Drought, Salinity and Flooding Tolerance of *Oryza sativa*, *Oryza glaberrima* and their Interspecific Cultivars

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Summary: In the densely populated northern Namibia, seasonal wetlands are formed due to flooding from Angola. Even though the climate of this region is semi-arid, rice can be introduced to the seasonal wetlands. However, several environmental stresses, such as drought, salt accumulation and flooding, often occur in this region. The objective of the present study was to evaluate the drought, salinity and flooding tolerance of *Oryza sativa*, *Oryza glaberrima* and their interspecific cultivars. *O. sativa* showed the highest salinity tolerance among the three species, and *O. glaberrima* did the highest flooding tolerance. As for drought tolerance, there was no statistical difference among species probably because the experiment was conducted under greenhouse conditions using pots. Among the 37 cultivars tested, Guayaba showed relatively better tolerance of all the three stress environments. This indicated that Guayaba can be one of the candidate cultivar for rice introduction to semi-arid regions of Africa, such as north central Namibia, which could have multiple stress environments. *O. glaberrima* showed high xylem sap flow rates at recovery period from drought stress compared with *O. sativa* and interspecific cultivars. It is considered that many genotypes of *O. glaberrima* have a mechanism of rapid recovery from drought stress and can use newly irrigated water in drought condition.

Key words: Drought, Flooding, NERICA, *Oryza glaberrima* Steud., Rice, Salinity

Introduction

In the densely populated north central region of Namibia, seasonal wetlands are usually formed during the rainy season due to flooding from Angolan highland (Zegada–Lizarazu *et al.* 2007). Even though the climate of this region is semi-arid, e.g. annual rainfall is around only 400 mm, rice can be introduced to the seasonal wetlands by using the flood water (Awala *et al.* 2009). However, several environmental factors may affect the productivity of rice in this region. Because of the low rainfall (200 ~ 400 mm), rice will be exposed to drought stress during a growing period. Salt accumulation within surface soil layers due to less precipitation should also be the major factor affecting crop growth. Because water level in such area cannot be controlled due to the irregular rainfall, a short or prolonged flooding occurs. Therefore, abiotic stress such as drought, salinity and flooding affects growth and productivity of rice in semi-arid regions of Africa (Manneh *et al.* 2007). To solve these environmental problems, rice cultivars which are tolerant to drought, salinity and flooding stresses must be introduced. Moreover, shoot elongation ability is required for prolonged flooding tolerance which is regarded as the crucial ability to survive under turbid flooding conditions.

Several studies have been conducted on drought (Ndjiondjop *et al.* 2012), salinity (Awala *et al.* 2010) and flooding (Sakagami *et al.* 2009) stresses separately in cultivated rice. However, currently little information is available on these three multiple stress tolerance. The objectives of this study were to compare the drought, salinity and flooding tolerance among *Oryza sativa*, *O. glaberrima* and their interspecific cultivars including NERICA (New Rice for Africa), and to find out the candidate cultivars for rice introduction to semi-arid regions of Africa, such as north central Namibia, which could have multiple stress environments.

Materials and methods

A pot experiment was conducted to evaluate drought, salinity and flooding tolerance of the rice genotypes during the vegetative growth stage at Kinki University, Japan. Based on the previous experiments for flooding tolerance (Cisse *et al.* 2009, Cisse *et al.* 2010), 37 genotypes (*Oryza glaberrima* Steud. (14), *Oryza sativa* L. (14) and interspecific cultivars (9)) were used (Table 1).

