

FIRST REPORT OF TWO PATHOTYPES OF *RICE YELLOW MOTTLE VIRUS SOBEMOVIRUS* IN NIGER STATE, NIGERIA

*^{1,2}Onwughalu J. T., ¹Abo M. E., ²Nwankiti A. O. and ²Okoro J. K.

¹National Cereals Research Institute, Badeggi, Niger State, Nigeria

²University of Agriculture Makurdi, Benue State, Nigeria

*Corresponding author's e-mail: tobechi44@yahoo.com; Tel.: 08033709696

SUMMARY

This study was conducted to determine the serological profile of *Rice yellow mottle virus* isolates collected from different locations in Niger State between 2010 and 2015. The Indirect Triple Antibody Sandwich Enzyme-Linked Immunosorbent Assay (TAS-ELISA) was used for profiling, and results indicated that the virus isolates belonged to serogroups 1 and 2 (S1 and S2). The isolates from Edozhigi and Gulu about 200 Km apart were characterized as S2; whereas isolates from Wuya and Edozhigi (barely 3 Km apart) were found to belong to S1 and S2 respectively. The RYMV isolate from Wuya was recovered from a weed host, *Echinochloa colona* (L.) Link., which confirmed the weed as reservoir host of RYMV in the area. The present study has established the presence of two serotypes of RYMV in the same State of Niger in the North Central Nigeria.

Keywords: RYMV; serotypes; weed-host; Niger State

RICE is no longer a luxury food in Nigeria; it plays significant role in sub-regional trade, and overall cash in-flow in the agricultural subsector in Nigeria. However, rice culture is affected by biotic and abiotic stresses among which, virus diseases are of great economic importance (51; 31). The *Rice yellow mottle virus* (RYMV) is the most economically important virus disease affecting rice cultivation in Africa (1; 17; 55). It

belongs to *Sobemovirus* group, a single stranded positive sense RNA (16; 22); and like other *sobemoviruses*, characterized for being mechanically transmissible and having relatively narrow host range (21). It was first reported in Nigeria in 1975 (25), and has spread wide in the country, having been reported in rice fields at tillering and panicle initiation stages in Niger, Kano, Bauchi, Gombe, and Benue States in north-

central zone of Nigeria (5; 42); Lagos, Oyo, Ogun, Ekiti and Ondo in the southwest (41), and many other parts of the country (51; 10; 14; 8; 1). RYMV symptoms range from intensities of yellowing and mottling of leaves of infected plants, often mistaken by farmers for iron or nitrogen deficiency (38). Infected plants are often found first near the bunds in the fields, which later spread to whole fields (2). Other characteristic symptoms may include plant death or stunted growth, bunchy tiller formation, poor panicle exertion and spikelet's sterility (43). Transmission of the virus is commonly by some insect vectors (32), and through mechanical contact (16), but not through seed (30; 6; 11). It has also been transmitted in irrigated rice crops by grazing cows, donkeys and grass rats (49).

RYMV variability was first observed by the detection of several serotypes in immunological studies with polyclonal and monoclonal antibodies (29; 34; 18; 19), by which strains followed a geographic distribution with a split between East and West African strains (54; 9). Five serotypes (Ser1 to Ser5) have been identified in Africa, with a high diversity indicating 3 serotypes (Ser1 – Ser3) in West African, and 2 (Ser4 – Ser5) in East Africa (27). These serotypes were further subdivided

into 6 strains, with 3 in West and Central Africa (S1, S2, S3), and the other 3 (S4, S5, S6) in East Africa (27). The existence of different RYMV strains in the field that differ in their pathogenicity has become a matter of considerable practical importance in Nigeria, and Africa in general (41; 20; 55); particularly in view of the risk this may pose to durability and stability of some traditional and transgenic rice cultivars in the region. The occurrence of resistance-breaking (RB) isolates of RYMV in the field as well as the wide geographical distribution and high frequencies of these RB isolates represent a high risk for the durability of resistance to RYMV (18; 20; 55). The implication is that if such RB isolates are frequent in field conditions, it could undermine the stability of resistance to RYMV existing in some traditional and transgenic rice cultivars in Africa. It is therefore necessary to determine the sero-diversity of RYMV isolates existing in Nigeria, as a key step for the development of durable resistance for RYMV in the country.

