REVIEW

Rice Yellow Mottle Virus Genus *Sobemovirus*: A Continental Problem in Africa

Olalekan Oyeleke BANWO[1]*, *Matthew Dada ALEGBEJO*[1] *and Myimodra Emmanuel ABO*[2]

[1]*Department of Crop Protection, Faculty of Agriculture, Ahmadu Bello University, Zaria, Nigeria;* [2]*National Cereals Research Institute, Badeggi, P.M.B. 8, Bida, Nigeria*

Abstract

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Rice yellow mottle virus genus *Sobemovirus* (RYMV) was first reported in Kenya in 1966. The disease caused by this virus is fast becoming a major limiting factor in the rice production in Africa and neighbouring islands. It is known to occur in eastern, western and southern African countries and, since very recently, in Central Africa. It is transmitted by insect vectors such as *Chaectonema* spp., *Sesselia pusilla* Gerst. and *Trichispa sericea* Guerin (all *Coleoptera*) and also by mechanical means. About six strains of the virus now exist. Yield losses caused by the virus range from 20 to 100%. Integrated pest management has been suggested to minimise damage caused by this disease to rice. This paper reviews the characteristics of the virus, symptomatology, host range, distribution, strains, transmission, vector dynamics and virus spread, the economic importance, and management strategies. The need of future research of RYMV is also highlighted.

Keywords: *Rice yellow mottle virus*; *Sobemovirus*; strains; rice; Africa

Rice (*Oryza sativa* L.) is one of the most important cereals in the world. It is an important food crop and a source of revenue for farmers in Africa. Rice is the primary staple food for more than two billion people in Asia, and for over seven hundred million people in Africa and Latin America (IRRI 1985). It is a popular food almost everywhere in Africa (FAO 1994, 2001) and the demand for rice in sub-Saharan Africa is becoming higher due to a general dietary shift from conventional foods (Houston 1972). Major rice producing areas of Africa are concentrated in the eastern and western parts of the continent and in Madagascar, a neighbouring island.

Many factors lower rice yields in Africa. These include weeds, low soil fertility, and plant pests (Kihupi & Pillai 1989; Kanyeka *et al*. 1995). *Rice yellow mottle virus (*RYMV) is considered to be one of the most important plant pests in Africa (Fargette *et al*. 2002). It is widely acknowledged that RYMV has now drawn attention for research in many rice growing countries of sub-Saharan Africa (Ali 2001).

RYMV, which belongs to the *Sobemovirus* group, is the main virus infecting rice in Africa (Abo 1998). It was first noticed in 1966 at Otonglo near Kisumu along the shores of Lake Victoria where the disease had probably been present for a number of years

(Bakker 1974). The disease was later found in most countries where rice is grown, i.e. East and West Africa (Abo 1998), some countries in southern Africa, and very recently in Central Africa (Traore *et al*. 2001). Reports (e.g. Ali 1999; Luzi-Kihupi *et al*. 2000) show that RYMV is rapidly spreading among and within the major rice growing areas. RYMV is known to be naturally very destructive and therefore threatening the rice production on the African continent on a large scale.

The increasing importance of RYMV in Africa is attributed to the cultivation of new highly susceptible exotic rice varieties mostly from Asia, and the availability of water through irrigation which allows for sequential planting and maintenance of higher crop intensity without dry season gaps (Rossel *et al*. 1982). Traditionally, in Africa rice is grown under upland rainfed conditions although cultivation in lowlands and swamps is practised in certain areas (Rossel 1986). It was under these conditions (lowlands and swamps) that RYMV was first reported on rice in East Africa (Bakker 1970), West Africa (Raymundo & Buddenhaggen 1976), and very recently in Central Africa (Traore *et al*. 2001).

Several insect species with chewing mouthparts, particularly chrysomelid beetles, can bring the primary inoculum into the rice crop from wild hosts and weeds (Reckhaus & Randrianangaly 1990). This occurs when the crop is young and particularly susceptible to the virus. The data on the molecular variability and strain differentiation would provide useful information on the identification of isolates/strains in pathogenecity and breeding studies of RYMV in Africa. Also, the distinction between strains is critical in epidemiological surveys (Fargette *et al*. 2002). Poor understanding of the epidemiology and transmission of the disease was reported to have increased the incidence and severity levels at an alarming rate from the late sixties to the nineties, predominantly affecting rice in the lowland ecosystems (Pinto 2000). In view of the increasing incidence and importance of RYMV on rice production in Africa, it is important and necessary to outline some of the main achievements of earlier works on the characteristics of the virus, symptomatology, host range, distribution, strains, transmission, vector dynamics and virus spread, the economic importance, and management strategies. Suggestions on pointers to the future are also made.

