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Occurrence, distribution and alternative hosts of *Wheat streak mosaic virus* infecting ginger in Kaduna State, Nigeria

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Abstract

A field survey was conducted during the 2018 rainy season (June – October) in three major ginger producing Local Government Areas (LGAs) of Kaduna State, Nigeria to determine the occurrence and spread of *Wheat streak mosaic virus* (WSMV) infecting ginger. Symptomatic and asymptomatic ginger leaf samples (n=180) and weed samples (n=45) were collected from the surveyed fields and indexed against WSMV using Double Antibody Sandwich Enzyme-linked Immunosorbent Assay (DAS-ELISA). The results obtained showed that WSMV occurred in all the LGAs surveyed but with significant ($P = 0.05$) variation in distribution. Jaba had the highest virus incidence (22.67 %) followed by Kagarko (17.67 %) while Kachia had the lowest virus incidence of 10.00 %. To the best of our knowledge, this is the first report of WSMV infecting ginger in Nigeria. *Rottboellia cochinchinensis* (Lour.) Clayton and *Setaria barbata* (Lam.) Kunth tested positive against WSMV as alternative weed hosts of the virus. The incidence of WSMV even at lower percentage is significant as population build-up could lead to a disease outbreak. Awareness programs need to be organised for farmers on yield loss potential of WSMV on ginger crop and the role of cultural practices on the incidence and management of the virus.

Keywords: Alternative weed host, DAS-ELISA, survey, WSMV

1 Introduction

Ginger (*Zingiber officinale* Rosc.) is a monocotyledonous perennial crop but commonly cultivated as an annual cash crop for harvesting as a spice and medicinal uses (Fikre & Kifle, 2013). Nigeria is the third world largest producer of ginger next only to India and China supplying over 0.3 million tons and 13 % of total world production (FAOSTAT, 2018). The production of ginger in Nigeria started vigorously in 1927, after discovering it could generate internal trade for the people of the southern part of Kaduna, the traditional home of ginger production in Nigeria (Erinle, 1988; Nair, 2013). Although ginger cultivation has now spread all over the geographical zones of Nigeria (Duniya, 2003; Bernard, 2008), Kaduna State remains the country's leading producer of the crop by predominantly poor resource peasant farmers as their sole means of livelihood mainly from Jaba, Jama'a, Kachia and Kagarko local Government Areas (Nmadu & Marcus, 2013; USAID-NEXTT, 2017). The region has a tropical continental climate with marked classifiable cool to hot dry and humid to wet seasonal regimes with rainfall commencing from April to October at an average of 2000 mm/annum and mean temperature range of 23 °C to 28 °C (Ibrahim, 2018). A slightly acidic (5.5 – 6.5 pH) well-drained sandy loam that is rich in humous characterise the main soils in the area (Asumugha *et al.*, 2006).

Ginger production activities span through the 12 calendar months of the year, where cultivation starts at the onset of rains in April with manual tillage and levelling to form flatbeds (Ibrahim, 2018). Farmers source their seeds for next season cultivation from on-farm stored ginger rhizomes, as a gift by relatives and friends or purchase these from neighbouring communities (Ibrahim, 2018). *Taffin Giwa* (elephant's foot) and *Yatsun Biri* (monkey's finger) are the two common commercial varieties cultivated in Nigeria (Zakka *et al.*, 2010) which have gained the international standard quality of being good and suitable for both production of ginger oleoresins and essential oil due to their higher con-

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tent of monoterpenes, sesquiterpenic gingerols and shogaols compounds (Dambatta *et al.*, 1998; USAID-NEXTT, 2017). Rhizome seeds are planted in April/May at a spacing of 20 x 20 cm and mulched with dry grasses (Sati & Bala, 2017). Ginger is often intercropped with maize or also sole cropped and weeds are manually managed. Harvesting of matured ginger rhizome with hand hoe commences from October and extends to April of the following year to control market glut and as an adopted seed storage strategy for next season planting (Sati & Bala, 2017; Ibrahim, 2018).