MATERIALS AND METHODS

RYMV isolates collection and maintenance: Leaves and whole rice plants with typical mottling and yellowing symptoms of RYMV were

collected from farmers' fields in Niger State during a nation-wide survey conducted by Abo, (8). Additional fresh isolates were collected between 2014 and 2015 in research and farmers' fields in the State. Back inoculation test (BIT) was carried out using a susceptible FKR 28 in 2016 to recover the virus, and confirm the presence of the virus. Wuya isolate was recovered from a weed host (*Echinochloa colona* (L.)), which was found with typical yellow-mottle symptoms in a rice field at Wuya village (Plate 1). The coordinates (Latitudes and Longitudes) of field locations where isolates were collected were recorded using the Global Positioning System (GPS).

Preparation of virus extracts and back inoculation procedure: Leaves of RYMV infected plants in the screen house were cut with sterilized razor blade and ground in an electric blender (6 g leaf-tissue/100 ml of distilled water i.e. 6% w/v). An abrasive, carborundum powder (600 mesh) was added to the inoculums at the rate of 5 mg ml⁻¹(29) to aid virus penetration into leaf tissues. Virus extracts were finger-rubbed on upper and lower leaves of the susceptible test plant (FKR 28) at three weeks after planting (3 WAP), and in order to avoid possible escapes from infection, all plants were re-

inoculated twice at 2-day intervals as described by Thottappilly and Rossel (53). RYMV symptom expression was scored based on Standard Evaluation Scale (SES) developed by IRRI (23), at 3 weeks after inoculation (i.e. 42 WAP).

Isolates characterization: The serological profiles of the virus isolates were determined using monoclonal antibodies (MAbs A, G and D) in the Triple-Antibody Sandwich-Enzyme Linked Immunosorbent Assay (TAS-ELISA) as described by Koenig and Paul (28). The indirect Antigen Coated Plate Enzyme Linked Immunosorbent Assay (ACP-ELISA) was also used for virus detection and quantification. Virus concentrations in infected plant leaves were indexed with reference to a standard optical density (OD, 405nm) reading of the positive control. The characterization of serotypes diversity and ELISA test were done at the Plant Pathology Laboratory of Africa Rice Center (AfricaRice), Cotonou, Benin Republic.

RESULTS

The results of Table 1 show the serological analysis using TAS-ELISA and the characterization of RYMV isolates collected from different locations in Niger State. The results indicated that two isolates

from Edozhigi and Gulu belonged to Ser2, whereas the isolate from Wuya belonged to Ser1 (Table 1). Wuya isolate originated from a weed host – *E. colona* L. found with characteristic yellow mottle symptoms of RYMV in a rice field at Wuya village. Table 2 shows the description of original virus isolates collected from rice fields, ELISA and BIT results. The result indicated that Wuya isolate

(Ser1) and Edozhigi II isolate (Ser2) are located in one Local Government Area of Niger State, which is barely 3 Km apart. The isolates collected earlier in 2010 could not reproduce typical symptoms of the RYMV during back inoculation (Table 2). ELISA test also detected the virus only on leaf extracts of isolates from Wuya, Edozhigi II and Gulu respectively.

Table 1: Serological analysis and characterization of RYMV isolates collected from different locations in Niger State.

