Evaluation of a set of near isogenic lines (NILS) for rice yellow mottle virus (RYMV) resistance and farmers’ participatory varietal evaluation in Sierra Leone

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Rice yellow mottle virus (RYMV) is the most important rice infecting virus in Africa. Isolates of the virus were collected from Eastern, Southern and Northern Provinces of Sierra Leone and evaluated for pathogenicity on rice, using visual symptom rating and other disease-related traits such as plant height and yield depression. Near Iso-lines NIL 2, NIL 16, NIL 54 and NIL 130, developed by AfricaRice and conferring RYMV resistance were evaluated for resistance to the disease under natural infection. The accessions, together with popularly grown released and local rice varieties, were evaluated by farmers in demonstration plots in the Eastern, Southern and Northern Provinces of Sierra Leone. Results show that the isolates varied in pathogenicity but all developed symptoms of the disease following inoculation of rice plants all the NIL accessions were resistant to the disease. NIL 2 was identified as the best variety by 5, 2.5 and 42.5% farmers in Kenema, Bo and Kambia, respectively. NIL 130 was also identified as the best variety by 7.5, 17.5 and 5% farmers in Kenema, Bo and Kambia, respectively. High tillering and panicles with many spikelets were the main selection criteria by farmers. NIL 16 and NIL 54 were location-specific and selected as the best variety by 20 and 12.5% farmers in Kenema and Kambia, respectively. The NILS, particularly NIL 2 and NIL 130 with multi-locational acceptance, show promise for rice varietal improvement in Sierra Leone.

Key words: Rice yellow mottle virus, isolates, pathogenicity, varietal selection.

INTRODUCTION

Rice yellow mottle virus (RYMV), Sobemovirus was first reported in 1970 near Lake Victoria in the Nyanza province of western Kenya (Bakker, 1974). It was discovered in Eastern Sierra Leone in 1976 (Raymundo and Buddenhagen, 1976) and has since then been found in most parts of Sierra Leone, causing yield reduction in excess of 80% in susceptible rice cultivars (Taylor, 1989). The disease is most common in lowland rice cultures, including mangrove swamp and floating rice, but also in the uplands (Awoderu, 1991). RYMV disease occurs sporadically in some areas but is more endemic where intensified cropping is practiced. Severity levels vary from...
year to year.

Rice is the staple in Sierra Leone with over 70% of farmers cultivating the crop, mostly for subsistence. However, the Government of Sierra Leone’s desire to boost production to meet national needs and excess for export is encouraging intensification and commercialization of rice cropping. This is likely to increase the incidence of the disease in lowland rice cultures.

Serodiagnostic tests on viral isolates in Sierra Leone indicate that isolates are closely related but with some degree of divergence (Fomba, 1990; Taylor, 2000). The virus induces chlorosis in leaves, stunting and yield reduction in susceptible hosts. N’Guessan et al. (2001) reported a significant relationship between symptom severity and yield loss. However, yield losses allowed better discrimination among isolates and varietal responses to RYMV infection than did symptom expression or plant height. Large differences in pathogenicity were observed amongst isolates when inoculated into different host plants. Issaka et al. (2012) reported the existence of several pathotypes among RYMV isolates collected in Niger. Sow et al. (2015) observed variability in aggressiveness of RYMV isolates in West Africa. Because of RYMV’s devastating effect on the crop (Kouassi et al., 2005), extensive research has been conducted on the development of varieties with resistance to the disease (Salaudeen, 2014; Sereme et al., 2016).