Nigeria is ranked 2^{nd} in the world based on land area for ginger production (111,196 ha), but is the 23^{rd} in terms of yield (4,703 kg ha^{-1}) and therewith positioned among the world's lowest (FAOSTAT, 2018). So, Nigeria has a large ginger production area, but the full potential of the crop is significantly underexploited and several factors could be responsible for this. Several works have reported the menace of insect pests and diseases as a factor limiting ginger production (ISPS, 2005; Reddy, 2010; Zakka *et al.*, 2010; Abate, 2013). Nmadu & Marcus (2013), as well as Abraham *et al.* (2019), also reported the incidence of insect pests and diseases being an important constraint to the profitable production of ginger in Kaduna State, Nigeria. Virus diseases account for more losses in farmer's fields than other pathogenic diseases (Nono-Womdim, 2003). Plant viruses such as *ginger mosaic virus* (GMV), *Wheat streak mosaic virus* (WSMV), *ginger chlorotic fleck virus* (GCFV), and *chirke virus* have been reported as pathogens of cultivated ginger in tropical and sub-tropical regions (Ganguly & Raychaudhuri, 1971; Roy *et al.*, 2003; Dohroo, 2004; Nair, 2013; Meenu & Kaushal, 2017). *Wheat streak mosaic virus* (WSMV: type species, family *Potyviridae*, genus *Tritimovirus*) is considered as one of the world's most economically important plant viruses attacking monocotyledonous crops, with a report of losses ranging from minimal to complete crop failure in wheat (Rabenstein *et al.*, 2002, French & Stenger, 2003; Byamukama *et al.*, 2014) and a marginal loss of up to \$ 464.5 ha^{-1} have been reported (Velandia *et al.*, 2010). WSMV is reported to be transmitted by species complex of a microscopic obligatory phytophagous vector, *Aceria tosichella* Keifer (wheat curl mite) (Navia *et al.*, 2013). Both nymph and adult wheat curl mites transmit the WSMV while feeding and have retention potential of the virus from 6 days to 2 months depending on the time of acquisition and temperature as reviewed by Hadi *et al.* (2011). Wheat curl mites are wingless so they are dispersed principally by the wind. As a mechanism, they always move to the tip of the host crop or weeds within and around the farm waiting to be blown by the wind to the next crop where they continue feeding and transmission of the virus (Jeppson *et al.*, 1975). Symptoms of infection due to WSMV usually starts on young leaves as light green streaks which elongate to form discontinuous yellow to pale green stripes, forming a mosaic pattern running parallel to the leaf veins as symptoms progress (Singh *et al.*, 2018).

Weed species have been reported to serve as alternative hosts of both plant viruses and their vectors in the field (Alegbejo & Banwo, 2005; Asala *et al.*, 2014; Price *et al.*, 2014) thereby, making the management of viruses and their vectors difficult. Previous studies have documented several wild grass species found to be alternative hosts of both WSMV and its vector in nature (Sill & Connin, 1953; Sill & Agusiobo, 1955; Brakke 1971; Christian & Willis, 1993). Effective management of plant viruses relied heavily on accurate detection and diagnosis of viruses and their alternative host species through serological and molecular tests (Sastry & Zitter, 2014). Given the devastating yield loss potentials of WSMV over other viruses infecting ginger and as little or no information exist on whether this virus is present and to what extent in ginger fields in Nigeria, this study, therefore reports the occurrence, distribution and alternative hosts of *Wheat streak mosaic virus* in Kaduna State, Nigeria.