RICE YELLOW MOTTLE VIRUS GENUS *SOBEMOVIRUS*

Characteristics of *Rice yellow mottle virus*

Rice yellow mottle virus genus *Sobemovirus* is a single stranded positive sense RNA and a distinctive spherical virus measuring about 28 ± 3 nm in diameter (Bakker 1974; Opalka *et al*. 1995), having at least 15% single stranded RNA and a molecular weight of 1.41×10^6 daltons (about 4500 nucleotides) (Hull 1988). The percentage of nucleic acid in the infective virus particle was estimated to be 23.6 ± 0.5% (Bakker 1974). It consists of 4 open reading frames (ORFs). The ORF1 (nt 80 to 553) encodes a protein called P1 of 17.8 kd known to be the movement protein of the virus, whereas ORF2 (nt 608 to 3607) encodes a polyprotein of 110 kd and contains a putative linked protein (VPg), helicase, protease and polymerase. ORF3 (nt 2092 to 2467) encodes a small protein of 13.7 kd of an unknown function, and the ORF4 (nt 3447 to 4116) codes for the coat protein (CP) of 26 kd (Yassi *et al*. 1994). The virus is a member of the *Sobemovirus* group (Seghal 1981; Opalka *et al*. 1995). *Sobemoviruses* are characterised by being mechanically transmissible, having relatively narrow host ranges, and having isometric particles of 25–30 nm diameter (Hull 1988) that sediment between 110 and 120S. The particles are found in the cytoplasm of most cells (Bakker 1974; Hull 1988) and in the nuclei (Francki *et al*. 1985), and occur at relatively high concentrations in infected plants (Nault *et al*. 1978). Most members lack immunological reactions with other *Sobemoviruses* (Thottappilly 1992). The natural vectors of most *Sobemoviruses* are insects (Hull 1986), and the most efficient transmission is effectuated by Chrysomelid beetles.

Symptomatology and infectivity of sap

RYMV is characterised by leaf mottling and yellowing symptoms of varying intensities depending on the genotype. It could be mistaken for iron or nitrogen deficiency (Thottappilly & Rossel 1993) as well as the damage by iron toxicity. Infected rice plants are found first near the bunds and thereafter whole fields may be infected (Bakker 1975). Bakker (1974) reported yellowish leaves on cv. Sindano, mild yellowish green on cv. Basmati or orange on cv. IR 8, and in each case the youngest leaves showed mottling. Raymundo and Buddenhaggen

(1976) stated that infected plants had pale-yellow mottled leaves, stunted, reduced tillering, asynchronous flowering, poor panicle exertion, spikelet discoloration and sterility, erect panicles, compact appearance of spikelets, brown to dark-brown discoloration of grains, a consequence of secondary infection by fungi, and crinkling of new growth. Others developed conspicuous bronze or orange pigmentation followed by the rolling of leaf margins and subsequent leaf desiccation. Symptoms occur at any stage from transplanting to booting and in severe cases the affected plants may die (Bakker 1971, 1974; Thottappilly & Rossel 1993). Symptoms are more pronounced on ratoons (Raymundo & Buddenhaggen 1976).

Sap derived from young infected rice leaves (2–3 weeks old) is infective at a dilution of 10^{-11}; however, the dilution end point varies with the origin of the inoculum (Fauquet & Thouvenel 1977). The virus remains infective for 35 days at 27 to 29°C, but when stored at 9°C, the sap remains infective for 71 days (Bakker 1970, 1974), and at 4°C for 84 days (Fauquet & Thouvenel 1987). However, the inoculum progressively loses its capacity for infection at temperatures from 55°C to 70°C, although in crude sap the virus remains viable for at least 34 days at 27°C (Fauquet & Thouvenel 1987). The virus is stable in crude sap and dry leaves that are readily preserved and can remain infectious for several months, and can replicate at a surprisingly rapid rate (Fauquet & Thouvenel 1977).

Host range

Host range is narrow, being restricted to species of *Graminea*, mainly to the tribes of *Oryzeae* and *Eragrostidae* (Bakker 1974; Ou 1985). Bakker (1974) reported that the virus had been probably present around Lake Victoria on these grass hosts before the rice cultivation was introduced, and that it then spread to rice. The grass species reported as diagnostic hosts include *Eleusine indica* Gaertiner, *Echinocloa crus-galli* L.P. Beak, *Dinebra retroflexa* (Vahl) Panz. , *Eragrostis tenifolia* (A. Rich) Steud., *Phleum arenarium* (Bakker 1974; Okioma *et al*. 1983). Inoculation tests in Kenya with RYMV did not infect forest rice *Oryza eichingeri* Peter., *Eleusine* spp., *Leersia hexandri* Sw., and other grass species but rice was the only host naturally infected (Bakker 1974). On the other hand, Raymundo *et al*. (1979) reported artificial infection with the virus of *Eleusine indica* and *Echinochloa crus-galli* in Sierra Leone, West Africa. RYMV was also found in *O. longistaminata* A. Chev. & Roehr, a wild species of rice growing in marshy areas and in rice fields in West Africa (John *et al*. 1984). No infection was obtained with cultivated cereals such as *Sorghum bicolor* (L.) Moench, *Zea mays* L., *Pennisetum americanum* and *Triticum aestivum* L., neither with some sedges and broad leaved weeds (Abo 1998). Thus it is evident that the host range is narrow.

Geographical distribution

Rice yellow mottle virus genus *Sobemovirus* was first reported in Kenya, East Africa in 1966 in irrigated fields (Bakker 1970). Later reports were from West Africa in Sierra Leone under hydromorphic and swamp conditions (Raymundo & Buddenhagen 1976), irrigated rice in Cote d'Ivoire (Fauquet & Thouvenel 1977) and Nigeria (IITA 1978) lowland, and irrigated rice fields in Niger (Sy 1994), Burkina Fasso, Senegal, and deep waters of Mali (John *et al*. 1984), Gambia, Guinea, Guinea Bissau, Liberia, Ghana and Togo (Abo 1998). It is present in lowland and irrigated rice in Mozambique (Guei – pers. com.) in southern Africa and Madagascar in the Indian Ocean (Reckhaus & Randrianangaly 1990). The disease has also been very recently noticed on irrigated rice in Cameroon and Chad (Traore *et al*. 2001), both in Central Africa. It was reported in Tanzania mainland (IRRI 1987) and Zanzibar (Ali & Abubakar 1995) under lowland irrigated and rainfed conditions. The disease is fast becoming a major limiting factor in the rice production in Africa and is found in virtually all rice growing countries of East, West and Southern Africa (Figure 1). Disease outbreaks have been reported mainly from irrigated and rainfed lowland production systems. Also, it does occur in both the highly susceptible exotic and indigenous varieties under rainfed upland production ecosystems (Awoderu 1991). It is gradually building up in other countries of Africa (Abo *et al*. 1995; Anno-Nyako & Twumasi 1995; Singh 1995).

Strains

Serological differences were first reported between an isolate from Ivory Coast (West Africa) and one from Kenya (East Africa) (Fauquet & Thouvenel 1977). Later, serological diversity of five isolates (Ivory Coast, Kenya, Niger, Nigeria and Sierra-Leone) was studied and three serogroups were

▼ countries where *Rice yellow mottle virus* has been reported

Figure 1. Distribution of *Rice yellow mottle virus* in Africa (adapted from Abo *et al*. 1998; Traore *et al*. 2001; Banwo 2002)

defined, but there was no apparent geographical basis for their distribution (Mansour & Baillis 1994). By contrast, in Burkina-Faso (West Africa), the three serogroups found were tentatively linked to their ecological origin and pathogenecity (Konate *et al*. 1997). Subsequently, Pinel *et al*. (2000) reported three major strains (S1 to S3) in Ivory Coast further suggesting that several strains/serotypes can co-exist in the same country. N'Guessan *et al*. (2001) reported a preferential distribution of S1 strain in the north of the country which was consistent with the detection of S1 isolates from Mali and Burkina-Faso in the north. In Tanzania, immunological tests (Agar-gel) with two types of antisera showed the presence of two predominant strains S4 and S5 (Ali 2001). The last author reported that the S4 strain was limited to the Lake Zone area while the S5 strain was observed in the lowland rainfed areas of Morogoro and Mbeya and the irrigated areas of Moshi and Pemba. She also observed that the S5 strain was found in areas that had been found to have a high disease incidence (hotspot areas).

Pinel *et al*. (2000) and Fargette *et al*. (2002) carried out molecular assays of coat protein gene sequences of 40 and 52 isolates of RYMV in Africa. In all, they differentiated five major strains, three (S1, S2 and S3) from Central and West Africa and two (S4 and S5) from East Africa, with a spatial overlap of strains within each of these two regions showing that geographical isolation alone cannot explain the genetic diversity of RYMV. Different down stream primers were needed to amplify all RYMV isolates of the different strains, in particular for S1 vs S2 isolates, and for West vs East African isolates. Out of the three isolates collected in Tanzania, Pinel *et al.* (2000) observed that molecular assays of coat protein gene sequences showed a similarity between one isolate from Tanzania and the five from Madagascar (S4), while two other isolates from Tanzania identified as S5 did not show similarity to the other 39 studied. However, Fargette *et al*. (2002) using four isolates from Tanzania showed that two of the isolates showed similarities to the six from Madagascar and the only one from Kenya (S4). Interestingly, in the evaluation of some molecular characteristics of RYMV isolates occurring on rice in Tanzania, a comparison of isolates from Central, East and West Africa and Madagascar was also made, and Banwo *et al*. (2002b) observed a completely new group/strain of RYMV referred to as S6. When the CP sequences of S1–S5 as described by Pinel *et al*. (2000) were compared with the S6 group, the latter showed < 90% overall sequence identity with the S1–S4 groups while a significant sequence relationship was not found either with the S5 isolates from Tanzania. Pinel *et al*. (2000) and Fargette *et al*. (2002) reported that in general, variability was two fold higher among the East African isolates than among the West African isolates. Fargette *et al*. (2002) reported that East African strains S4 and S5 were more distantly related to each other and to the Central/West African strains (S1–S4) with an average nucleotide divergence of about 11%. Isolates collected from a place a few kilometers apart in the same country could belong to different strains as it was observed in both West and East Africa (Pinel *et al*. 2000; Banwo *et al*. 2002b). About 3 strains are now known to exist in both West Africa (S1–S3) and East Africa (S4, S5 and S New) (Fargette *et al*. 2002; Banwo *et al*. 2002b).

Transmission of *Rice yellow mottle virus* genus *Sobemovirus* (RYMV)

The earlier a plant is infected, the higher the percentage of seed that will transmit the virus (Ryder 1973). It was reported that most seed transmitted viruses are transmitted through the pollen of infected plants (Fulton *et al*. 1987). RYMV was not seed transmissible (Bakker 1974; Fauquet & Thouvenel 1977) but more recently, some authors noted that there is some evidence for RYMV to be seed transmitted and suggested that the question should be re-examined (Awoderu 1991). Furthermore, varieties not tested in earlier studies (Bakker 1974) which showed high levels of susceptibility to the disease are now available, and it is widely known that varieties may react with the same virus differently. However, low rates of seed transmission in conjunction with secondary spread by insect vectors can produce viral disease epidemics (Dinant & Lot 1992) since the virus is introduced into the crop at a very early stage. This allows the infection to spread to other plants while they are still young and very susceptible (Maule & Wang 1996). Very recently, RYMV was reported to be seedborne but not seed transmitted in rice seeds (Abo *et al*. 2000; Konate *et al*. 2001; Banwo 2002). While Abo (1998) detected the virus in the husk instead of the rice embryo, there was an indication that RYMV is one of the few non-seed transmitted viruses found in the embryo (Konate *et al*. 2001).