RYMV Isolate	OD Readings at 405nm and monoclonal antibodies (MAbs) used			Serological group
	MAB A	MAB G	MAB D	
Gulu	0.374 ⁻	3.169 ⁺	0.474 ⁻	S2
Wuya	0.744 ⁺	3.196 ⁺	0.475 ⁻	S1
Edozhigi	0.566 ⁻	3.213 ⁺	0.469 ⁻	S2

- $OD \leq 0.31 \leq 0.6 = 1$ (negative); $OD \leq 0.61 \leq 1.2 = 2$ (positive); $OD \leq 1.21 \leq 1.8 = 3$ (positive); $OD \leq 1.81 = 4$ (positive).
- If, MAb A (positive) and MAb D (negative) = S1, MAb A (positive) and MAb G (positive) = S1, MAb A (negative) and MAb D (positive) = S2, MAb A (negative) and MAb G (positive) = S2.

Table 2: Results of back-inoculation and Enzyme-Linked Immunosorbent Assays of original virus isolates from rice fields in Niger State, Nigeria.

Location /Isolate	LGA	Year collected	Description	Coordinates	*BIT	**OD values at 405nm
Chanchaga	Lavun	2010	Farmers' field	09°07.369'N/06°10.256'E	-	-
Badeggi	Lavun	2012	Research field	09°045'N/06°07'E	-	-
Wuya	Gbako	2014	From weed sample	09°08.456'N/05°85.723'E	+	1.758(+++++)
Edozhigi I	Gbako	2013	Farmer's field	09°05.586'N/05°50.957'E	-	-
Edozhigi II	Gbako	2015	Research	09°05.596'N/05°50.910'E	+	1.289 (++++)
Kanko	Wushishi	2010	Farmer's field	09°66.456'N/06°10.621'E	-	-
River Basin site	Wushishi	2010	Research farm	09°66.484'N/06°10.112'E	-	-
Gulu	Lapai	2015	Farmer's field	08°19.112'N/06°40.962'E	+	1.366 (++++)

*BIT = Back Inoculation Test; - = negative result (RYMV symptoms failed to express on susceptible test plant in the screen house); + = positive result (Characteristic RYMV symptoms expressed on test plants).

** Absorbance values indicating reaction strength of Enzyme-Linked Immunosorbent Assay; + = \geq positive control 405nm, 3hrs) = 0.482, - = \leq Negative control (OD 405nm, 3hrs) = 0.173

DISCUSSION

Edozhigi and Wuya isolates, barely 3 Km apart were shown to belong to different sero-groups, Ser2 and Ser1 respectively (Table 1). There has also been report of isolates collected from the same country, and sometimes

only a few kilometers apart belonging to different viral strains (44). Salaudeen *et al.*, (47) had also reported two serotypes within the same state of Kaduna in Gangara and Tudun Iya, which is less than 2 km apart. N'Guessan *et al.* (35) also

discovered two different serotypes of the virus co-existing in the nearby fields in Cote d'Ivoire, with S2 predominating overwhelmingly in surveyed locations. In the present study, two isolates belonged to Ser2 (Gulu and Edozhigi), and one belonged to Ser1 (Wuya). Moreover, RYMV incidences of 50 and 25 % have been reported respectively at Edozhigi and Wuya in Niger State on differential rice cultivars (5). The establishment of the presence of two serotypes of RYMV in the same state of Niger in the southern Guinean savanna of Nigeria is also an indication that the zone might be the center for virus strain evolution in Nigeria.

The Wuya isolate in the present study was recovered from a weed host – *Echinochloa colona* (L.) Link. at Wuya village. RYMV was also earlier detected by ELISA test on *Echinochloa pyramidalis* L. and *Echinochloa crus-galli* Schultes infected in a natural manner in the field (4; 5). The epidemics reported in eastern Uganda (39) and in The Gambia (50) were not caused by strains prevalent in nearby cultivated rice regions, but were presumably caused by the emergence of local strains which originated in wild rice species or other Poaceae species (45). Viruses overwinter in weed hosts, which serve as source of fresh

infection in rice; and cross-species transmission has also impacted RYMV evolution (45). The symptom expression and detection of RYMV on *Echinochloa colona* L. in the present study confirms earlier reports of detection of RYMV on *Echinochloa spp* (5; 48) in contrast with the recent report by Longue et al., (2016) that *Echinochloa colona* L. is not susceptible to RYMV. Non-expression of symptoms on earlier collected leaf samples with characteristic yellow mottle symptom of RYMV, and the subsequent negative values with ELISA and BIT tests, is an indication of lost viability over long period of storage in dry form.

CONCLUSION

The present study has established the existence of two pathotypes of RYMV on Niger State. Wuya was classified as Ser1, whereas isolates from Edozhigi and Gulu belonged to Ser2. The development of RYMV resistant cultivars adaptable in the zone should take into account the presence of these serotypes in the area.

REFERENCES

1. Abo, M. E., and Sy, A. A. 1998. Rice yellow mottle virus diseases. Epidemiology and Management Strategies. *Journal of*

- Sustainable Agriculture*, 11 (2/3): 113 – 134.
- 2. Abo, M. E., Sy, A. A., and Alegbejo, M. D. 1998.** Rice yellow mottle virus (RYMV) in Africa: Evolution, Distribution, and Economic Significance on Sustainable Rice Production and Management Strategies. *Journal of Sustainable Agriculture*, 11(2/3): 85 – 111.
- 3. Abo, M. E., Alegbejo, M. D., Sy, A. A., and Misari, S. M. 2000.** An overview of the mode of transmission, host plants and method of detection for Rice yellow mottle virus. *Journal of Sustainable Agriculture*, 17 (1): 19 – 36.
- 4. Abo, M. E., Alegbejo, M. D., Sy, A. A. and Sere, Y. 2002a.** Field incidence of Rice yellow mottle virus, Genus Sobemovirus on Rice and a weed species in the field in Cote d'Ivoire. *Acta Agronomica Hungarica*, 50 (1): 85 – 89.
- 5. Abo, M. E., Ukwungwu, M. N. and Onasanya, A. 2002b.** The Distribution, Incidence, Natural Reservoir Hosts and Insect Vectors of Rice yellow mottle virus (RYMV), Genus Sobemovirus in Northern Nigeria. *Tropicultura*, 20 (4): 198 – 202.
- 6. Abo, M. E., Alegbejo, M. D., and Sy, A. A. 2004.** Evidence of non-transmission of Rice yellow mottle virus through rice seed. *Tropicultura*, 22 (3): 116 – 121.
- 7. Abo, M. E., Gana, A. S., Maji, A. T., Ukwungwu, M. N., and Imolehin, E. D. 2005.** The resistance of farmers' rice varieties to Rice yellow mottle virus (RYMV) at Badeggi, Nigeria. *Tropicultura*, 23 (2): 100 – 104.
- 8. Abo, M.E. 2010.** Plant virus diseases of rice, sesame and sugarcane in twelve (12) Northern States of Nigeria - Technical Report submitted to International Institute of Tropical Agriculture, (IITA), Ibadan, Oyo State as Consultant Plant Virologist on a Nation-wide Pest Survey Project, August 2010, 70pp.
- 9. Abubakar, Z., F. Ali, A. Pinel, O. Traore', P. N_Guessan, J.-L.Notteghem, F.Kimmins, G. Konate', and D. Fargette. 2003.** Phylogeography of Rice yellow mottle virus in Africa. *Journal of General Virology*, 84: 733–743.
- 10. Alegbejo, M. D., Raji, B. A., Abubakar, I. U., Banwo, O. O. 2006.** Rice yellow mottle virus. A new disease of Rice in Zamfara. *International Rice Research Notes*, 31: 1.
- 11. Allarangaye, M.D., Traoré, O., Traoré, E. V. S., Millogo, R. J. and G. Konaté, G. 2006.** Evidence of Non-Transmission of Rice yellow mottle virus through Seeds of wild

host species. *Journal of Plant Pathology*, 88 (3): 309-315.

12. Alkali, G., Alegbejo, M. D., Kashina, B. D. and Banwo, O. O. 2014. First report of Rice yellow mottle virus Genus Sobemovirus in Borno State, Nigeria. *Nigerian Journal of Experimental and Applied Biology*, 15: 87 – 91.

13. Alkali, G., Alegbejo, M. D., Kashina, B. D. and Banwo, O. O. 2016. Alternative weed hosts of Rice yellow mottle sobemovirus in Northern Nigeria. *Nigerian Journal of Experimental and Applied Biology*, 17: 71 – 78.

14. Awoderu, V. A., 1991. Rice yellow mottle virus in West Africa. *Tropical Pest Management*, 37: 356 – 362.

15. Bakker, W. 1974. Characterization and ecological aspects of Rice yellow mottle virus in Kenya. Agricultural Research, Doctoral Thesis, University of Wageningen, The Netherland, 152pp.

16. Bakker, W. 1975. Rice yellow mottle virus. CMI/AAB Descriptions of Plant Viruses, No. 149. 1P.

17. Banwo, O. O., Alegbejo, M. D., Abo, M. E. 2004. Rice yellow mottle virus Genus Sobemovirus: A continental problem in Africa. *Plant Protection Science*, 40 (1): 26 – 36.

18. Fargette, D., Pinel, A., Traore, O., Ghesquiere, A., and Konate, G. 2002. Emergence of resistance-

breaking isolates of Rice yellow mottle virus during serial inoculations. *European Journal of Plant Pathology*, 108: 585 – 591.

19. Fargette, D. Pinel, A. Abubakar, Z. Traore´, O. Brugidou, C. Fatogoma, S., He´brard, E., Choisy, M., Se´re´, Y. Fauquet, C. and Konate´, G. 2004. Inferring the Evolutionary History of Rice yellow mottle virus from Genomic, Phylogenetic, and Phylogeographic Studies. *Journal of Virology*, 78 (7): 3252–3261.

20. He´brard, E., Pinel-Galzi, A., Bersoult, A., Sire, C. and Fargette, D. 2006. Emergence of a resistance-breaking isolate of Rice yellow mottle virus during serial inoculations is due to a single substitution in the genome-linked viral protein VPg. *Journal of General Virology*, 87: 1369–1373.

21. Hull, R. 1988. The Sobemovirus group. In: *The Plant Viruses, Polyhedral Virus with Monopartite RNA genomes.* (I. R). Koenig, (ed.). Plenum Press, New York, 3: 113 – 146.

22. ICTVdB 2006. 00.067.0.01.005. Rice yellow mottle virus. In: *ICTVdB The Universal Virus Database, version 4.* Bu¨chen-Osmond, C. (Ed), Columbia University, New York, USA. <http://www.ncbi.nlm.nih.gov/ICTVdb/ICTVdB/index.htm>. Accessed, 5th July, 2014.

- 23. IRRI (International Rice Research Institute), 1996.** The International Rice Testing Program – Standing Evaluation System (ITP-SES) for Rice, Los Banos, Laguna, The Philippines, 4th Edition, P.25.
- 24. IRRI (International Rice Research Institute), 2007.** Cropstat for Windows Version 7.2 2007.3. IRRI Metro Manila Philippines, GMcLaren@cgiar.org.
- 25. John, V. T., Thottappilly, G., and Awoderu, V. A. 1984.** Occurrence of Rice yellow mottle virus in some Sahelian Countries in West Africa. *FAO – Plant Protection Bulletin*, 32: 86 – 87.
- 26. Kanyeka, Z. I. (2006).** Pathogenicity of two strains of Rice yellow mottle virus on Aromatic Rice cultivars. *Tanzania Journal of Science*, 32 (1): 53 – 59.
- 27. Kanyeka, Z.I., Sangu, E., Fargette, D., Pinel-Galzi, A. and Herbrard, E. 2007.** Distribution and Diversity of Local Strains of Rice yellow mottle virus in Tanzania. *African Crop Science Journal*, 15 (4): 201 – 209
- 28. Koenig, R., and Paul, H. L. 1982.** Variants of ELISA in plant virus diagnosis. *Journal of Virological Methods*, 5: 113 – 125.
- 29. Konate G., Traore O., Coulibaly M.M. 1997.** Characterization of Rice yellow mottle virus isolates in sudano-sahelian areas. *Archives of Virology*, 142: 1117-1124.
- 30. Konaté, G., Sarra, S. and Traore, O. 2001.** Rice yellow mottle virus is seed borne but not seed transmitted in rice. *European Journal of Plant Pathology*, 107: 361-364.
- 31. Kouassi, N.K., N’Guessan, P., Albar, L., Fauquet, C.M. and Brigidou, C. 2005.** Distribution and Characterization of Rice yellow mottle virus: A Threat to African Farmers. *Plant Disease*, 89 (2): 124-133. DOI: 10.1094/PD-89-0124
- 32. Koudamilo, A., Nwilene, F. E., Togola, A. and Akogbeto, M. 2015.** Insect Vectors of Rice yellow mottle virus (Review Article). *Journal of Insects*, 12pp. <http://dx.doi.org/10.1155/2015/72175>, accessed 13 August, 2016.
- 33. Longué, R.D.S., Zinga, I., Semballa, S., Barro, N. and Traoré, O. 2016.** Detection and Serological Characterization of Rice yellow mottle virus in Central African Republic. *Agricultural Sciences*, 7: 911 – 919. <http://dx.doi.org/10.4236/as.2016.712082>
- 34. N’Guessan, P., Pinel, A., Caruana, M., Frutos, R., Sy, A., Ghesquière, A. and Fargette, D. 2000.** Evidence of the presence of two serotypes of rice yellowmottle sobemovirus in Côte d’Ivoire.

European Journal of Plant Pathology, 106:167–178.

35. N'Guessan, P., Pinel, A., Sy, A. A., Ghesquière, A., and Fargette, D. 2001. Distribution, pathogenicity, and interactions of two strains of Rice yellow mottle virus in forested and savannah zones of West Africa. *Plant Diseases*, 85:59 - 64.

36. Ndjiondjop, M. N., Albar, L., Fargette, D., Fauquet, C., and Ghesquière, A. 1999. The genetic basis of high resistance to Rice yellow mottle virus (RYMV) in cultivars of two cultivated rice species. *Plant Diseases*, 83:931-935.

37. Ndjiondjop, M. N., Brugidor, C., Zang, S., Fargette, D., Ghesquiere, A., and Fauquet, C. 2001. High resistance to Rice yellow mottle virus (RYMV) in two cultivated rice cultivars is correlated to the failure of cell-to-cell movement, *Physiology of Molecular Plant Pathology*, 59: 309 – 316.

38. Nwilene F. E., Sere, Y., Ndjiondjop, M. N., Abo, M. E., Traore, A. K., Asidi, A. N., Onasanya, A., Togola, A. and Agunbiade T. A. 2009. Rice yellow mottle virus (RYMV) and its insect vectors: Ecology and Control – *Field Guide and Technical Manual*. WARDA, Cotonou, 36pp.

39. Ochola, D., Issaka, S., Rakotomalala, M., Pinel-Galzi, A., Ndikumana, I., Hubert, J., Hebrard, E. and Sere, Y. 2015. Emergence of Rice yellow mottle virus in eastern Uganda: Recent and singular interplay between Strains in East Africa and in Madagascar. *Virus Research*, 195: 64 – 72.

40. Onasanya, A., Sere, Y., Sie, M., Akator, K., Coulibaly, M. M. and Hamadoun, A. 2006. Existence of two pathotypes of Rice yellow mottle virus, Genus Sobemovirus, in Mali. *Plant Pathology Journal*, 5 (3): 368 – 372.