2 Materials and methods

2.1 Field survey and sampling

Field survey and sampling was conducted in Kaduna State (northwestern Nigeria) at the vegetative growth stage (8–16 weeks) of ginger (Hunger *et al.*, 1992), during the 2018 wet season. Three local government areas (Jaba, Kachia and Kagarko) were selected based on ginger crop production history (KSMA, 2007). Three different farmers' fields were randomly selected for sample collection in each LGA. A 3×3 m sized-quadrat was set at four corners and one at the centre of each field (Kashina *et al.*, 2002) for collection of ginger leaf samples since infection due to WSMV usually starts from the field margins and then progresses inward as the mites migrate from wild grass alternative hosts and bordering crops (Hunger, 2010). Three symptomatic and one asymptomatic ginger leaves were randomly sampled per quadrat giving a total of twenty samples from each field. Five grass weed species were also collected within and around each ginger field and identified using Akobundu *et al.* (2016). Information on the coordinates, farm size, surrounding crops and some cultural practices of each field were also recorded (Table 1). Leaf samples were collected, labeled, wrapped in polythene bags, stored in an ice chest and transported to the Virology Laboratory of the Department of Crop Protection, Ahmadu Bello University Zaria for analyses. The samples were stored at –4 °C before diagnosis.

2.2 Serological assay

Serological tests were conducted for the detection of WSMV in the collected ginger leaf samples using the double antibody sandwich enzyme-linked immunosorbent serological assay (DAS-ELISA) (Seifers *et al.*, 2006) as specified by the supplier (Leibniz-Institut DSMZ – Deutsche Sammlung von Mikroorganismen und Zellkulturen Gmbh, Braunschweig, Germany) of the detection kits. The antigen-antibody reactions were detected and optical density (OD) of each well was measured after 1 h using an ELISA plate reader Uniequip (Martinseed, Germany) at a wavelength of 405 nm (Clark & Adams, 1977). ELISA values at least twice that of the negative control (check) were rated positive (Kumar, 2009). Virus incidence (VI in %) was calculated using the formula of Chaube & Pundhir (2005):

$$\text{VI} = \frac{\text{Number of positive samples/farm}}{\text{Total number of samples examined/farm}} \times 100$$

2.3 Data analysis

Data obtained on WSMV incidence were subjected to analysis of variance. Variation of means were considered significant at 5 % level of probability using either least significant difference (LSD) or by plotting standard error of means as described by Gomez & Gomez (1984).

Fig. 1: *Disease symptoms expression on ginger plants infected by WSMV: (A) healthy ginger leaf sample; (B) A typical WSMV disease symptom on young ginger leaves showing pale to yellow parallel interveinal streak and giving a mosaic pattern.*

3 Results

The ELISA results obtained showed that *Wheat streak mosaic virus* occurred in all the local government areas surveyed but with significant ($p = 0.05$) variation in distribution. In Jaba LGA, WSMV incidence was significantly higher ($p = 0.05$) in Chori followed by Nok while Kwoi had the lowest incidence (Fig. 2). Kurmin Musa had the highest virus incidence followed by Gumel while the least

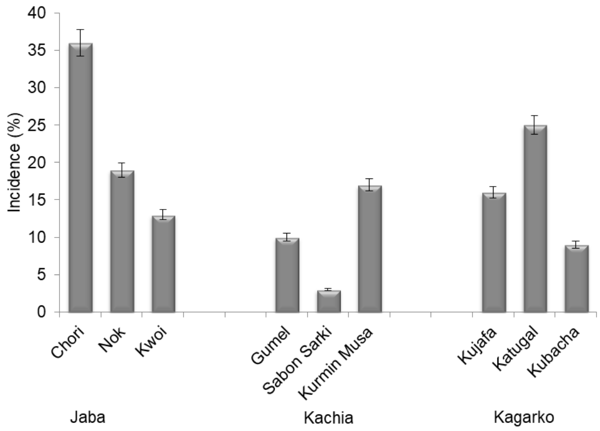

Fig. 2: *Incidence of Wheat streak mosaic virus in Jaba, Kachia and Kagarko Local Government Areas of Kaduna State during the 2018 rainy season. Bars indicate standard error of means at 5 % probability level.*

