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Screening Rice (*Oryza sativa* L.) Lines/Cultivars Against Salinity in Relation to Morphological and Physiological Traits and Yield Components

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ABSTRACT

Ten advanced rice lines were screened for salinity tolerance at seedling stage using a rapid screening technique. Out of the lines tested, five were found tolerant, four were graded as moderately tolerant and one as susceptible. It appeared that tolerant lines had higher root and shoot ratio at seedling stage thus providing a clue about salt tolerance potential of a genotype. Further comparative studies for salt tolerance in these rice genotypes in artificially saline conditions showed that salinity in general caused a marked reduction in yield and yield components in all the genotypes except in NR-2, where as little negative effect was observed. Thus it seems to possess better potential than Pokali- a recognized salt tolerant variety, and may boost up the rice production in salt affected areas.

Key Words: Rice genotypes; Variability; Salt stress; Agronomic attributes

INTRODUCTION

Sustainable crop production in Pakistan is threatened by several factors including soil degradation by light to moderate salinities and/or use of brackish ground water. According to some estimates, 6.8 mha are salt-affected in Pakistan and approximately 40,000 ha are becoming saline each year (Khan 1998). At present, Pakistan bear huge recurring losses in terms of limited productivity from the salt-affected lands, apart from serious socio-economic repercussions. But with the increase in population, effective utilization of these soils has become necessary either by reclamation or by growing same salt tolerant crops.

Rice is the premier food grain crop of Pakistan and is grown on an area of 2.2 million hectare for domestic consumption and export abroad with foreign exchange return of 33 million US $ (Zia *et al.,* 1998). It possesses quite low salt tolerance than other crops (Mass & Hoffman, 1997), thus be one of the contributory factors for lower production. Breeding salt tolerant crop varieties is considered to be the most pragmatic approach for better yield under saline conditions (Shannon *et al.,* 1998). Breeding for salinity tolerance in rice requires reliable screening techniques. These techniques must be rapid to keep pace with the large amount of breeding material generated. Screening under field conditions is difficult due to stress heterogeneity, presence of other soil related stress and significant influence of environmental factors such as temperature relative humidity and solar radiation. These complexities together with the degree of salinity and reproducibility, cause difficulties in developing and using reliable methods of screening voluminous materials. The rapid screening technique develop at International Rice Research Institute (IRRI), Glenn *et al.* (1997) is based on the ability of seedling to grow in salinized solution.

The present study was undertaken to evaluate some of the promising hybrid mutant strains, and compare them with standard variety, Basmati-349 (salt sensitive) and pokkali (salt tolerant) using rapid screening technique, ion up-take behavior and correlating this technique to yield and yield components of rice under field conditions.

MATERIALS AND METHODS

Rice genotypes included in the present study were either mutants/hybrid developed at NIAB, or were selected from exotic germplasm received from IRRI Phillipine as detailed below.

A laboratory study was laid out at NIAB Faisalabad with the above mentioned entries (Table I) for screening against salinity at seedling stage. Seeds were heat treated for 5 days in a convection oven set at 50°C to break seed dormancy. Surface sterilized seed with fungicide were placed in petri dishes with moistened filter papers and incubated at 30° C for 48 h. Two pre-germinated seeds were sown per hole on the styro foam sheet having 100 holes with a nylon net bottom floating on distilled water. On germination, the plants were subjected to salinized solution with EC 6 d Sm^{-1} for two days (Yoshida *et al.,* 1976). Salinity was gradually increased to EC 12 d Sm^{-1} by adding NaCl salt. The pH was adjusted daily to 5.0 (by adding either 1N NaOH or HCl). The nutrient solution was renewed after 8 days. Visual scoring of plants with standard evaluation score (SES) was done after the completion of