41. Onasanya, R.O., Olufolaji, D.B., Onasanya, A., Sere, Y., Nwilene, F.E., Wopereis, M. and Kiepe, P. 2011. Occurrence, Distribution and Characterization of Rice yellow mottle virus isolates Genus Sobemovirus in Southwest Nigeria. *Trends in Applied Sciences Research*, 6: 1301 – 1323.

42. Onwughalu, J. T., Abo, M. E. and Okoro, J. K. 2009. Preliminary investigation on the occurrence of Rice yellow mottle virus (RYMV) and its insect vectors in Benue State, Nigeria. *Nigerian Journal of Plant Protection*, 23: 44 – 52.

43. Onwughalu, J. T., Abo, M. E., Nwankiti, A. O. and Okoro, J. K. 2017. Symptoms diversity elicited by Rice yellow mottle virus (RYMV) infection on *Oryza* species in Nigeria.

International Journal of Agricultural Research and Food Production, 2 (2): 61 – 81.

44. Pinel, A., N'Guessan, P., Bousalem, M. and Fargette, D. 2000. Molecular variability of geographically distinct isolates of Rice yellow mottle virus in Africa. *Archives of Virology*, 145: 1621 – 1638.

45. Pinel-Galzi, A., Traore, O., Sere, Y., Hebrard, E., and Fargette, D. 2015. The biogeography of viral emergence: Rice yellow mottle virus as a case study. *Current Opinion in Virology*, 10: 7 – 13.

46. Raymundo, S.A. and Buddenhagen, I.W. 1976. A rice disease in West Africa. *International Rice Commission Newsletter*, 29: 51-53.

47. Salaudeen, M. T., Banwo, O. O., Kashina B. D. and Alegbejo M. D. 2008a. Preliminary studies on the serotypes and sero-distribution of Rice yellow mottle Sobemovirus in northern Nigeria. *Biological and Environmental Science Journal for the Tropics*, 5 (1): 23 – 26.

48. Salaudeen, M. T., Banwo, O. O., Kashina B. D. and Alegbejo M. D. 2008b. Possible wild hosts of Rice yellow mottle Sobemovirus in northern Nigeria. *Nigerian Journal of Weed Science*. 21: 67 – 71

49. Sarra, S. and Peters, D. 2003. Rice yellow mottle virus is

transmitted by cows, donkeys and grass rats in irrigated rice crops. *Plant disease*, 87 (7): 804 – 808.

50. Sere, Y., Sorho, F., Onasanya, A., Jobe, L., Darboe, S., Bojang, Y., Touray, M., Pinel-Galzi, A. and Fargette, D. 2008. First report of Rice yellow mottle virus in rice in The Gambia. *Plant Diseases*, 92: 316.

51. Singh, B. N., Fagade, S., Ukwungwu, M. N., Williams, C., Jagtap, S. S., Oladimeji, C., Efişue, A. and Okhidievbie, O. 1997. Rice growing environments and biophysical constraints in different agro-ecological zones of Nigeria. *Meteorological Journal*, 2 (1): 35 – 44.

52. Thottapilly, G. Van Lent, J. W., Rossel, H. W. Sehgal, O. P. 1992. Rottboellia yellow mottle virus, a new sobemovirus affecting Rottboellia cochinchinensis (Itch grass) in Nigeria, *Annals of Applied Biology*, 120: 405 – 415.

53. Thottappilly, G., and Rossel, H. W. 1993. Evaluation of Resistance to Rice yellow mottle virus in *Oryza* species. *Indian Journal of Virology* 9(1): 65 – 73.

54. Traoré, O., Pinel, A., Fargette, D., and Konaté, G. 2001. First report and characterization of Rice yellow mottle virus in Central Africa. *Plant Diseases*, 85: 920.

55. Traoré O, Pinel A, Hébrard E, Gumedzo M, Fargette D, Traoré A,

Konaté G 2006. Occurrence of Resistance-Breaking Isolates of Rice yellow mottle virus in West and

Central Africa. *Plant Diseases*, 90(3): 259-263.