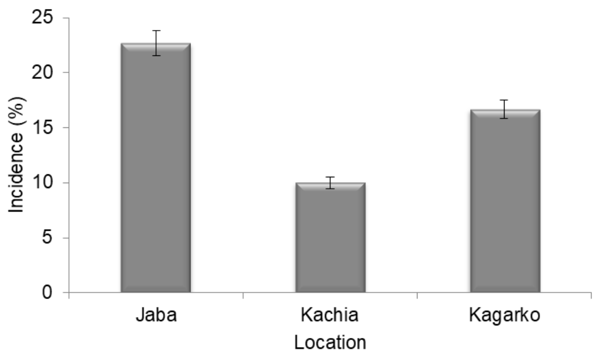

Fig. 3: *Mean incidence of Wheat streak mosaic virus in Jaba, Kachia and Kagarko Local Government Areas of Kaduna State during the 2018 rainy season. Bars indicate standard error of means at 5 % probability level.*

incidence was recorded at Sabon Sarki in Kachia LGA (Fig. 2). In Kagarko LGA, the highest virus incidence was recorded at Katugal followed by Kubacha while Kujafa had the lowest virus incidence. Among the three surveyed Local Government Areas for WSMV, the virus was significantly ($p = 0.05$) more prevalent in Jaba followed by Kagarko while Kachia had the least virus incidence (Fig. 3). The results obtained on the occurrence of the alternative host of WSMV showed that out of 45 weed samples indexed for the virus incidence from the three local government areas, two weeds; *Rottboellia cochinchinensis* (Lour.) Clayton (Corn grass) and *Setaria barbata* (Lam.) Kunth (Bristly foxtail grass) tested positive from Gumel and Sabon Sarki respectively in Kachia LGA.

Table 1: *Symptoms of Wheat streak mosaic virus on ginger and cropping information of the locations surveyed in Kaduna state during the 2018 wet season.*

LGA	*Location*	*Coordinates*	*Farm size (ha)*	*Variety*	*Source of seed**	*Symptoms†*	*Sanitary condition*	*Surrounding crops*	*Crop growth stage‡*	*Cropping pattern§*
Jaba	Chori	09.57081 N 08.02277 E	2.29	*Taffin giwa*	PS	IC, CF, M, S	Weedy	Maize, rice, sorghum	Veg.	MCM
	Nok	09.48290 N 08.01929 E	1.12	*Taffin giwa*	PS	IC, S, M	Weedy	Maize, sorghum	Veg.	MCM
	Kwoi	09.45068 N 08.01440 E	1.07	*Taffin giwa*	PS	IC, CF, M, S	Weeded	Maize, rice, turmeric	Veg.	MCM
Kachia	Gumel	09.85167 N 07.96377 E	1.34	*Yasun biri*	PS	IC, CF, M	Weedy	Rice, maize, groundnut	Veg.	SC
	Sabon Sarki	09.64680 N 08.01272 E	1.23	*Yasun biri*	LF	IC, CF, S	Weedy	Maize	Veg.	SC
	Kurmin Musa	09.59620 N 08.02168 E	3.51	*Taffin giwa*	PS	IC, CF, M, S	Weedy	Rice, sorghum	Veg.	MCM
Kagarko	Kujafa	09.47205 N 07.90730 E	1.15	*Yasun biri*	LF	IC, CF, M	Weeded	Turmeric, maize	Veg.	SC
	Katugal	09.46443 N 07.88249 E	1.73	*Taffin giwa*	PS	IC, CF, M, S	Weedy	Maize, rice	Veg.	MCM
	Kubacha	09.44092 N 07.82235 E	1.12	*Yasun biri*	LF	CF, S, M	Weeded	Turmeric, maize	Veg.	SC

* PS = Previous season; LF = Purchased from local farmers. † IC= Interveinal chlorosis; CF= Chlorotic flecks; M= Mosaic; S= Streak.
‡ Veg. = Vegetative. § MCM = Mixed cropping with maize; SC = Sole cropping.