Table I. Experimental Material (cultivars/ lines) included in study

	Variety / Line	Source of Origin
1	NIAB-RICE-2	Developed at NIAB from a cross between Jhona 349 x Basmati-370 (hereafter designated as NR-2).
2	NIAB-RICE-3	Developed at NIAB from Basmati-385 through radiation at 25 KR (hereafter designated as NR-3).
3	NIAB-RICE-4	Developed at NIAB from Basmati-385 through radiation at 20 KR (hereafter designated as NR-4).
4	NIAB-RICE-5	Developed at NIAB from Basmati-385 through radiation at 25 KR (hereafter designated as NR-5).
5	Basmati-385xNIAB IRRI-9	Developed at NIAB from a cross between Basmati-385 aromatic variety and NIAB-IRRI-9
6	Basmati-370	An aromatic fine variety of Pakistan
7	DM-51-24	A dwarf mutant selected at NIAB
8	NIAB-IRRI-9xDM-25	Developed at NIAB from a cross between a coarse variety and a dwarf mutant derived from Basmati-370.
9	Jhona-349	A coarse non aromatic salt tolerant variety
10	Pokali	An exotic variety received from IRRI, Phillipine.

Two separate studies were conducted as follow

Standard Evaluation Score (SES)

Score	Observation	Tolerance
1	Normal growth, no leaf symptoms	Highly tolerant
3	Nearly normal growth, but leaf tips of few leaves whitish and rolled.	Tolerant
5	Growth severely retarded, most leaves rolled, only a few are elongating.	Moderately tolerant
7	Complete cessation of growth, most leaves dry some plants dying	Susceptible
9	Almost all plants dead or dying	Highly susceptible

salinization period of 16 days to assess salt injury level. Root shoot ratio was also calculated as a growth parameter as affected by salinity.

This field study was conducted at Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad Pakistan, in artificially salinized (6x6x1m) cemented tanks. Salinization was done by mixing four salts i.e., Na_2SO_4, NaCl, $MgCl_2$ and $CaCl_2$ in the ratio of 10:5:1:4, respectively on equivalent basis, representing a type of salinity found in most parts of Pakistan (Qureshi *et al.*, 1977). The experimental material comprised of ten varieties/variants/mutant lines. Forty days old seedling grown on non-saline fields were transplanted as single seedling per hill maintaining a distance of 20 cm. The study was laid out in randomized complete block design (RCBD) with three replicates. Crop was also simultaneously grown in normal clay loamy soil in texture .The soil characteristics of normal soil pH 8.00-8.15, EC 2.0-2.7 dSm^{-1}, SAR 10.0-12.8 m mol I^{-1} where as that of salinized soil ranged from pH 8.65-9.25, EC 5.34-10.2 d Sm^{-1} SAR 15.9-43.4 m mol I^{-1}. The crop was applied fertilizer @ 120-60-00 kg ha^{-1} N-P-K. At maturity data were recorded on various yield components as no. of productive tillers per plant, panicle length (cm), fertility percentage and grain yield kg ha^{-1}.

The harmful effects induced by salinity were computed in percent reduction over control (% ROC) for above cited plant attributes by the following formula.

$$\left[\%ROC = \frac{Value\,in\,control\,value\,in\,saline\,envirment}{Value\,in\,control} * 100 \right]$$

RESULTS AND DISCUSSION

The test entries NR-2, NR-3, NR-4 and NR-5 scored 3, 3.5 and 4, respectively and were graded as tolerant. Basmati-370 scored 7 and was graded as susceptible. DM-51-24 and NIAB-IRRI-9xDM-25 scored 5.5 and were graded as moderately tolerant. Jhona-349 was also graded as moderately tolerant which scored 5 (Table I). Pokali variety scored 4 and graded as tolerant. Visual salt injury symptoms were compared with the actual grain yield obtained in the field under saline and normal soil conditions as shown in data (Table III). Score based on visual symptoms is related well to grain yield and proved the reliability of visual symptoms of salt stress as a selection for rapid screening of voluminous breeding material.

It was observed that in some cases lines with higher root shoot ratio had visual grading score raging from 3-4 *i.e.,* NR-2, NR-3 NR-4 and NR-5 respectively. Thus root shoot ratio may be useful helpful parameter in screening the rice germplasm against salinity. Such results in agreement with the results obtained by Akbar and Yabuno (1974), Ansari *et al.* (1990), Niazi *et al.* (1990) and Glenn *et al.* (1997) who also confirmed the reliability of this screening technique.