Insects infest rice at all stages and feed on all parts of the plant. RYMV is transmitted by insects with biting and chewing mouthparts (Hull 1988). It is most efficiently transmitted by Chrysomelid beetles, possibly in a semi-persistent manner (Bakker 1974). *Chaetocnema pulla*, *Trichispa sericea*, *Dicladispa* spp. and *Dactylispa* spp. all *Coleoptera*, were reported as vectors of RYMV (Bakker 1974; Reckhaus & Adamou 1986; Awoderu 1991; Abo 1998; Banwo 2002). Also, grasshoppers (e.g. *Conocephalus* spp. and *Oxya* spp.) (Bakker 1974; Reckhaus & Andriamasintseheno 1995; Abo 1998) are also known to transmit RYMV. The insects already established as vectors of RYMV in Africa are listed in Table 1. Heinrichs *et al*. (1997) and Reckhaus and Andriamasintseheno (1997) are of the view that RYMV infection is highly variable in time and space. The West Africa Rice Development Association (WARDA) is of the opinion that the main mode of transmission capable of explaining the dynamic nature of RYMV is yet to be fully elucidated (Sere – pers. comm.). One important aspect towards understanding the dynamics of RYMV on rice is to elucidate the bionomics of the vectors. WARDA (1993) reported that severe RYMV infections in the rice cv. Bouake 189 at Sakassou in Ivory Coast were associated with high *Trichispa sericea* populations. However, Heinrichs *et al*. (1997) found no correlation between the vector abundance and RYMV incidence in Mbe, Ivory Coast. In Tanzania, Banwo *et al*. (2002a) showed very clearly that *Chaetocnema* sp. (near *varicornis*) was more abundant in hotspot than in non-hotspot areas. In West Africa, Awoderu (1991) reported higher RYMV incidence in warm or hot zones, in areas poorer in rainfalls and in areas with low relative humidity while Heinrichs *et al*. (1997) found no correlations between RYMV and both windspeed and rainfall. In Tanzania, it is not clear how the environmental factors such as temperature, rainfall, and relative humidity

Table 1. Insect vectors of *Rice yellow mottle virus* genus *Sobemovirus* in Africa

Country	Order: Family	Species
Ivory Coast	*Coleoptera*: *Chrysomelidae*	*Chaetocnema pulla*
	Coleoptera: *Chrysomelidae*	*Trichispa sericea*
	Coleoptera: *Coccinelidae*	*Epilachna similis*
	Orthoptera: *Tettigonidae*	*Conocephalus longipennis*
Kenya	*Coleoptera*: *Chrysomelidae*	*Chaetocnema pulla*
	Coleoptera: *Chrysomelidae*	*Dactylispa bayoni*
	Coleoptera: *Chrysomelidae*	*Dicladispa viridicynea*
	Coleoptera: *Chrysomelidae*	*Sessilia pusilla*
	Coleoptera: *Chrysomelidae*	*Trichispa sericea*
	Orthoptera: *Tettigonidae*	*Conocephalus merumontanus*
Madagascar	*Coleoptera*: *Chrysomelidae*	*Chaetocnema pulla*
	Coleoptera: *Chrysomelidae*	*Dicladispa gestroi*
	Orthoptera: *Acrididae*	*Oxya* sp.
Guinea	*Coleoptera*: *Chrysomelidae*	*Chaetocnema pulla*
Niger	*Coleoptera*: *Chrysomelidae*	*Aulocophora africana*
	Coleoptera: *Chrysomelidae*	*Trichispa sericea*
Mali	*Coleoptera*: *Chrysomelidae*	*Trichispa sericea*
Nigeria	*Coleoptera*: *Chrysomelidae*	*Aulocophora africana*
	Coleoptera: *Chrysomelidae*	*Chaetocnema* spp.
Tanzania	*Coleoptera*: *Chrysomelidae*	*Chaetocnema* sp. (near *varicornis*) *Chaetocnema pulla*
	Coleoptera: *Chrysomelidae*	*Dactylispa lenta*

Adapted from Bakker (1974), Awoderu (1991), Reckhaus and Andriamasintseheno (1997), Abo (1998), and Banwo (2002)

bring about differences in the vector populations and RYMV incidence (Banwo 2003). However, in Madagascar, Reckhaus and Andriamasintseheno (1997) reported that the rice cv. Asara planted in the rainy season suffers most from RYMV while cv. Jeby grown mainly under irrigation is the most productive.

RYMV can also be transmitted through other sources. The virus was found in leaf debris and empty rice spikelets (Abo 1998). RYMV could then be transported in rice sacks containing contaminated and partially winnowed rice seeds to new areas far from its origin and spread there. In Mali, 100% infections were reported to occur in transplanted rice fields but not in directly seeded fields thus indicating a possible connection with the infection from the nursery (Sy 1994). The virus is transmitted mechanically through sap (Bakker 1974, 1975; Fauquet & Thouvenel 1977). It could also be transmitted through gutter fluid and by the irrigation water of heavily infected rice fields (Bakker 1974; Ou 1985). It is also transmitted by farm implements such as sickle used for rice harvesting (Tsuboi *et al*. 1995). Cow dung and soil containing insufficiently decomposed plant material can also contribute to the infection with RYMV (Reckhaus & Andriamasintseheno 1995). RYMV is transmitted through leaf contact in closely spaced plants, by contaminated hands, rice stubbles incorporated into the soil, and through rice roots intertwined together (Abo 1998). Although many nematodes are associated with rice in Africa (Coyne *et al*. 1996), no evidence is available for the transmission of RYMV by nematodes (Bakker 1974; Raymundo *et al*. 1979; Abo 1998).