4 Discussion

The incidence, distribution and alternative host of *Wheat streak mosaic virus* in ginger in Kaduna State were investigated in this study. Interveinal chlorosis, chlorotic flecks, mosaic pattern, streak appearance were symptoms observed on ginger leaf samples from which the virus tested positive (Fig. 1) and have been reported to be incited by the virus (Hadi *et al.*, 2011). Other virus-like symptoms such as chlorosis, interveinal chlorosis, vein clearing, leaf spot, and flecks observed on some ginger samples which tested negative against WSMV might be due to other viruses and phytoplasmas or due to other abiotic factors such as nutrient deficiency (Hull, 2014). The results showed that WSMV occurred in all the three Local Government Areas (Jabba, Kachia and Kagarko) of Kaduna State. This agrees with works of Ganguly & Raychaudhuri (1971) and Tripathti (2007) who also reported the occurrence of WSMV in ginger causing a significant disease incidence. A common practice of preservation, exchange and purchase of ginger rhizomes as propagules for next season cultivation among farmers might to a greater extend be a factor for the widespread of the WSMV (Singh *et al.*, 2018) throughout the surveyed areas since the virus is preserved in ginger rhizomes (Tripathti, 2007; Abraham *et al.*, 2019). ISPS (2005) observed that most ginger pathogens are been distributed through the ginger rhizome used as propagules. Studies have also reported transmission of WSMV through wheat and maize seed leading to a successful introduction of the virus in many countries (CABI, 2018). Farmers in study area usually reserve unharvested portions of matured ginger crops in the fields to control market glut and as a source of seed for next season planting (Ibrahim, 2018). This practice supports successful overwintering of both WSMV and its vector until subsequent planting hence, ensuring the disease persistence in the area. *Tafin giwa*, being a predominant ginger variety cultivated in Jaba LGA might be a factor for the higher virus disease incidence (23 %) recorded in this specific location as against the significantly lower virus disease incidence (10 %) recorded in Kachia LGA where *Yasun biri* was the major cultivated variety. Disease incidence due to WSMV as high as 76.11 % has also been reported in Pune ginger variety (Tripathti, 2007). The common practice of intercropping ginger with maize which is a host of WSMV and its vector (*Aceria tosichella* Keifer), might have also influenced the higher incidence of the virus in Jaba and Kagarko compared to sole cropping practice of ginger in Kachia which had a significantly lower incidence of the virus (Table 1).

Rottboellia cochinchinensis (Lour.) Clayton (Corn grass) and *Setaria barbata* (Lam.) Kunth (Bristly foxtail grass) were found to be alternative hosts of WSMV. Wheat curl mites which are the vectors of WSMV have been reported to thrive on various wild grasses as alternative hosts (Hadi *et al.*, 2011; Chalupníková *et al.*, 2017). Christian & Willis (1993) have earlier reported two species of grasses (*Setaria viridis* and *S. faberi*) as alternative hosts of WSMV. This is the first report of Corn grass and Bristly foxtail grass as wild hosts of WSMV in their natural environment and therefore provides an update to the previous report of CABI (2018) on the checklist of alternative weed hosts of WSMV. Corn grass and Bristly foxtail grass were among the dominant weed species within and around all the ginger farms surveyed. Farmers' unawareness about this virus and its management could potentially be a challenge to the profitable production of ginger in these locations if not checked.

5 Conclusion

This study reported the occurrence and widespread distribution of *Wheat streak mosaic virus* in ginger crops surveyed from three major ginger producing Local Government Areas of Kaduna State. To the best of our knowledge, this is the first report of WSMV on ginger in Nigeria. Unrestricted movement of ginger propagules and on-farm seed storage are major factors for the spread and prevalence of WSMV throughout the localities surveyed. The incidence of WSMV even at lower percentage is significant as population build-up could lead to a disease outbreak. Awareness programmes need to be organised for farmers on yield loss potential of *Wheat streak mosaic virus* on ginger crop and the interplay of cropping system, variety and alternative weed hosts on the incidence and management of the virus.