The typical mechanism of salinity tolerance in rice is the Na^+ exclusion or uptake reduction and increased absorption of K^+ to maintain a good Na^+: K^+ balance in the shoot. The mean performance for salinity rating, Na^+, K^+ and Na^+: K^+ absorption ratio in the shoot of rice cultivars is presented in table II. The ranking according to Na^+, K^+ absorption alone is not a reliable parameter for salinity tolerance reactions. However, the classification of susceptible moderately tolerant and tolerant based on field, laboratory and greenhouse tests is clearly related to the Na^+ K^+ concentration. Thus Na^+:K^+ ratio, which is the balance between Na^+ and K^+ in shoot, could be a valid criterion in measuring salinity tolerance in rice.

Data of various yield components (Table III) as

Table II. Salinity score and mean Na^+, K^+ and Na^+ K^+ ratio in shoot of some rice cultivars grown under salinized culture solution

Entry	Salinity score	Root Shoot Ratio	Na^+	K^+	Na^+ K^+ ratio	Reaction to salinity
NR-2	3.0	1.20	0.36	2.49	0.14	Tolerant
NR-3	3.5	1.10	0.46	2.88	0.16	Tolerant
NR-4	4.0	1.05	0.51	2.35	0.28	Tolerant
NR-5	4.0	1.00	0.51	2.37	0.22	Tolerant
Basmati-385 x NIAB-IRRI-9	4.8	0.95	0.52	2.443	0.21	Moderately Tolerant
Basmati-370	7.0	0.74	0.65	2.13	0.30	Susceptible
DM-51-24	5.5	0.85	0.53	2.47	0.21	Moderately Tolerant
NIAB-IRRI-9 x DM-25	5.5	0.87	0.54	2.45	0.22	Moderately Tolerant
Jhona-349	5.0	0.93	0.59	2.33	0.25	Moderately Tolerant
Pokkali	4.0	0.85	0.52	2.38	0.22	Tolerant

Table III. Salinity rating under salinized culture solution and grain yield and yield components under saline and normal soil field conditions

Entry	No. of productive tillers			Panicle length (cm)			Panicle fertility %			Grain yield (kg/ha)		
	normal	saline	% ROC	normal	saline	% ROC	normal	saline	% ROC	normal	saline	% ROC
NR-2	25.0	23.4	6.50 EF	27.8	27.0	2.87E	88.8	85.5	3.73G	5750	4953	13.8E
NR-3	26.8	20.6	23.2 B	25.5	23.7	7.06CDE	86.4	80.6	6.73F	4500	3746	16.7CD
NR-4	28.5	21.4	24.9 B	27.1	25.8	4.82E	92.3	72.4	21.6BC	4200	3499	16.7CD
NR-5	23.3	18.5	20.7 C	29.4	25.1	14.6A	82.6	66.3	19.7CD	4250	3498	17.7C
Basmati-385 x NIAB-IRRI-9	17.8	14.3	19.8 CD	30.0	27.9	7.00CDF	78.0	62.8	19.5D	3500	2722	22.2B
Basmati-370	23.3	16.8	28.1 A	31.5	27.7	12.3AB	78.6	58.8	25.3	4070	1907	53.1A
DM-51-24	19.6	18.7	4.78 F	18.4	16.7	9.25BCD	88.2	81.4	7.70F	3950	3372	14.6DE
NIAB-IRRI-9 x DM-25	17.5	14.4	17.7 D	22.1	21.0	4.88E	89.3	68.5	23.3D	3975	3266	17.8C
Jhona-349	25.0	18.0	28.0 A	23.8	21.3	10.5BC	51.5	45.6	11.5E	4850	4036	16.8CD
Pokkali	16.0	14.8	7.39 E	27.4	25.7	6.30DE	59.3	46.2	22.1B	3640	3033	16.7CD

Salinity level: pH= 8.65-9.25, EC= 5.34-10.2 d Sm^{-1}, SAR= 15.9-63.3 m.md l^{-1}
Control: pH= 8.00-8.15, EC= 2.00-2.70 d Sm^{-1}, SAR= 10.0-12.8 m.md l^{-1}

affected by salinity stress is briefly discussed below.