Economic importance

The losses caused by RYMV in paddy fields have reached alarming proportions and some farmers have suffered complete crop failure (Yaboue 1989). Yield losses of 58–67% were reported in Niger (Reckhaus & Adamou 1986), of 54–97% in Sierra Leone (Taylor 1989), of 20–45% in Burkina Faso (Sere 1991), of 67–84% in Ivory Coast, and of 64–100% in Mali (Sy *et al*. 1993). In Tanzania, the yield loss estimates ranged from 25–100% (Luzi-Kihupi *et al*. 2001). It was reported that some farmers in the Kilombero valley (eastern Tanzania) could not harvest any rice while others completely abandoned their fields. This is also true in Bujonde Ward in Kyela (southern highlands, Tanzania) near Malawi where in 1995 farmers also abandoned the severely infected rice crop and grazed their cattle in those rice fields (Kanyeka – pers. comm.). Crop abandonment due to the infection of rice fields by RYMV was also reported in Zamfara State, Nigeria (Alegbejo *et al*. 2001).

Management practices for *Rice yellow mottle virus* genus *Sobemovirus* and insect vectors

The control of RYMV has been largely concentrated on the development of resistant varieties because the host plant resistance is the most farmer-friendly pest management option. RYMV caused devastating epidemics in countries with one or more highly susceptible varieties on a large acreage (e.g. Sindano, Basmati 217 and IR 22 in Kenya; BG 90-2 in Mali; Bouake 189 in Ivory Coast; IR 1529-680-3 in Niger and Jaya in Senegal) (Singh 1995). Most of the popularly grown varieties in Tanzania such as Supa, Kula na Bwana, Afaa Mwanza, and IR 54 are highly susceptible (Luzi-Kihupi 2001). Varieties found resistant to RYMV in West Africa include; IRAT 133, IRAT 156, IR 47686-15-5-1, WABIS 18, FARO 300 and ITA 305 (Awoderu 1991; WARDA 1994). In East Africa, the resistant varieties include IR 47686-15-1-1, Gigante, IR 53734-27-1, FARO 300, TGR 78, ITA 305, IRAT 302, CT 7244-9-1-52, Supa SSD1 and Supa SSD5 (Luzi-Kihupi 2001). Also reported to be resistant to RYMV are FARO 11, ITA 235, IRAT 235, IRAT 133, FARO 300 and ITA 195 (Kanyeka *et al*. 1996).

Insecticides such as endosulfan, lindane, phosphamidon, diazon, dimethoate, carbofuran, malathion, and carbaryl have been used against insect vectors of RYMV in Mali (Coulibaly 1995) and Madagascar (Reckhaus & Andriamasintseheno 1995). According to Breniere (1983), spreading a light layer of insecticides or petrol on the surface of the water and thus causing insects to drop on it, as well as using granulated insecticides in the water of the paddy against the larvae are effective strategies for the control of hispid beetles.

Cultural control is the manipulation of the agroecosystem to make it unfavourable for insect pests and more suitable for crop growth and natural enemies of the pests (Nwilene & Nwanze 1998). WARDA's Integrated Pest Management Task Force (IPM-TF) and national rice scientists have recommended the following cultural practices to farmers in Madagascar, Mali, Niger, Nigeria and Ivory Coast: (1) destruction of rice residues after harvest and ratoons that harbour the virus and insect vectors, (2) synchronous planting, (3) diversification of varieties on a single plot, (4) change of site for nurseries, (5) early transplanting before the outbreak of *Trichispa sericea* and reduction in spacing of plants, (6) rouging of infected plants and immediate replanting, (7) reduction of fertiliser application (e.g. urea) on attacked plots, (8) early and double weeding to reduce the weed reservoir of the virus and insect vectors, and (9) withholding irrigation between planting to provide a rice-free period and so restrict the build-up of the virus infection and insect population (Reckhaus & Adamou 1986; Coulibaly 1995; Reckhaus & Andriamasintseheno 1995; Abo *et al*. 1998). In Tanzania, the husbandary methods recommended by Fakih *et al*. (1998) include; controlling water levels in the fields since Hispid beetles readily attack tender plants too deeply immersed in water and the use of *Tephrosia vogelii* (syn. *Cracca vogelii*) as an insect repellent. It is a leguminous plant native to Tropical Africa containing rotenone, an important non-residual insecticide.

THE FUTURE

1. More information on the dynamics of the virus spread and the role of the vectors is needed in each of the RYMV prevalent country. Future studies should be geared in this direction in order to provide a basis for the development of appropriate methods of control.

2. Breeders are advised to use the 6 different strains of RYMV (currently believed to exist) as sources of inocula in studies of the resistance of rice against RYMV since the use of resistant varieties

remains to date the most economical and effective means in the management of the disease.

3. More research on the distribution and distinction between strains needs to be conducted in view of their epidemiological importance. Also, the availability of this information may help breeders to focus on areas that are known to have a high disease incidence and where the relevant strains cause more damage than in the relatively low incidence areas.

4. Also, the influence of environmental factors such as temperature, rainfall, or relative humidity on the vector population and RYMV incidence need be elucidated.

References

Abo M.E. (1998): Studies on the mode of transmission of RYMV. [Ph.D. Thesis.] Ahmadu Bello University, Zaria, Nigeria.

Abo M.E., Alegbejo M.D, Sy A.A., Misari S.M. (2000): An overview of the mode of transmission, host plants and methods of detection of rice yellow mottle virus. J. Sustainable Agric., **17**: 19–36.

Abo M.E., Okusanya B.A., Imolehin E.D. (1995): The status of *rice yellow mottle virus* (RYMV) in Nigeria. In: 1st Int. Symp. RYMV, 18–22 Sept. 1995, Mbe, WARDA/ADRAO, Bouake, Cote d'Ivoire.

Abo M.E., Sy A.A., Alegbejo M.D. (1998): Rice Yellow Mottle Virus (RYMV) in Africa: Evolution, distribution and economic significance on sustainable rice production and management strategies. J. Sustainable Agric., **11**: 85–111.

Ali F. (1999): Epidemiology of *rice yellow mottle virus* in Tanzania. [Ph.D. Thesis.] University of Greenwich.

Ali F.H. (2001): Survey of rice yellow mottle virus disease in the two cropping systems in Tanzania. In: Workshop on Rice Research in Eastern and Southern Africa Region, 12–16 March, 2001, Kilimanjaro Agricultural Training Institute, Moshi, Tanzania.

Ali F.H., Abubakar Z.M. (1995): Incidence of *rice yellow mottle virus* in Zanzibar. In: 1st Int. Symp. RYMV, 18–22 Sept. 1995, Mbe, WARDA/ADRAO, Bouake, Cote d'Ivoire.

Alegbejo M.D., Raji B.A., Abubakar I.U. (2001): Report on an outbreak of *rice yellow mottle Sobemovirus* in Zamfara State, Nigeria submitted to the Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria.

Anno-Nyako F.O., Twumasi J.K. (1995): The threat of RYMV and the future of rice production in Ghana. In: 1st Int. Symp. RYMV, 18–22 Sept. 1995, Mbe, WARDA/ADRAO, Bouake, Cote d'Ivoire.

Awoderu V.A. (1991): *Rice yellow mottle virus* in West Africa. Trop. Pest Manage., **37**: 356–362.

Bakker W. (1970): Rice yellow mottle a mechanically transmissible virus disease of rice in Kenya. Neth. J. Plant Pathol., **76**: 53–63.

Bakker W. (1971): Three new beetle vectors of *rice yellow mottle virus* in Kenya. Neth. J. Plant Pathol., **77**: 201–206.

Bakker W. (1974): Characterisation and ecological aspects of *rice yellow mottle virus* in Kenya. Agricultural Research Report. Centre for Agricultural Publishing and Documentation, Wageningen.

Bakker W. (1975): *Rice yellow mottle virus*. CMI/AAB Description of Plant Viruses No. 149.

Banwo O.O. (2002): Vector identity, bionomics and molecular characterisation of *rice yellow mottle virus* in Tanzania. [Ph.D. Thesis.] Sokoine University of Agriculture, Morogoro, Tanzania.

Banwo O.O. (2003): *Rice yellow mottle virus* disease: A national problem in Tanzania. Acta Phytopathol. Entomol. Hung., **38**: 99–107.

Banwo O.O., Makundi R.H., Abdallah R.S., Mbapila J.C., Kimmins F.M. (2002a): Bionomics and importance of two species of *Chaetocnema* in *rice yellow mottle virus* transmission in lowland rice in Tanzania. Phytoparasitica, **30**: 96–104.

Banwo O.O., Winter S., Koerbler M., Abdullahi I., Abdallah R.S., Makundi R.H. (2002b): Molecular characterisation of *rice yellow mottle virus* isolates from Tanzania. In: 8th Int. Plant Virus Epidemiology Symp., May 12–17, 2002, Aschersleben, Germany.

Breniere J. (1983): The Principal Insect Pests of Rice in West Africa and Their Control. West Africa Rice Development Association, Monrovia, Liberia. 2nd ed.

Coulibaly Y.M. (1995): Le RYMV ou Mosaique du riz: Une menace pour l'intensification de la riziculture a l'office du Niger. In: 1st Int. Symp. RYMV, Mbe, 18–22 Sept., 1995, WARDA/ADRAO, Bouake, Cote d'Ivoire.

Coyne D.L., Plowright R.A., Fofana I. (1996): Preliminary investigations of nematodes associated with rice in Guinea, Benin and Togo. Afro-Asian J. Nematol., **6**: 70–72.

Dinant S., Lot H. (1992): *Lettuce mosaic virus*. Plant Pathol., **41**: 528–542.

FAO (1994): Annual Report Research Highlights. Rome, Italy.

FAO (2001): Annual Report Research Highlights. Rome, Italy, **2**: 22–23.

Fakih A.O., Hamad S.F., Wipfler C. (1998): IPM in irrigated rice for smallholders in Pemba, Zanzibar. ILEIA Newslett., **13**: 16.

Fargette D., Pinel A., Halimi H., Brugidou C., Fauquet C., Van Regenmortel M. (2002): Comparing of molecular and immunological typing of isolates of *rice yellow mottle virus*. Arch. Virol., **147**: 583–586.

Fauquet C.M., Thouvenel J.C. (1977): Isolation of *rice yellow mottle virus* in Ivory Coast. Plant Dis. Rep., **61**: 443–446.

Fauquet C.M., Thouvenel J.C. (1987): Plant Viral Diseases in Ivory Coast. Initiations-Documentation Techniques No 46. ORSTOM-PARIS.

Francki R.I.B., Milne R., Italta T. (eds) (1985): Atlas of Plant Viruses. Vol. 1. CRC Press, Boca Raton, Florida.

Fulton J.P, Gergerich R.C., Scott H.A. (1987): Beetle transmission of plant viruses. Annu. Rev. Phytopathol., **25**: 111–123.

Heinrichs E.A., Sy A.A., Akator S.K., Oyediran I. (1997): Seasonal occurrence of *rice yellow mottle virus* in lowland rice in Cote d'Ivoire. Int. J. Pest Manage, **43**: 291–297.

Houston D.F. (1972): Rice chemistry and technology. American Association of Cereal Chemists Inc., St. Paul, Minnesota.

Hull R. (1986): The potential for using dot-blot hybridisation in the detection of plant viruses. In: Jones R.A.C., Torrance L. (ed.): Developments and Applications in Virus Testing. Dev. Appl. Biol., **1**: 3–12.