Rice plants were grown in a greenhouse condition using plastic pots with 14.0 cm height and 11.3 cm diameter, each of which filled with 1.5 kg of soil (Table 2) mixed with synthetic fertilizer (N : P$_2$O$_5$ : K$_2$O = 0.2 : 0.2 : 0.2 g kg$^{-1}$ soil). The pots were arranged in a complete randomized block design with three
replications. The seeds of *O. glaberrima* genotypes were kept in a convection oven at 49°C for 7 d to break seed dormancy. Seeds were surface-sterilized with a Benomyl hydrate solution for 24 hr. After washing several times with water, seeds were soaked in water and incubated at 30°C for 48 hr in darkness to promote germination. Five pre-germinated seeds of each genotype were sown at the center of pot in June 20, 2012. Seedlings were thinned into one plant per pot at 12 d after sowing (DAS). Each stress of drought, salinity and flooding was given from 22 DAS in the following ways. In drought treatment, the soil water content (gravimetric basis) was adjusted every day at 5.8% for 28 d until harvesting. Salinity stress was imposed by adding 80 mM NaCl solution to pots for 15 d. Thereafter, as plants might be died owing to severe stress, NaCl solution in pots was replaced with water and plants were grown for 4 d. At 41 DAS, salinity stress was again imposed by adding 80 mM NaCl for 2 d
and 120 mM NaCl for 7 d. In flooding treatment, pots were placed in the container (1.0 m depth) which filled with turbid water (30 cm depth). The water level was raised every 10 cm per day. Rice seedlings were submerged completely in turbid water (1.0 m depth) from 29 to 50 DAS. The turbidity was kept at 53.8 ppm during flooding stress period. In control treatment, water level in the pots was maintained at approximately 3 cm above the soil surface until the plants were harvested.

The biomass samples were separated into shoots and roots. Each part was oven-dried at 80°C for 72 hr and the dry weight was measured. In control, drought and salinity treatment, xylem sap was collected by cutting the stems, placing cotton puffs on the top of the stumps, and wrapping them with thin polyethylene film, according to the method described by Morita and Abe (1999). The xylem sap flow rate per plant was determined as the increase in the weight of the cotton puff. To evaluate recovery from each stress, drought and salinity stress was finished at 3 d before collecting xylem sap, and the plants were grown under water logging conditions until harvested.

Results and discussion

Shoot and root growth

Table 3 shows the shoot dry weight and the relative shoot dry weight of 37 rice genotypes as affected by drought, salinity and flooding stress. In drought stress, CK801 showed the highest relative shoot dry weight followed by NERICA1, CG14 and CK90. In salinity stress, Agalhane showed the highest relative shoot dry weight followed by CK21, CK72 and CK801. In flooding stress, Dembou B. noir showed the highest relative shoot dry weight followed by Loubi blanc, Soutane rouge and Soutane blanc. Among the 37 cultivars tested, Guayaba (O. glaberrima) showed relatively better tolerance of all the three stress environments; it recorded the relative shoot dry weight of 0.225 in drought, 0.344 in salinity and 0.664 in flooding. This indicated that Guayaba can be one of the candidate cultivar for rice introduction to Namibia as the multiple stress tolerance cultivars. The range of the relative shoot dry weight was 0.14 – 0.26 in drought stress, 0.21 – 0.49 in salinity stress, and 0.01 – 0.93 in flooding stress. These results for shoot growth indicate that genotype variation caused by abiotic stresses was various among the three stresses. We found that the tolerance and susceptibility to drought showed very small genotypic differences within O. glaberrima, O. sativa and interspecific cultivars. In addition, there was no significant difference in the relative shoot dry weight in drought stress among species (Table 4) whereas previous studies showed that drought tolerance differed in cultivated rice (Morishima et al. 1962, Furuya et al. 1994, Jones et al. 1997). The reason for very small genotypic differences in this study is probably because the experiment was conducted under greenhouse conditions using pots. The relative shoot dry weight in salinity stress of O. sativa was significantly higher than that of O. glaberrima and interspecific cultivars (Table 4). The salinity tolerance of interspecific cultivars is reported to be better than that of O. sativa (Awala et al. 2010) or in between those of O. sativa and O. glaberrima (Sone et al. 2010). In the both studies, O. glaberrima showed much susceptibility to salinity compared with O. sativa. O. glaberrima showed the highest relative shoot dry weight among the three species in flooding stress (Table 4). In all the O. glaberrima genotypes except for CG14 and VIAH, the top leaf reached to water surface at the end of flooding stress. In O. sativa genotypes, all plants of Agalhane, CK21, Danta Blanc, Haira Koreye, Kakua and Soutane Rouge survived under flooding stress by resurfacing, but CK801, FR13A and WABS6-104 died completely during 21 d flooding stress. All of the interspecific cultivars died in flooding stress. The survival rates of O. glaberrima (90.5%) were higher than those of O. sativa (40.5%) and interspecific cultivars (0%). O. glaberrima genotypes have submergence escape strategy, that is, rapid leaf and stem elongation, therefore it can survive under short or prolonged flooding conditions (Sakagami et al. 2012). Our results suggest that O. glaberrima have submergence escape strategy under turbid flooding condition as well. On the other hand, indica cultivar FR13A, which is reported to be highly tolerant to submergence by restricting leaf and internode elongation during submergence and resuming the leaf development when flood water subsides (Singh et al. 2001, Das et al. 2005), died completely under submerged conditions for 21 d (Table 3). This is because the submergence period for 21 d in this experiment may be too long for FR13A to survive under flooding condition. Interspecific cultivars were severely affected by flooding stress on account of the slow shoot elongation.

