, T.P. and Holmes, G.J., 2013. Compendium of sweet potato diseases, pests and disorders. Second edition. St. Paul, Minnesota: APS Press. pp. 37-40. https://doi.org/10.1094/9780890544952

Clark, C.A., Jeffrey, A.D., Jorge, A.A., Wilmer, J.C., Segundo, F., Jan, F.K., Richard, W.G., Settumba, B.M., Arthur, K.T., Fred, D.T. and Jari, P.T.V. 2012. Sweet potato viruses: 15 years of progress on understanding and managing complex diseases. Plant Dis., 96(2): 168-185. https://doi.org/10.1094/PDIS-07-11-0550

Ebregt, E., Struik, P.C., Abidin, E.P. and Odongo, B., 2004. Farmers' information on sweet potato production and millipede infestation in north-eastern Uganda. I. Associations between spatial and temporal crop diversity and the level of pest infestation. NJAS-Wageningen J. Life Sci., 52(1): 47-68. https://doi.org/10.1016/S1573-5214(04)80029-0

Echodu, R., Edema, H., Wokorach, G., Zawedde, C., Otim, G., Luambano, N., Ateka, E.M. and Asiimwe, T., 2019. Farmers' practices and their knowledge of biotic constraints to sweet potato production in East Africa. Physiol. Mol. Plant Pathol., 105: 3-16. https://doi.org/10.1016/j.pmpp.2018.07.004

El-Sheikha, A.F. and Ray, R.C., 2017. Potential impacts of bioprocessing of sweet potato: Review. Crit. Rev. Food Sci. Nutr., 57(3): 455-471. https://doi.org/10.1080/10408398.2014.960909

FAOSTAT, 2024. Available on: https://www.fao.org/faostat/en/#data/QCL (Accessed 13 January 2024).

Gamarra, H.A., Fuentes, S., Morales, F.J., Glover, R., Malumphy, C. and Barker, I., 2010. *Bemisia afer* sensu lato, a vector of sweet potato chlorotic stunt virus. Plant Dis., 94(5): 510-514. https://doi.org/10.1094/PDIS-94-5-0510

Gbemavo, D.S.J.C., Gnanglé, P.C., Azontondé, A. and Kakaï, R.G., 2014. Modélisation du stock de biomasse et dynamique de séquestration minérale et du carbone de *Jatropha curcas* L. sous différents types de sol au Bénin. Ann. Sci. Agron., 18(1): 1-21.

Gibson, R.W., Mwanga, R.O.M., Kasule, S., Mpembe, I. and Carey, E.E., 1997. Apparent absence of viruses in most symptomless field-grown sweet potato in Uganda. Ann. Appl. Biol., 130(3): 481-490. https://doi.org/10.1111/j.1744-7348.1997.tb07676.x

Islam, W., Awais, M., Noman, A. and Wu, Z., 2016. Success of bio products against bacterial leaf blight disease of rice caused by *Xanthomonas oryzea* pv. *oryzae*. PSM Microbiol., 1(2): 50-55.

Islam, W., Nazir, I., Noman, A., Zaynab, M. and Wu, Z., 2017. Inhibitory effect of different plant extracts on *Trogoderma granarium* (Everts) (Coleoptera: Dermestidae). Int. J. Agric. Environ. Res., 3(1): 121-130.

Johnson, A.C. and Gurr, G.M., 2016. Invertebrate pests and diseases of sweet potato (*Ipomoea batatas*): A review and identification of research priorities for smallholder production. Ann. Appl. Biol., 168(3): 291-320. https://doi.org/10.1111/aab.12265

Johnston, L.G. and Sabin, K., 2010. Echantillonnage déterminé selon les répondants pour les populations difficiles à joindre. Methodol. Innov. Online, 5(2): 38-48. https://doi.org/10.4256/mio.2010.0017a

Jones, R.A.C., 2014. Plant virus ecology and epidemiology: Historical perspectives, recent progress and future prospects. Ann. Appl. Biol., 164(3): 320-347. https://doi.org/10.1111/aab.12123

Karyeija, R., Gibson, R. and Valkonen, J., 1998. The significance of sweet potato feathery mottle virus in subsistence sweet potato production in Africa. Plant Dis., 82(1): 4-15. https://doi.org/10.1094/PDIS.1998.82.1.4

Kim, H., Lee, C., Kim, S., Ji, C., Kim, S., Kim, J., Kim, S. and Kwak, S., 2018. Current status on global sweet potato cultivation and its prior tasks of mass production. J. Plant Biotechnol., 45(3): 190-195. https://doi.org/10.5010/JPB.2018.45.3.190

Kismul, H., Van den Broeck, J. and Lunde, T.M., 2014. Diet and kwashiorkor: A prospective study from rural DR Congo. PeerJ, 2: e350. https://doi.org/10.7717/peerj.350

Kwak, H.R., Kim, M.K., Shin, J.C., Lee, Y.J., Seo, J.K., Lee, H.U., Jung, M.N., Kim, S.H. and 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. Plant Pathol. J., 30(4): 416-424. https://doi.org/10.5423/PPJ.OA.04.2014.0029

Lebot, V., 2010. Sweet potato. In: Bradshaw JE,

ed. Root and tuber crops. New York: Springer Science Business Media. pp. 97-125. https://doi.org/10.1007/978-0-387-92765-7_3

Loebenstein, G., 2015. Control of sweet potato virus diseases. Adv. Virus Res., 91: 33-45. https://doi.org/10.1016/bs.aivir.2014.10.005

Mbanzibwa, D.R., Tugume, A.K., Chiunga, E., Mark, D. and Tairo, F.D., 2014. Small RNA deep sequencing-based detection and further evidence of DNA viruses infecting sweet potato plants in Tanzania. Ann. Appl. Biol., 165(3): 329-339. https://doi.org/10.1111/aab.12136

Mbewe, W., Mtonga, A., Chiipanthenga, M., Masamba, K., Chitedze, G., Pamkomera, P., Gondwe, E., Mwenye, O. and Chipungu, F. 2021. Incidence and distribution of sweetpotato viruses and their implication on sweet potato seed system in Malawi. J. Plant Pathol., 103(3): 961-968. https://doi.org/10.1007/s42161-021-00830-4

Ministère du Cadre de Vie et du Développement Durable (MCVDD), 2020. Zones agro-écologiques de la République du Benin. https://www.changementsclimatiques.bj/actualites/zones-agro-ecologiques-de-la-republique-du-benin.html. (Accessed January 28, 2022).

Mukasa, S.B., Rubaihayo, R.P. and Valkonen, T.P.J., 2003. Incidence of viruses and virus like diseases of sweet potato in Uganda. Plant Dis., 87(4): 329-335. https://doi.org/10.1094/PDIS.2003.87.4.329

Neela, S. and Fanta, S.W., 2019. Review on nutritional composition of orange-fleshed sweet potato and its role in management of vitamin A deficiency. Food Sci. Nutr., 7(6): 1920-1945. https://doi.org/10.1002/fsn3.1063

Rehman, A., Mehboob, S., Islam, W. and Khan, N.A., 2013. Reaction of gram (*Cicer arietinum* L.) varieties against gram blight disease (*Didymella rabiei* (Kovatsch.) Arx) and its management through foliar fungicides in rain fed areas of Pakistan. Pak. J. Phytopathol., 25(1): 7-14.

Rey, M.E.C., Ndunguru, J., Berrie, L.C., Paximadis, M., Berry, S., Cossa, N., Nuaila, V.N., Mabasa, K.G., Abraham, N.E., Rybicki, P., Martin, D., Pietersen, G. and Esterhuizen, L.L., 2012. Diversity of dicotyledenous-infecting geminiviruses and their associated DNA molecules in Southern Africa, including the South-West Indian Ocean Islands. Viruses 4(9): 1753-1791. https://doi.org/10.3390/v4091753

Schreinemachers, P., Balasubramaniam, S., Boopathi, N.M., Viet Ha, C., Kenyon, L., Praneetvatakul, S., Sirijinda, A., Tuan Le, N., Srinivasan, R. and Wu, M.H., 2015. Farmers' perceptions and management of plant viruses in vegetables and legumes in tropical and subtropical Asia. Crop Prot., 75: 115-123. https://doi.org/10.1016/j.cropro.2015.05.012

Tchemadon, C.G., Zinsou, A.V., Sikirou, R. and Zime Soko N'douro, M., 2021. Farmers' knowledge, perception and practices in soybean bacterial leaf pustule management in Benin. J. Appl. Biosci., 158: 16289-16298. https://doi.org/10.35759/JABs.158.3

Temfack, D.D.C., Achiangia, P.N., Chofong, G.N., Djomo, S.H., Lontsi-Demano, M. and Fonkou, T., 2021. Farmers' knowledge of potato viruses and management strategies in the western highlands of Cameroon. Open J. Appl. Sci., 11(7): 818-831.

Toure, O.Y., Sanni Worogo, J.S.B., Tchemadon, C.G., Nebie, B., Afouda, L.A.C. and Achigan Dako, E.G., 2023. Farmers' knowledge and perceptions of Kersting's groundnut [*Macrotyloma geocarpum* (Harms) Marechal and Baudet] diseases and pests in Benin. Plant Dis., 107(6): 1861-1866. https://doi.org/10.1094/PDIS-09-22-2190-RE

Trenado, H.P., Orilio, A.F., Marquez-Martin, B., Moriones, E. and Navas-Castillo, J., 2011. Sweep viruses cause disease in sweet potato and related. *Ipomoea* spp.: fulfilling Koch's postulates for a divergent group in the genus *Begomovirus*. PLoS One, 6: e27329. https://doi.org/10.1371/journal.pone.0027329

Valverde, R.A., Clark, C.A. and Valkonen, J.P., 2007. Viruses and virus disease complexes of sweetpotato. Plant Viruses, 1(1): 116-126.

Van den Bosch, F., Jeger, M.J. and Gilligan, C.A., 2007. Disease control and its selection for damaging plant virus strains in vegetatively propagated staple food crops, a theoretical assessment. Proc. Biol. Sci., 274(1606): 11-18. https://doi.org/10.1098/rspb.2006.3715

Wokorach, G., Edema, H. and Echodu, R., 2018. Sweet potato seed exchange systems and knowledge on sweet potato viral diseases among local farmers in Acholi Sub Region-Northern Uganda. Afr. J. Agric. Res., 13(45): 2551-2562. https://doi.org/10.5897/AJAR2018.13384