Number of productive tillers per plant. Data showed that no of productive tillers per plant were significantly more in NR-2 than all other varieties included in trials. It produced 23.4 tillers per plant under saline conditions but reduction in productive tillers per plant under stress was observed slightly more in Pokkali than the said variety. The most affected genotype was Jhona-349 and Basmati-370 which showed almost 28% reductions in productive tillers per plant followed by NR-4 which showed 29.4% reduction.

Panicle length. Salinity induced reduction in panicle length ranging from 2.87-14.6%. Least influence was significantly observed on NR-2 followed by NR-4 and NIAB IRRI-9 x DM-25 the longest panicle under the saline environment was of Basmati-385 x NIAB-IRRI-9.

Panicle fertility percentage. The root zone salinity induced affliction of the plant attribute varied from 3.7-25.3%. It is evident that the least influence was observed on NR-2 followed by NR-3.Under the saline environment significantly higher panicle fertility percentage was of NR-2 and the highest panicle fertility affected in Basmati-370 which was 25.3% thus significantly different from other entries.

Grain yield kg ha^{-1}. Grain yield reduced in all the genotypes under salinity the yield reduction varied from 13.8-53.1%. The most affected genotype was Basmati-370 where yield reduction was 53.1% the least affected genotype was NR-2 where reduction in yield was observed up to 13.8% only followed by NR-3 where this was only 16.7%.

It is evident from the results of present study that the root zone EC level of 7.0 d Sm^{-1} depressed the yield and yield components of all the genotypes under study. The only exception was NR-2 where for most of the plant attributes either little or no effect of salinity treatment was observed. The magnitude of reduction varied not only for plant attributes but also the genotype studied. This shows that the genotype of different genetic constitution show a differential reaction to salinity. As compared to other plant attributes, yield and yield components were more adversely affected by salinity in all the genotypes. Such results are also on the record in rice (Akbar *et al.,* 1972, 1979; Sajjad, 1983, 1984).

To confirm the reliability of this rapid screening technique, the visual salt -injury symptoms were compared with the actual grain yield of some test entries obtained in the field under saline and normal soil conditions. The score based on visual symptoms and reduction due to salt stress relates well to grain yield and yield components under saline field conditions. This shows the reliability of visual symptoms of salt stress after 16 days of salinization as the selection criterion for rapid screening of voluminous breeding materials. Our results are in accordance with Glenn *et al.* (1997). They are successfully using this rapid screening method for screening germplasm and breeding populations. Whenever phytotron space is not available the green house is being used. To confirm the reliability of this screening technique, the visual salt-injury symptoms were compared with the actual grain yield of test entries obtained in the field under saline and normal soil conditions. This score based on visual symptoms related well to grain yield under saline field conditions and yield reduction due to salt stress. This shows the reliability of visual symptoms of salt stress after 16 days of salinization as the selection criterion for rapid screening of voluminous breeding material

Salt tolerance is not a function of single organ or plant attribute, but it is the product of all the plant attributes (Bernstein, 1977). Therefore a genotype exhibiting relative salt tolerance for all the plant attributes may be ideal one. Fortunately the hybrid NR-2 has shown comparatively minimum salinity induced reduction for the plant attributes. Under the saline environment, it has given the maximum number of productive tillers per plant (23.4), panicle length (27.0 cm) panicle fertility (85.5%) and grain yield 4953 kg ha^{-1}. In this study some genotypes have shown some tolerance to salinity for the plant attributes that NR-2 lacked. These genotypes may be used as donors for these characters in further improvement of NR-2.

CONCLUSION

It may be concluded from the results that screening at seedling stage along with root / shoot ratio may provide a clue about the salt tolerance potential of a genotype. This technique provides rapid screening of large number of material and reproducible results. NR-2 exhibited tolerance to salinity for most of the characters studied the other mutant lines i.e. NR-3, NR-4 and NR-5 have the other good plant attributes which NR-2 lacked. These mutant lines will be used in hour further plant breeding Programme

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