The range of the relative root dry weight was 0.07 – 0.21 in drought stress, 0.06 – 0.35 in salinity stress, and 0.02 – 0.39 in flooding stress (Table 5). In drought stress, interspecific cultivars showed the highest value followed by O. sativa and O. glaberrima (Table 4). The relative root dry weight in salinity stress of O. sativa (0.240) was significantly higher than that of O. glaberrima (0.138) and interspecific cultivars (0.139). Although in this experiment rice plants were cultivated in pots where root growth was restricted, there was much genotypic differences in root dry weight compared with shoot dry weight. These results suggest that root growth should be appreciated in the evaluation of drought and salinity tolerance.

Xylem sap flow rate at recovery period

Xylem sap flow rates were evaluated as an indicator of recovery from drought and salinity stress (Table 6). Drought and salinity stress treatment was finished at 3 d before collecting xylem sap. In many genotypes of O. glaberrima and O. sativa, xylem sap flow rates of drought treatment were higher than that
Table 3: Shoot dry weight and relative shoot dry weight of *O. glaberrima*, *O. sativa* and their interspecific cultivars grown in different stress environments, i.e., drought, salinity and flooding

<table>
<thead>
<tr>
<th>Species</th>
<th>Genotype / cultivar</th>
<th>Shoot dry weight ($g$ plant$^{-1}$)</th>
<th>Relative shoot dry weight($^{ab}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control Drought Salinity Flooding Control Drought Salinity Flooding</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>O. glaberrima</em></td>
<td>CG14</td>
<td>16.88 4.01 3.75 1.62</td>
<td>0.238 0.225 0.098</td>
</tr>
<tr>
<td></td>
<td>Dembou B. blanc</td>
<td>19.58 3.66 5.01 11.85</td>
<td>0.188 0.258 0.599</td>
</tr>
<tr>
<td></td>
<td>Dembou B. noir</td>
<td>21.75 4.07 5.57 20.13</td>
<td>0.188 0.257 0.930</td>
</tr>
<tr>
<td></td>
<td>Djingua blanc</td>
<td>23.07 4.23 6.49 14.89</td>
<td>0.183 0.284 0.631</td>
</tr>
<tr>
<td></td>
<td>Douboutou II</td>
<td>17.41 3.45 5.33 4.67</td>
<td>0.198 0.307 0.267</td>
</tr>
<tr>
<td></td>
<td>Gnene sila</td>
<td>16.97 3.50 4.96 4.01</td>
<td>0.207 0.295 0.237</td>
</tr>
<tr>
<td></td>
<td>Guayaba</td>
<td>20.21 4.54 6.95 13.46</td>
<td>0.225 0.344 0.664</td>
</tr>
<tr>
<td></td>
<td>Loubi blanc</td>
<td>19.48 4.00 5.84 15.49</td>
<td>0.205 0.300 0.793</td>
</tr>
<tr>
<td></td>
<td>Malia Noir IV</td>
<td>17.59 3.22 5.96 6.21</td>
<td>0.183 0.339 0.353</td>
</tr>
<tr>
<td></td>
<td>Saligbeli</td>
<td>15.87 3.56 3.63 5.62</td>
<td>0.225 0.230 0.354</td>
</tr>
<tr>
<td></td>
<td>Saria 473</td>
<td>16.70 3.65 4.59 5.80</td>
<td>0.220 0.278 0.343</td>
</tr>
<tr>
<td></td>