Hull R. (1988): The sobemovirus group. In: Koenig I.K. (ed.): The Plant Viruses. Vol. 3. Polyhedral Virus with Monopartite RNA Genomes. Plenum Press, New York.

IITA (1978): Annual Report, Rice Research Programme. Ibadan, Nigeria: 33–34.

IRRI (1985): International Rice Research 25 Years of Partnership. Los Banos, Philippines.

IRRI (1987): IRTP – East Africa Annual Report. Morogoro-Tanzania.

John V.T., Thottappilly G., Awoderu V.A. (1984): Occurrence of *rice yellow mottle virus* in some Sahelian countries of West Africa. FAO Plant Protect. Bull., **32**: 86–87.

Kanyeka Z.L., Msomba S.W., Penza M.S.F., Alluri K. (1995): Rice ecosystems in Tanzania. Int. Rice Res. Notes, **20**: 1.

Kanyeka Z.L., Kibanda J., Mbapila J. (1996): *Rice yellow mottle virus* in Tanzania. In: Sem. Potential and Constraints for Improvement of Rice Cultivation in Tanzania, 11–15 March 1996, KATC, Moshi, Tanzania.

Kihupi A.N., Pillai K.G. (1989): Rice research and production trends in Tanzania. In: IRTP Workshop, 21–23 March, 1989. ICIPE, Duduville, Nairobi, Kenya.

Konate G., Traore O., Coulibaly M. (1997): Characterisation of *rice yellow mottle virus* isolates in Sudano-Sahelian areas. Arch. Virol., **142**: 1117–1124.

Konate G., Sarra S., Traore O. (2001): *Rice yellow mottle virus* is seed-borne but not seed transmitted in rice seeds. Eur. J. Plant Pathol., **107**: 361–364.

Luzi-Kihupi A., Mgoo S.O., Bernando V.R., Mabagala R.B., Mlozi M.R.S., Msolla-Nchimbi S., Mushobozy D.M.K. (2000): Rice yellow mottle wirus (RYMV) in Tanzania. In: 1st University-wide Conf., 5–7 April, 2000. Sokoine University of Agriculture, Morogoro, Tanzania.

Luzi-Kihupi A. (2001): *Rice Yellow Mottle Virus* in Tanzania. In: Rice Research Workshop for Rice Researchers in Kenya, Malawi, Tanzania and Zambia, March 12–16, 2001. Kilimanjaro Agricultural and Training Centre, Moshi, Tanzania.

Mansour A.N., Baillis K.W. (1994): Serological relationships among *rice yellow mottle virus* isolates. Ann. Appl. Biol., **125**: 133-140.

Maule J., Wang D. (1996): Seed transmission of plant viruses: a lesson in biological complexity. Trends Microbiol., **4**: 153–158.

Nault L.R., Styer W.E, Coffey M.E., Gordon D.T., Negi L.S., Nibblet C.L. (1978): Transmission of *maize chlorotic mottle virus* by chrysomelid beetles. Phytopathology, **68**: 1071.

N'Guessan P., Pinel A., Sy A.A., Ghesquire A., Fargette D. (2001): Distribution, pathogenecity and interaction of two strains of *rice yellow mottle virus* in forested and savanna zones of West Africa. Plant Dis., **85**: 59–64.

Nwilene F., Nwanze K.F. (1998): Cultural control of insect pests in tropical crops. In: Dhaliwal G.S., Heinrichs E.A. (eds.): Critical Issues in Insect Pest Management. Commonwealth Publ., New Delhi, India: 26–66.

Okioma S.N.M., Muchoki R.N., Gathuru E.M. (1983): Alternate hosts of *rice yellow mottle virus* in the lake Victoria basin in Kenya. Trop. Pest Manage, **29**: 295–296.

Opalka N., Fauquet C.M., Johnson J., Beachy R.N., Yeager K. (1995): Three dimensional structure analysis of RYMV. In: 1st Int. Symp. RYMV, Mbe, 18–22 Sept., 1995, WARDA/ADRAO, Bouake, Cote d'Ivoire.

Ou S.H. (1985): Rice Diseases. 2nd ed. Kew, Commonwealth Mycological Institute, England.

Pinel A., N'Guessan P., Bousalem M., Fargette D. (2000): Molecular variability of geographically distinct isolates of *rice yellow mottle virus* in Africa. Arch. Virol., **145**: 1621–1638.

Pinto Y.M. (2000): Transgenic resistance to rice yellow mottle virus disease: highlighting some of the issues facing the potential introduction of biotechnological products into Africa. AgBiotechNet., **2**: 1–4.

Raymundo S.A., Buddenhaggen I.W. (1976): A rice disease in West Africa. Int. Rice Commis. Newslett., **29**: 51–53.

Raymundo S.A., Buddenhaggen I.W., Fomba S.N., Akibbo-Betts D.T. (1979): Recent advances in knowledge of rice viruses and resistance to a beetle transmitted mottle of rice in West Africa. In: Sem. Proc. Rice Breeding and Varietal Improvement II. 13–17 Sept., 1979. West Africa Rice Development Association, Mbe, Ivory Coast. No. 6: 203–212

Reckhaus P.M., Adamou I. (1986): Rice diseases and their economic importance in Niger. FAO Plant Protect. Bull., **34**: 77–82.

Reckhaus P.M., Randrianangaly S. (1990). *Rice yellow mottle virus* on rice in Madagascar. Int. Rice Res. Notes, **15**: 1.

Reckhaus P.M., Andriamasintseheno H.E. (1995): Development of an Integrated Pest Management Strategy to fight RYMV and constraints to its implementation in Madagascar. In: 1st Int. Symp. RYMV, 18–22 Sept., 1995, WARDA/ADRAO, Bouake, Cote d'Ivoire.

Reckhaus P.M., Andriamasintseheno H.E. (1997): *Rice yellow mottle virus* in Madagascar and its epidemiology in north west of the island. J. Plant Dis. Protect., **104** (3): 289–295.

Rossel H.W. (1986): *Rice yellow mottle virus* and African soybean dwarf virus, newly discovered virus disease of economic importance in West Africa. Tropical Agricultural Research Series No. 19. Tropical Agricultural Research Centre, Ministry of Agriculture, Japan: 145–153.

Rossel H.W., Thottappilly G., Buddenhaggen I.W. (1982): Occurrence of *rice yellow mottle virus* in two important rice growing areas of Nigeria. FAO Plant Protect. Bull., **31**: 137–139.

Ryder E.J. (1973): Seed transmission of lettuce mosaic virus in mosaic resistant lettuce. J. Am. Soc. Hortic. Sci., **98**: 610–614.

Seghal O.P. (1981): Southern bean mosaic group. In: Kurstak E. (ed.): Plant Virus Infections, Comparative Diagnosis. Elsevier/North Holland Biomedical Press, Amsterdam: 91–121.

Sere Y. (1991): Phytopathologie du riz-syntheses des activities 1990. In: Rapport d'activities du Programme Riz. Doc. Roneot. INERA, Ouagadougou: 72–97.

Singh B.N. (1995): Breeding for r*ice yellow mottle virus* resistance. In: 1st Int. Symp. RYMV, Mbe, 18–22 Sept., 1995. WARDA/ADRAO, Bouake, Cote d'Ivoire.

Sy A.A. (1994): The Integrated Pest Management-Task Force (IPM-TF) Monitoring Tour in Mali, Nov., 1994.

Sy A.A., Alluri K., Akator K. (1993): Selection of RYMV resistant and estimation of RYMV induced yield loss under natural and artificial pressure. In: WARDA Annual Report for 1993, WARDA, Bouake, Ivory Coast: 44–45.

Taylor D.R. (1989): Resistance of upland rice varieties to pale *yellow mottle virus* disease in Sierra Leone. IRRI Newslett., 14: 11.

Thottappilly G. (1992): Plant virus diseases of importance to African agriculture. J. Phytopath., **134**: 265–288.

Thottappilly G., Rossel W. (1993): Evaluation of resistance to *rice yellow mottle virus* in *Oryza* species. Indian J. Virol., **9**: 65–73.

Traore O.,Pinel A., Fargette D., Konate G. (2001): First report and characterisation of *rice yellow mottle virus* in Central Africa. Plant Dis., **85**: 920.

Tsuboi T., Goto A., Boua B., Koto H. (1995): Outbreak of *rice yellow mottle virus* in paddy rice in Bandoma basin on Ivory Coast and its epidemiological causes. In: 1st Int. Symp. RYMV held at WARDA, Mbe/Bouake, Ivory Coast, 18–22 Sept., 1995.

WARDA (West Africa Rice Development Association) (1993): Report of the multidisciplinary task force monitoring tour to the Republics of Cote d'Ivoire and Ghana.

Yaboue W.N. (1989): Screening for resistance to RYMV in Ivory Coast. In: Report on Monitoring Tours to West African Countries, 1988 and 1989, Africa. International Rice Testing Programme for Africa: 50–51.

Yamatoto T., Pyuza A.G., Lusewa R.C., Harrison M., Tomikata M. (1995): Rice diseases in some parts of Tanzania. Kilombero Agric. Training Centre Newslett., **1**: 4.

Yassi N'gon A.M, Ritzenthaler C., Brugidou C., Fauquet C., Beachy R.N. (1994): Nucleotide sequence and genome characterisation of *rice yellow mottle virus* RNA. J. Gen. Virol., **75**: 249–257.

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Souhrn

Banwo O.O., Alegbejo M.D., Abo M.E. (2004): ***Rice yellow mottle virus* rodu *Sobemovirus*: kontinentální problém Afriky**. Plant Protect. Sci., **40**: 26–36.

Virus *Rice yellow mottle virus* rodu *Sobemovirus* byl poprvé pozorován v Keni v roce 1966. Choroba způsobená tímto virem se rychle stává hlavním limitujícím faktorem produkce rýže v Africe a na přilehlých ostrovech. Vyskytuje se v zemích východní, západní a jižní Afriky a odnedávna i ve střední Africe. Přenáší se hmyzími vektory, jako jsou druhy rodu *Chaeoctonema*, *Sesselia pusilla* a *Trichispa sericea* (všechny patří do řádu *Coleoptera*), a rovněž mechanicky. Do dnešní doby bylo zjištěno šest kmenů tohoto viru. Ztráty výnosu způsobené virem dosahují 20–100 %. Pro minimalizaci škod způsobených u rýže touto chorobou byl navržen systém integrované ochrany. V práci je uveden přehled vlastností viru, je pojednáno o symptomatologii, okruhu hostitelů, rozšíření kmenů, přenosu, dynamice vektorů a šíření viru, ekonomickém významu a o strategii ochranných opatření. Je rovněž zdůrazněna potřeba dalšího výzkumu viru.

Klíčová slova: *Rice yellow mottle virus*; *Sobemovirus*; kmeny viru; rýže; Afrika

Corresponding author:

Dr. Olalekan Oyeleke Banwo, Ahmadu Bello University, Faculty of Agriculture, Department of Crop Protection, P.M.B. 1044, Zaria, Nigeria
tel.: + 234 69 550 681, e-mail: banleks@yahoo.co.uk