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Conflict of interest

The authors declare that they have no conflict of interest.

References

Abate, S. (2013). Protection of ginger. In: Fikre, T. & Kifle, A. (eds). Ginger (*Zingiber oficinale* Rosec.) production, postharvest handling, processing and marketing: a comprehensive extension package manual. Hawassa, Ethiopia, 139 p.

Abraham, P., Banwo, O. O., Kashina, B. D. & Alegbejo M. D. (2019). Occurrence, distribution and alternative hosts of *Wheat streak mosaic virus*, infecting ginger in Kaduna State, Nigeria. Paper presented at the 44th annual conference of the NSPP, held at the Federal University Oye-Ekiti, Ikole Campus, Nigeria, 7th–12th April 2019.

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.

Alegbejo, M. D. & Banwo, O. O. (2005). Hosts of *Bemisia tabaci* Genn. *Northern Nigeria Journal of Plant Protection Research*, 45 (2), 93–98.

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 J.*, 22 (2), 109–115.

Asumugha, G. N., Anyaegbunam, H. N., Ezulike T. O. & Nwosu, K. I. (2006). Guide to Ginger production and marketing in Nigeria, Extension Guide No. 7, Extension services programme, National Root Crops Research Institute, Umudike, Nigeria.

Bernard, A. (2008). Diseases, pest and other factors limiting ginger (*Zingiber officinale* Rosec) production in River State. Agricultural Product Development Strategy Workshop. Uptonville Foundation under the aegis of Rivers State Sustainable Development Agency (RSSDA). Retrieved fromhttp://uptonvilleoginstu.org/ginger.litm.

Brakke, M. K. (1971). *Wheat streak mosaic virus*. CMI/AAB Descriptions of Plant Viruses 48.

Byamukama, E., Wegulo, S. N., Tatineni, S., Hein, G.L., Graybosch, R. A., Baenziger, P. S. & French, R. (2014). Quantification of yield loss caused by *Triticum mosaic virus* and *Wheat streak mosaic virus* in winter wheat under field conditions. *Plant Disease*, 98, 127–133.

CABI (2018). Invasive species compendium: Datasheet on *Wheat streak mosaic virus*. CAB International, Wallingford, UK. https://www.cabi.org/isc/datasheet/56858.

Chalupníková, J., Kundu, J. K., Singh, K., Bartaková, P. & Beoni, E. (2017). *Wheat streak mosaic virus*: incidence in field crops, potential reservoir within grass species and uptake in winter wheat cultivars. *Journal of Integrative Agriculture*, 16, 60345-60357.

Chaube, H. S. & Pundhir, V. S. (2005). Crop Diseases and their Management. Prentice-Hall India Private Ltd. 724 p.

Christian, M. L. & Willis, W. G. (1993). Survival of *Wheat streak mosaic virus* in grass hosts in Kansas from wheat harvest to fall wheat emergence. *Plant Disease*, 77, 239–242.

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.

Dambatta, B. B., Kazaure, M. A. & Tapley, K. N. (1998). Extraction and characterization of essential oils from Nigerian ginger. *Advances in Colour Science and Technology*, 1 (3), 80–82.

Dohroo, N. P. (2004). Diseases of ginger. In: Ravindran, P.N. & K. N. Babu (editors) Ginger: The Genus *Zingiber*, Medicinal and Aromatic Plants – Industrial Profiles, CRC Press, Washington, D.C., 573 p.

Duniya, I. B. (2003). *An assessment of the marketing perspectives, in the development and implementation, of Kaduna State-owned agro-allied projects: A case study of Kachia food company limited.* MSc Thesis, Department of Business Administration, Ahmadu Bello University Zaria, Nigeria. 98 p.