Some rare accessions of African cultivated Oryza sativa (Gigante-Tete) and traditional rice species Oryza glaberrima (Tog 5681) are highly resistant to RYMV (Ndjiondjop, 1999). The high and partial resistances are controlled by a single recessive gene (rymv) and several genes (quantitative traits loci), respectively. However, the natural recessive resistance gene found in Gigante is more stable than both the partial resistance and the transgenic resistance (Sorho et al., 2005). The mode of resistance of these rice plants has been elucidated (Ndjiondjop et al., 2001) and resides on the point mutation of the plant factor that is supposedly interacting with the gene Vpg located in the RYMV genome. The resistance gene was mapped on the long arm of chromosome 4 in a 3.7-cM interval spanned by PCR markers (Ndjiondjop, 1999; Albar et al., 2003). The major gene for resistance against RYMV (Rymv 1) has been identified in the resistant O. sativa variety Gigante (Albar et al., 2006). This gene encodes a translation initiation factor (eIF(iso)4G) and is also responsible for the resistance of the O. glaberrima accessions Tog5681 and Tog5672, whose alleles (rymv1-3 and rymv1-4, respectively) are distinct from each other and are both distinct from that of Gigante (rymv1-2) which is fine-mapped on chromosome 4. The resistance gene RYMV2 has also been identified in an accession Tog7291 (Thiemele et al., 2010).

MAS, also called marker-assisted backcrossing (MAB), is the process of using the results of DNA tests to assist in the selection of individuals which will become the parents in the next generation of a genetic improvement program. This approach has been developed to avoid problems connected with conventional plant breeding by changing the selection criteria from the selection of phenotypes towards the selection of genes that control traits of interest, either directly or indirectly. MAS techniques appear to be most advantageous for the introgression of the single recessive RYMV gene. It may allow earlier selection and reduces the plant population size used during selection programs. Furthermore, it is a diagnostic tool for tracing the presence of the target RYMV gene for which direct selection is difficult or impossible (foreground selection). AfricaRice has introgressed RYMV1 resistant gene from the cultivar Gigante (a donor parent) into the background of locally-adapted but susceptible varieties (IR 64, FKR 28, Sahelika, IR 47) using molecular markers associated with the rymv1-2 resistant allele. The basis by which the Near Isogenic Lines (NILs) were developed.

In this paper, we report (i) the evaluation of NILs for resistance to RYMV isolates in Sierra Leone, (ii) the pathogenicity testing of RYMV isolates in Sierra Leone, under natural infection, on NILs to evaluate their resistance to the disease, and (iii) farmers’ assessment of the varieties.

METHODOLOGY
Isolate collection

RYMV isolates were collected in 2009 from various locations in Sierra Leone (Table 1 and Figure 1).

Evaluation of isolates

Inocula were prepared by macerating 2.5 g of young infected leaves in 100 ml of 0.01 m phosphate buffer (pH 7) in a wharing blender. The homogenate was sieved through cheese cloth and the filtrate used to inoculate test plants. Fine grade carborundum (400-mesh) was added to facilitate infection.

Isolates were inoculated onto 3-weeks old rice seedlings of the variety ROK 24 established in plastic buckets at the rate of one seedling per hill and three hills per bucket spaced 10 cm apart. Non-inoculated plants were established as control.

Plants received 3.6 g 15:15:15 compound fertilizer per bucket 2 weeks after seeding (WAS) and 0.3 g urea 6 and 10 WAS. Daily observations were made up to 2 weeks after inoculation for the expression of symptoms in the host. Plant height was measured at maturity and yield obtained after harvest. Plant height and yield reduction were obtained by subtracting the yields of inoculated plants from those of the control plants and computing percentage values relative to the control.

Field evaluation of rice varieties under natural infection levels

Resistant accessions (NIL 2, NIL 16, NIL 54, NIL 130), susceptible checks (IR 64, FKR 28, SAHELIKA, IR 47) and the RYMV-resistant
Table 1. RYMV isolates collection sites.