<td>VIAH</td>
<td>14.51 2.89 3.73 1.86</td>
<td>0.199 0.256 0.125</td>
</tr>
<tr>
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<td>Wana Thireye</td>
<td>22.10 3.98 5.67 7.35</td>
<td>0.180 0.257 0.332</td>
</tr>
<tr>
<td></td>
<td>Yele 1A</td>
<td>18.60 4.09 5.13 3.75</td>
<td>0.220 0.277 0.199</td>
</tr>
<tr>
<td><em>O. sativa</em></td>
<td>Agalhane</td>
<td>18.62 4.10 9.09 3.13</td>
<td>0.221 0.488 0.169</td>
</tr>
<tr>
<td></td>
<td>Chinois</td>
<td>17.29 3.76 5.93 4.75</td>
<td>0.217 0.344 0.278</td>
</tr>
<tr>
<td></td>
<td>CK21</td>
<td>18.69 3.98 8.07 3.78</td>
<td>0.214 0.434 0.206</td>
</tr>
<tr>
<td></td>
<td>CK72</td>
<td>13.17 3.02 5.66 1.29</td>
<td>0.230 0.434 0.096</td>
</tr>
<tr>
<td></td>
<td>CK90</td>
<td>17.45 4.08 6.81 2.00</td>
<td>0.234 0.390 0.115</td>
</tr>
<tr>
<td></td>
<td>CK801</td>
<td>15.04 3.93 6.30 0.68</td>
<td>0.263 0.422 0.045</td>
</tr>
<tr>
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<td>Danta Blanc</td>
<td>18.14 3.44 5.26 7.50</td>
<td>0.189 0.290 0.414</td>
</tr>
<tr>
<td></td>
<td>FR13A</td>
<td>19.81 3.30 4.55 0.54</td>
<td>0.166 0.231 0.027</td>
</tr>
<tr>
<td></td>
<td>Haira Koreye</td>
<td>19.49 3.90 5.39 9.88</td>
<td>0.200 0.277 0.501</td>
</tr>
<tr>
<td></td>
<td>Kakua</td>
<td>20.40 3.50 6.46 2.83</td>
<td>0.172 0.317 0.139</td>
</tr>
<tr>
<td></td>
<td>Pokkali</td>
<td>21.05 3.01 7.34 3.92</td>
<td>0.143 0.348 0.183</td>
</tr>
<tr>
<td></td>
<td>Soutane blanc</td>
<td>18.77 3.75 5.25 13.38</td>
<td>0.200 0.280 0.708</td>
</tr>
<tr>
<td></td>
<td>Soutane rouge</td>
<td>20.52 3.84 4.64 15.13</td>
<td>0.187 0.227 0.737</td>
</tr>
<tr>
<td></td>
<td>WAB56-104</td>
<td>14.69 3.40 4.24 0.63</td>
<td>0.233 0.289 0.043</td>
</tr>
<tr>
<td>Interspecific</td>
<td>NERICA1</td>
<td>13.57 3.27 3.62 0.49</td>
<td>0.241 0.269 0.035</td>
</tr>
<tr>
<td></td>
<td>NERICA2</td>
<td>13.59 3.08 2.84 1.09</td>
<td>0.227 0.209 0.082</td>
</tr>
<tr>
<td></td>
<td>NERICA3</td>
<td>14.20 2.64 3.89 0.54</td>
<td>0.185 0.275 0.039</td>
</tr>
<tr>
<td></td>
<td>NERICA4</td>
<td>14.39 2.68 4.31 0.41</td>
<td>0.187 0.299 0.028</td>
</tr>
<tr>
<td></td>
<td>NERICA5</td>
<td>14.17 2.97 3.01 0.11</td>
<td>0.209 0.212 0.007</td>
</tr>
<tr>
<td></td>
<td>NERICA6</td>
<td>14.02 2.82 2.91 0.56</td>
<td>0.201 0.207 0.039</td>
</tr>
<tr>
<td></td>
<td>NERICA7</td>
<td>15.29 3.32 5.87 0.45</td>
<td>0.218 0.385 0.030</td>
</tr>
<tr>
<td></td>
<td>NERICA8</td>
<td>15.16 3.35 3.48 0.76</td>
<td>0.220 0.231 0.047</td>
</tr>
<tr>
<td></td>
<td>NERICA10</td>
<td>13.55 2.97 4.24 0.42</td>
<td>0.220 0.313 0.031</td>
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<td></td>
<td>LSD$_{0.05}$</td>
<td>1.49 0.62 1.20 4.13</td>
<td></td>
</tr>
</tbody>
</table>