Erinle, I. D. (1988). Horticultural Crops Research Programme, IAR, ABU Zaria. Proceedings of the first National Ginger workshop at Umudike, Nigeria p. 8-15.

FAOSTAT (2018). Food and Agriculture Organization of the United Nations (FAO) Rome, Italy. https://www.atlasbig.com/en-us/countries-ginger-production. Last accessed April 20, 2020.

Fikre, T. & Kifle, A. (2013). Ginger (*Zingiber oficinale* Rosec.) production, postharvest handling, processing and marketing: a comprehensive extension package manual. Hawassa, Ethiopia, 139 p.

French, R. & Stenger, D. C. (2003). Evolution of Wheat streak mosaic virus: dynamics of population growth within plants may explain limited variation. *Annual Review Phytopathology*, 41, 199–214.

Ganguly, B. & Raychaudhuri, S. P. (1971). Purification of *Wheat streak mosaic virus*. *Journal of Phytophatology*, 70 (1), 11–14.

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

Hadi, B. A. R., Langham, M. A. C., Osborne, L. & Tilmon, K. J. (2011). *Wheat streak mosaic virus* on Wheat: Biology and Management. *J. of Integrated Pest Management*, 1(2), 1-5.

Hull, R. (2014). Plant virology (5th ed.). Elsevier, USA, 1120 p.

Hunger, R. L. (2010). *Wheat streak mosaic virus*. In: Bockus, W. W., Bowden, R. L., Hunger, R. L., Morril, W. L., Murray, T. D. & Smiley, R. W. (Eds.). Compendium of Wheat Diseases and Pests (3rd ed.) APS Press, St. Paul, MN, pp 115–117.

Hunger, R. M., Sherwood, J. L., Evans, C. K. & Montana, J. R. (1992). Effects of planting date and inoculation date on the severity of *Wheat streak mosaic* in hard red winter wheat cultivars. *Plant Disease*, 76, 1056-1060.

Ibrahim, A. M. (2018). Ginger farming practice in Jaba region, Kaduna State, Nigeria. *Dutse Journal of Pure and Applied Sciences*, 4(2): 155-168.

ISPS. (2005). Experiences in Collaboration. Ginger Pests and Diseases. Indo-Swiss Project Sikkim Series 1, 75 p.

Jeppson, L. R., Keifer, H. H. & Baker, E. W. (1975). Mites injurious to economic plants. University of California Press, Berkeley, CA.

Kaduna State Ministry of Agriculture (2007). A Survey Report on Ginger Production. Kaduna State Agricultural Development Project, Zone IV, MOA, Kaduna. pp. 1- 10.

Kashina, B. D., Mabagala, R. B. & Mpunami, A. A. (2002). Reservoir weed hosts of *Tomato yellow leaf curl begomovirus* from Tanzania. *Archives of Phytopathology and Plant Protection*, 35 (4), 269–278.

Kumar, V. (Ed.) (2009). Methods for the Diagnosis of Plant Virus Diseases: A Laboratory Manual. Training course on Diagnosis of Plant Virus Diseases held during 28th April – 10th May 2009 at IITA, Ibadan, Nigeria. 90 p.

Meenu, G. & Kaushal, M. (2017). Diseases infecting ginger (*Zingiber officinale* Roscoe): A review. *Agricultural Reviews*, 38 (1), 15–28.

Nair, K. P. P. (2013). The agronomy and economy of turmeric and ginger: The invaluable medicinal spice crops. Elsevier Inc., Vewnes USA, 544 p.

Navia, D., de Mendonca, R.S., Skoracka, A., Szydło, W., Knihinicki, D., Hein, G.L., da Silva Pereira, P.R., Truol, G. & Lau, D. (2013). Wheat curl mite, *Aceria tosichella*, and transmitted viruses: an expanding pest complex affecting cereal crops. *Experimental and Applied Acarology*, 59, 95–143.

Nmadu, J. N. & Marcus, P. L., (2013). Efficiency of ginger production in selected local government areas of Kaduna State, Nigeria. *International Journal of Food and Agricultural Economics*, 1 (2), 39–52.

Nono-Womdim, R. (2003). An overview of major virus diseases of vegetable crops in Africa and some aspects of their control, pp. 213–232. In: Hughes, J. d'A. & Odu, J. (eds.). Plant virology in Sub-Saharan Africa, Proceedings of Conference Organized by IITA Ibadan, Nigeria.

Price, J. A., Simmons, A. R., Rashed, A., Workneh, F. & Rush, C. M. (2014). Winter wheat cultivars with temperature-sensitive resistance to *Wheat streak mosaic virus* do not recover from early-season infections. *Plant Disease*, 98, 525–531

Rabenstein, F., Seifers, D. L., Schubert, J., French, R. & Stenger. D. C. (2002). Phylogenetic relationships, strain diversity and biogeography of tritimoviruses. *Journal of General Virology*, 83, 895–906.

Reddy, P. P. (2010). Bacterial and viral diseases and their management in horticultural crops. *Scientific Publishers*, 288 p.

Roy, A., Savithri, H. S. & Usha, R. (2003). Spices: Chilli pepper, black pepper, cardamom, garlic and ginger. In: Loebenstein, G. & Thottappilly, G. (eds). Virus and Virus-like Diseases of Major Crops in Developing Countries, Springer Science + Business Media Dordrecht, pp. 773–789.

Sastry, K. S. & Zitter, T. A. (2014). Plant virus and viroid diseases in the tropics, volume 2: epidemiology and management. Springer, 489 p.

Sati, S. A. & Bala, G. (2017). A Comparative Analysis of Ginger Cultivation Methods in Kurmin-Jatau, District of Jaba Local Government Area, Kaduna State, Nigeria. *Asian Journal of Soil Science and Plant Nutrition*, 1 (1), 1–18.

Seifers, D. L., Martin, T. J., Harvey, T. L., Haber, S. & Haley, S. D. (2006). Temperature sensitivity and efficacy of *Wheat streak mosaic virus* resistance derived from CO960293 wheat. *Plant Disease*, 90 (5), 623–628.

Sill, W. H. & P. C. Agusiobo. (1955). Host range studies of the *Wheat streak mosaic virus*. *Plant Disease Reporter*, 39, 633–642.

Sill, W. H. & Connin, R. V. (1953). Summary of known host range of the *Wheat streak mosaic virus*. *Transactions of the Kansas Academy of Science*, 56, 411–417.

Singh, K., Wegulo, S. N., Skoracka, A. & Kundu, J. K. (2018). *Wheat streak mosaic virus*: a century-old virus with rising importance worldwide. *Molecular Plant Pathology*, 19 (9), 2193–2206.

Tripathti, D. P. (2007). Introductory plant virology (2nd ed.). Kalyani Publishers, Ludhiana, 532 p.

USAID- NEXTT (2017). Model feasibility study and business plan for ginger processing to oleoresin- an industry-wide study report- Final Report. USAID-NEXTT (Nigeria Expanded Trade and Transport) Romis Consultants Ltd., Lagos, Nigeria. 83 p.

Velandia, M., Rejesus, R. M., Jones, D. C., Price, J. A., Workneh, F. & Rush, C. M. (2010). Economic impact of *Wheat streak mosaic virus* in the Texas High Plains. *Crop Protection*, 29, 699–703.

Zakka, U., Lale, N. E. S. & Okereke, V. C. (2010). A survey of pests of stored Ginger (*Zingiber officinale* (Rosec.)) in some selected markets in Rivers State, Nigeria. *African Journal of Agricultural Research*, 5 (18), 2529–2534.