<table>
<thead>
<tr>
<th>Site</th>
<th>Chiefdom</th>
<th>District</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mano junction</td>
<td>Nongowa</td>
<td>Kenema</td>
</tr>
<tr>
<td>Jimi site, Blama</td>
<td>Small Bo</td>
<td>Kenema</td>
</tr>
<tr>
<td>New site, Blama</td>
<td>Small Bo</td>
<td>Kenema</td>
</tr>
<tr>
<td>China Farm</td>
<td>Lambayama</td>
<td>Kenema</td>
</tr>
<tr>
<td>Geima</td>
<td>Dama</td>
<td>Kenema</td>
</tr>
<tr>
<td>Joru</td>
<td>Gaura</td>
<td>Kenema</td>
</tr>
<tr>
<td>Zimmi</td>
<td>Makpele</td>
<td>Pujehun</td>
</tr>
<tr>
<td>New London</td>
<td>Kakua</td>
<td>Bo</td>
</tr>
<tr>
<td>Makeni</td>
<td>Bombali Sebora</td>
<td>Bombali</td>
</tr>
<tr>
<td>Rokupr</td>
<td>Magbema</td>
<td>Kambia</td>
</tr>
<tr>
<td>Maforki</td>
<td>Maforki</td>
<td>Port Loko</td>
</tr>
<tr>
<td>Simbek</td>
<td>Bureh</td>
<td>Port Loko</td>
</tr>
<tr>
<td>Malal</td>
<td>Bureh</td>
<td>Port Loko</td>
</tr>
</tbody>
</table>

Figure 1. Map of Chiefdoms in Sierra Leone indicating RYMV isolates collection sites in red.

check Gigante were established in upland nurseries and transplanted into the lowlands 3 WAS in an RYMV-endemic site at
Figure 2. Effect of RYMV isolates in the rice variety ROK 24 (Inoculated left and right, control center).

RESULTS AND DISCUSSION

Figures 2 to 5 indicate that all isolates collected produced symptoms of chlorosis, stunting and yield reduction in infected rice plants. Variability existed amongst isolates in the period for expression of symptoms following inoculation. Earliest symptoms occurred with the Zimmi, New London and China Farm isolates and latest in the Makeni isolate (Figure 3).

Variability also occurred in levels of stunting induced by isolates, with severity being highest in Zimmi, Malal, Geima Dama and Mano junction isolates (Figure 4). All isolates also suppressed grain yield, Malal, China farm, Zimmi, Geima Dama, New site and Mano junction being the most effective (Figure 5).

The Zimmi isolate appears to be the most aggressive with regard to the time taken for symptom expression after infection, stunting and yield reduction. Pinel et al. (2000) observed five major strains of RYMV in Africa with nucleotide and amino acid divergence indicating geographical distinctness; Issaka et al. (2012) reported four major pathotypes among RYMV isolates in Niger and Sow et al. (2015) reported variability in aggressiveness amongst RYMV isolates in the West African sub-region. Indications are that strain differentiation occurs within the West African sub-region and that even within countries some degree of divergence occurs. Therefore, although the results indicate that all isolates are capable of producing symptoms of the disease in susceptible rice varieties.
plants, variability in the pathogenicity of RYMV isolates in host plants will need to be taken into consideration in evaluating RYMV resistance in rice varieties.

When the varieties were exposed to natural RYMV infection in an RYMV-endemic farmer’s field, Gigante showed no symptom of the disease (Table 2). Disease scores were less than 1 for NIL 130 and NIL 16, and less than 2 for NIL 2 and NIL 54, indicating resistance of these varieties to RYMV. Scores for the susceptible varieties ranged from 3.7 for Sahelika to 5.3 for FKR 28, indicating
Figure 5. Effect of RYMV isolates on yield reduction.