1) Means of the three replications.
2) Relative value to the control.

Table 4: Comparison among *O. glaberrima*, *O. sativa* and interspecific cultivars for shoot and root growth and xylem sap flow rate as affected by drought, salinity and flooding stress

<table>
<thead>
<tr>
<th>Species</th>
<th>Shoot dry weight ($g$ plant$^{-1}$)</th>
<th>Root dry weight ($g$ plant$^{-1}$)</th>
<th>Xylem sap flow rate ($g$ h$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control Drought Salinity Flooding Control Drought Salinity Flooding Control Drought Salinity Flooding</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>O. glaberrima</em></td>
<td>18.62 3.77 5.19 8.34</td>
<td>13.88 1.60 1.85 1.47</td>
<td>0.543 0.863 0.398</td>
</tr>
<tr>
<td><em>O. sativa</em></td>
<td>18.08 3.64 6.07 4.96</td>
<td>12.11 1.62 2.81 1.82</td>
<td>0.613 0.673 0.395</td>
</tr>
<tr>
<td>Interspecific</td>
<td>14.21 3.01 3.60 0.53</td>
<td>9.12 1.42 1.23 nd$^2$</td>
<td>0.752 0.556 0.519</td>
</tr>
</tbody>
</table>

1) Means of the three replications. Values with the same alphabet letters within each column are not significantly different (P < 0.05) among the species by Tukey’s multiple range test.
2) Data were not taken.
of control, and in particular *O. glaberrima* showed high xylem sap flow rates at recovery period from drought stress (Table 4). On the other hand, interspecific cultivars did not show any recovery from drought stress. These results indicate that many genotypes of *O. glaberrima* have a mechanism of rapid recovery from drought stress and can use newly irrigated water in drought condition. As the genotypic differences in drought tolerance for shoot growth were not observed, xylem sap flow rates might be an indicator of drought tolerance and recovery from drought. Judging from xylem sap flow rates, there was not much recovery from salinity stress in all *O. glaberrima, O. sativa* and interspecific cultivars because the recovery period was short in this study.

Table 5 Root dry weight and relative root dry weight of *O. glaberrima, O. sativa* and their interspecific cultivars grown in different stress environments, i.e., drought, salinity and flooding

<table>
<thead>
<tr>
<th>Species</th>
<th>Genotype / cultivar</th>
<th>Root dry weight (g plant⁻¹)</th>
<th>Relative root dry weight (g plant⁻¹)</th>
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<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Drought</td>
<td>Salinity</td>
</tr>
<tr>
<td><em>O. glaberrima</em></td>
<td>CG14</td>
<td>16.44</td>
<td>2.41</td>
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<td></td>
<td>Dembou B. blanc</td>
<td>14.58</td>
<td>1.22</td>
</tr>
<tr>
<td></td>
<td>Dembou B. noir</td>
<td>12.99</td>
<td>1.24</td>
</tr>
<tr>
<td></td>
<td>Djingua blanc</td>
<td>12.61</td>
<td>1.65</td>
</tr>
<tr>
<td></td>
<td>Douboutou II</td>
<td>13.76</td>
<td>1.26</td>
</tr>
<tr>
<td></td>
<td>Gne sila</td>
<td>13.12</td>
<td>1.42</td>
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<tr>
<td></td>
<td>Guayaba</td>
<td>11.24</td>
<td>1.32</td>
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<td></td>
<td>Loubi blanc</td>
<td>12.02</td>
<td>2.01</td>
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<td>Mala Noir IV</td>
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<td>2.36</td>
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<td>1.06</td>
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<td>Chinois</td>
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<td>1.74</td>
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<td>CK801</td>
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<td>FR13A</td>
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<td>Haire Koreye</td>
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LSDₐ₀.₀₅

4.08 0.71 1.18 0.93

1) Means of the three replications.
2) Relative value to the control.
3) Data were not taken.
Table 6 Xylem sap flow rate of *O. glaberrima*, *O. sativa* and their interspecific cultivars at recovery period from drought and salinity stress

<table>
<thead>
<tr>
<th>Species</th>
<th>Genotype / cultivar</th>
<th>Xylem sap flow rate$^{1)}$ (g h$^{-1}$)</th>
<th>Ratio to Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Control</td>
<td>Drought</td>
</tr>
<tr>
<td><em>O. glaberrima</em></td>
<td>CG14</td>
<td>0.34 ± 0.14</td>
<td>0.83 ± 0.10</td>
</tr>
<tr>
<td></td>
<td>Dembou B. blanc</td>
<td>0.90 ± 0.16</td>
<td>1.05 ± 0.09</td>
</tr>
<tr>
<td></td>
<td>Dembou B. noir</td>
<td>0.88 ± 0.28</td>
<td>1.04 ± 0.03</td>
</tr>
<tr>
<td></td>
<td>Djingua blanc</td>
<td>1.07 ± 0.31</td>
<td>0.97 ± 0.03</td>
</tr>
<tr>
<td></td>
<td>Dmboutou II</td>
<td>0.63 ± 0.07</td>
<td>0.55 ± 0.06</td>
</tr>
<tr>
<td></td>
<td>Gnene sila</td>
<td>0.52 ± 0.15</td>
<td>0.65 ± 0.15</td>
</tr>
<tr>
<td></td>
<td>Guayaba</td>
<td>0.35 ± 0.19</td>
<td>0.86 ± 0.04</td>
</tr>
<tr>
<td></td>
<td>Loubi blanc</td>
<td>0.67 ± 0.37</td>
<td>1.01 ± 0.38</td>
</tr>
<tr>
<td></td>
<td>Mala Noir IV</td>
<td>0.45 ± 0.10</td>
<td>0.77 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>Saligbeli</td>
<td>0.34 ± 0.15</td>
<td>0.85 ± 0.09</td>
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<tr>
<td></td>
<td>Saria 473</td>
<td>0.37 ± 0.15</td>
<td>0.85 ± 0.07</td>
</tr>
<tr>
<td></td>
<td>WAH</td>
<td>0.33 ± 0.09</td>
<td>0.67 ± 0.09</td>
</tr>
<tr>
<td></td>
<td>Wana Thiereye</td>
<td>0.38 ± 0.17</td>
<td>0.90 ± 0.03</td>
</tr>
<tr>
<td></td>
<td>Yele 1A</td>
<td>0.37 ± 0.07</td>
<td>1.09 ± 0.09</td>
</tr>
<tr>
<td><em>O. sativa</em></td>
<td>Agalhane</td>
<td>0.69 ± 0.01</td>
<td>0.54 ± 0.05</td>
</tr>
<tr>
<td></td>
<td>Chinois</td>
<td>0.60 ± 0.10</td>
<td>0.69 ± 0.05</td>
</tr>
<tr>
<td></td>
<td>CK21</td>
<td>0.77 ± 0.06</td>
<td>0.60 ± 0.05</td>
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<tr>
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<td>CK72</td>
<td>0.70 ± 0.15</td>
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<tr>
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<tr>
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<td>CK801</td>
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<tr>
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<td>Danta Blanc</td>
<td>0.87 ± 0.06</td>
<td>0.86 ± 0.38</td>
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<tr>
<td></td>
<td>FR13A</td>
<td>0.55 ± 0.16</td>
<td>0.79 ± 0.06</td>
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<tr>
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<td>Haira Koreye</td>
<td>0.69 ± 0.15</td>
<td>0.80 ± 0.26</td>
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<tr>
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<td>Kakua</td>
<td>0.44 ± 0.09</td>
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<tr>
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<td>Pokkali</td>
<td>0.81 ± 0.19</td>
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<td>Soutane blanc</td>
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<td>0.47 ± 0.17</td>
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<tr>
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<td>Soutane rouge</td>
<td>0.50 ± 0.07</td>
<td>0.90 ± 0.31</td>
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<tr>
<td></td>
<td>WA856-104</td>
<td>0.49 ± 0.08</td>
<td>0.53 ± 0.05</td>
</tr>
<tr>
<td>Interspecific</td>
<td>NERICA1</td>
<td>0.92 ± 0.23</td>
<td>0.62 ± 0.09</td>
</tr>
<tr>
<td></td>
<td>NERICA2</td>
<td>0.98 ± 0.07</td>
<td>0.55 ± 0.01</td>
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<tr>
<td></td>
<td>NERICA3</td>
<td>0.64 ± 0.11</td>
<td>0.41 ± 0.07</td>
</tr>
<tr>
<td></td>
<td>NERICA4</td>
<td>0.62 ± 0.06</td>
<td>0.61 ± 0.17</td>
</tr>
<tr>
<td></td>
<td>NERICA5</td>
<td>0.76 ± 0.05</td>
<td>0.48 ± 0.04</td>
</tr>
<tr>
<td></td>
<td>NERICA6</td>
<td>0.81 ± 0.02</td>
<td>0.59 ± 0.05</td>
</tr>
<tr>
<td></td>
<td>NERICA7</td>
<td>0.77 ± 0.05</td>
<td>0.66 ± 0.03</td>
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<td></td>
<td>NERICA8</td>
<td>0.50 ± 0.13</td>
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<td>NERICA10</td>
<td>0.78 ± 0.04</td>
<td>0.60 ± 0.03</td>
</tr>
</tbody>
</table>

$^{1)}$ Means of the three replications ± standard error.

$^{2)}$ Data were not taken.

Acknowledgements

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References


乾燥、塩、冠水ストレスに対するアジアイネ、アフリカイネおよび種間交雑品種の耐性評価

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要旨：ナミビア国の北部地域では雨季になると陸国アングラからの洪水が流れ込み、広大な季節湿地が形成される。この季節湿地には、ナミビア国の約 4 分の 1 の人口が集中しており、湿地の水資源を利用する稲作栽培が期待されている。しかしながら、当地域では乾燥や不安定な洪水、塩分集積などの環境問題が存在している。本研究の目的は、アジアイネ、アフリカイネおよびそれらの種間交雑品種の乾燥、塩、冠水ストレスに対する耐性を評価することである。各ストレスに対する耐性を種間で比較すると、アジアイネが塩ストレスに対して高い耐性を示し、冠水ストレスに対してはアフリカイネが高い耐性を示した。乾燥ストレス耐性には種間で差異はみられなかった。供試した 37 品種の中で、Guayaba は全てのストレスに対して高い耐性を示したため、ナミビアでの稲作導入における候補品種であると示唆された。乾燥ストレスからの回復を出芽成育率から評価した結果、アジアイネおよび種間交雑品種と比較して、アフリカイネがより高い出芽成育率を示した。この結果は、アフリカイネは乾燥からの速い回復機構を持っており、乾燥条件下で新たに供給される水を利用することが出来ることを示唆している。

キーワード：乾燥、ネリカ、アフリカイネ、塩、冠水

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連絡責任者：飯嶋盛雄（iijimamorio@nara.kindai.ac.jp）