Table 2. Performance of RYMV-resistant rice varieties in a farmer’s field testing at Rokupr.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Mean disease score</th>
<th>Plant height (cm)</th>
<th>Yield (g/4 m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GIGANTE</td>
<td>0</td>
<td>120.6</td>
<td>748</td>
</tr>
<tr>
<td>IR 64</td>
<td>4.7</td>
<td>110.0</td>
<td>1609</td>
</tr>
<tr>
<td>NIL 130</td>
<td>0.7</td>
<td>112.7</td>
<td>2516</td>
</tr>
<tr>
<td>FKR 28</td>
<td>5.3</td>
<td>125.4</td>
<td>1735</td>
</tr>
<tr>
<td>NIL 2</td>
<td>1.7</td>
<td>120.0</td>
<td>2167</td>
</tr>
<tr>
<td>SAHELIKA</td>
<td>3.7</td>
<td>11.09</td>
<td>1965</td>
</tr>
<tr>
<td>NIL 16</td>
<td>0.7</td>
<td>112.0</td>
<td>2601</td>
</tr>
<tr>
<td>IR 47</td>
<td>5.0</td>
<td>128.4</td>
<td>836</td>
</tr>
<tr>
<td>NIL 54</td>
<td>1.7</td>
<td>145.7</td>
<td>757</td>
</tr>
<tr>
<td>se.</td>
<td>0.4</td>
<td>1.9</td>
<td>62.7</td>
</tr>
</tbody>
</table>

Correlation analysis indicated that disease score was negatively correlated to plant height and yield with a value of -0.791 at 0.05 level of significance.

The results indicate that visual rating of period for symptom expression, reduction in plant height and grain yield per plant can be useful symptomatology studies for differentiating RYMV isolates and evaluating rice varieties for RYMV resistance. This is in accordance with the findings of Fomba et al. (2001), N’Guessan et al. (2001) and Sow et al. (2015). Resistance of the NILs to RYMV have been reported elsewhere in the West African sub-region (Sereme, 2016). These accessions could provide promising resistance sources for rice breeding. They could also be used for cultivation under integrated management systems in the sub-region.

Figure 6 shows varieties ranked by farmers as being amongst their best three varieties. At Rokupr, 69% of farmers included NIL 2 amongst their best three varieties and over 40% mentioned the variety as the best. In Bo, the most frequently selected variety was NERICA-L 19, selected by 85% of farmers (Figure 6). Amongst the NILS, 48% of farmers selected NIL 130 while 38% chose NIL 2 among their best three varieties. Over 15% of farmers included NIL 130 as their best variety (Figure 7). In Kenema, the most popular varieties were NERICA-L
Figure 6. Percentage of farmers including variety amongst best three varieties.

Figure 7. Percentage of farmers listing variety as best.
19 and ROK 14. Amongst the NILs, NIL 16 was the most frequently selected, with 63% of farmers including it amongst their best three varieties and 20% of farmers as their best entries (Figure 7).

Figure 8 lists farmers’ criteria for selecting the NILs. The most popular criterion was high tillering ability, selected by over 80% of farmers in all locations, followed by panicles with many spikelets. As all materials were not yet mature at the time of farmers’ evaluation, high yielding was not highly rated. RYMV resistance was not identified as a selection criterion since the incidence of the disease was low at all locations during the season. Joshi and Witcombe (2008), Wopereis et al. (2009), Singh et al. (2014) and Angarawai et al. (2016) identified farmer participatory varietal selection as the best approach for exposing farmers to cultivars and improving adoption rates.

The NILs show promise for improving rice production in Sierra Leone. Early indications are that they are acceptable to farmers and meet many of their selection criteria. Continued exposure of these accessions to farmers through extensive on-farm evaluation could significantly contribute to increasing rice yields in the sub region.

Conclusions

Artificial inoculation of the RYMV-susceptible rice variety, ROK 24, produced symptoms of the disease by all isolates. Isolates varied in their aggressiveness in inducing visual disease symptoms and disease-related traits such as plant height and yield. All NILs showed good resistance to RYMV under natural infection levels in the field. Based on farmers’ participatory evaluation of the NILS, NIL 2 and NIL 130 seem to be more acceptable to farmers in all locations whereas NIL 16 and NIL 54 were location-specific for Kenema and Rokupr, respectively. These lines need to be further subjected to on-farm adaptive trials in RYMV “hot spots”.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES


