Plant and Soil **150**: 99–107, 1993.

PLSO 9778

A rapid screening technique for salt tolerance in rice (*Oryza sativa* L.)

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Received 17 September 1992. Accepted in revised form 23 December 1992

Key words: rice lines, salinity type, salt-affected field, salt-tolerance, screening, short term salinity effect, soil culture, solution culture

Abstract

An effecient, reproducible and simple mass screening technique for the selection of salt tolerant rice lines has been developed. Fourteen-day old seedlings raised in silica gravel culture were transplanted to foam-plugged holes in polystyrene (thermopal) sheets floated over 100 dm^3 of nutrient solution in painted galvanised-iron growth tanks lined with plastic (120 × 90 × 30 cm). Three days after transplanting, NaCl was added to salinize the medium in increments, at the rate of 25 mol m^{-3} per 24 hours, up to the desired salinity levels which ranged from 50–200 mol m^{-3} NaCl. Six plants of each line were transplanted and allowed to grow for 15 days after the maximum desired stress level was achieved in each case. Absolute shoot fresh and dry weights, as well as percent mortality, were used as criteria for assessing relative salt tolerance. Related studies were also conducted to standardize the technique. The validity of this technique was tested by conducting experiments in salinised soil (pot culture) and in salt-affected field where 9 rice lines were grown up to maturity and absolute paddy yield was considered as the criterion for salt tolerance. Salt tolerance behaviour of cultivars based on different selection criteria was compared. Good reproducibility of results among the three solution culture experiments and their close association with the results of pot culture and of salt-affected field study, authenticated the validity of this technique for practical purposes.

Introduction

Salinity is a serious constraint to obtaining increased crop yields under irrigated agriculture throughout the world. This problem has special relevance to Pakistan where, out of 6.2 million hectares of salt-affected land, over one million hectares are under rice cultivation (Qureshi et al., 1991); rice is an irrigated crop sensitive to salinity (Aslam et al., 1989; Maas and Hoffman, 1977). Annual losses due to the low yield of rice in salt-affected areas of Pakistan are estimated to be around US$107 million (Personal communication, Qureshi, R.H., Officer Incharge, Saline Agri. Research Centre, UAF). Thus the selection of rice varieties capable of yielding adequately under saline conditions is a pre-requisite for generating income for rice farmers in most areas of Pakistan and this in turn requires a reliable and quick procedure for screening rice germplasm for tolerance to salinity.

Screening for salt tolerance in rice has been attempted using a variety of culture techniques with plant material ranging from germinating seeds through seedlings to mature plants. Culture solution salinised with NaCl alone or NaCl + $CaCl_2$ has been used (see Ikehashi and Ponnamperuma, 1978; Jones and Stenhouse, 1983; Maas and Hoffman, 1977; Ponnamperuma, 1984; Yeo and Flowers, 1984), as has artificially salinised soil in pots (IRRI, 1978; Jones and Stenhouse, 1983) and irrigation with saline water (Farah and Anter, 1978). There have also been attempts to screen germplasm in naturally saline areas (Ponnamperuma, 1984) as well as using cell culture techniques and physiological characteristics (Yano et al., 1982; Yeo et al., 1990).

Mass screening for salt tolerance in soil culture or directly in the field is difficult and has a variety of limitations. It is complicated by the status of soil fertility, by irrigation and management practices (Maas and Hoffman, 1977; Ponnamperuma, 1984), salinity type (Aslam et al., 1988) and meteorological factors like temperature and humidity (Akbar, 1986; Cabuslay and Akita, 1986; Iwaki, 1956; Singh et al., 1979) as well as natural variation within fields (e.g. Richards, 1983). On the other hand, the use of solution culture does not truly represent field conditions. However, for practical purposes, a good mass screening technique should be efficient, reliable, reproducible and simple.

Keeping this in view, we have attempted to develop a simple solution-culture screening technique against salinity using seedlings and to relate the results obtained at this stage with the other experiments in soil, both in pots and in a naturally salt-affected field.

Materials and methods

The studies undertaken to develop a suitable method for mass screening of rice (*Oryza sativa* L.) cultivers for their response to salinity were investigations of (a) the effect of the type of salinity on the growth of rice in soil in pots; (b) the effect of the stage of growth at which the plants were salinised in solution culture; (c) the effect of a variety of salt concentrations in culture solution on seedlings; (d) the effect of salinity on grain yield in soil in pot culture, and (e) screening under naturally salt-affected field conditions. The details of these experiments are:

Growth conditions

All the pot and solution culture studies were conducted in a big net house without any environmental control, having glass covered roof, sides open, having only wire gauze and no problem of sunlight. Inside the net house, maximum temperature 28–40°C, minimum temperature 15–27°C, relative humidity 50–80% and bright sunlight, with active photoperiod of 11–14 hours.

Effect of type of salinity

The effect of NaCl alone, NaCl + $CaCl_2$ (1:1; equivalent basis), Na_2CO_3 alone and a salt mixture (commonly present in soils of Pakistan of $Na_2SO_4 + NaCl + CaCl_2 + MgSO_4$ (in the ratio of 9:5:5:1; equivalent basis) on growth of four rice lines, Basmati 370, NIAB6, BG 402–4 and IR 1561 was studied in glazed pots (27 cm depth, 27 cm diameter) filled with 10 kg of sandy clay loam soil. The soil was salinised with the respective salts to an EC_e level of 10 dSm^{-1} and puddled before transplanting of rice seedlings. Untreated soil (EC_e 1.1 dSm^{-1}; pH 7.9; SAR* 1.0) was used as control. An adequate dose of fertilizers (150-90-50-7; N, P_2O_5, K_2O, $ZnSO_4$; kg ha^{-1} was also applied. The experimental layout was a completely randomized design. Four 30-day old seedlings of each line were transplanted in each pot. After 30 days of growth, shoot and root fresh weights were recorded.

Effect of stage of salinization on rice growth

Fourteen-day-old seedlings of four rice lines (Basmati 370, NIAB6, BG402-4, IR 1561) were transplanted to 1 cm plugged holes in thermopal sheets floated over 15 litres of Yoshida nutrient solution (Yoshida et al., 1972) in plastic tubs. Three holes were used for a line, each hole having one seedling. (One repeat; there were three repeats of the experiment). Salt stress (100 mol m^{-3} NaCl) was applied at three different stages of growth for 10 days only. At a particular growth stage the salt was applied at 33 mol m^{-3} NaCl per day. The plants were stressed at 100 mol m^{-3} NaCl for 10 days and after that, within three days, they were again brought back to normal solution conditions. A control was also kept to compare the results. At maturity, paddy (rice grain with husk) and straw yields were recorded.

*Sodium adsorption ration.

Screening at seedling stage

Seeds of each line were sown in plastic-coated galvanized-iron trays (60 × 30 × 5 cm), filled with silica gravel (4 mm diameter). For the first three days, canal water (0.3 dSm^{-1}) was applied and trays remained covered. Later on, Yoshida nutrient solution was applied until the seedlings were transplanted. Fourteen-day-old seedlings were transplanted to foam-plugged holes in thermopal sheets floated over 100 dm^3 of canal water containing Yoshida nutrient solution in tanks (120 × 90 × 30 cm) made of galvanized iron, which were painted and then lined with plastic, supported on iron stands 90 cm above ground. Three days after transplanting NaCl was added to salinize the medium in increments of 25 mol m^{-3} per 24 hours up to the final salinity level (0, 50, 70, 100, 150, 200 mol m^{-3} NaCl). The solution was changed weekly. Each line was replicated a number of times depending upon the number of lines to be tested. This experiment was repeated in three sets at the University of Agriculture, Faisalabad, in a net house. In the first instances 34 rice lines were tested, in the second set 16 rice lines (15 selected out of 34 and Pokkali, a salt tolerant check) were repeated, whereas in the third set 7 lines (selected out of 16) were tested. In each case only three salt levels (0, 50 and 100 mol m^{-3} NaCl) were used. Plants were harvested after 15 days of salt stress for measuring shoot and root weights and other growth characters.

Screening at maturity in soil culture

Ten kg clay loam soil (EC_e 1.1 dSm^{-1}; pH 7.9; SAR 1.0) was filled in glazed pots (27 cm deep, 27 cm diameter), salinised with NaCl to EC_e levels of 5 and 10 dSm^{-1} and puddled before the transplanting of rice seedlings. The pots were placed in the same net house used for other studies. Untreated soil served as control. Fertilizers were applied as urea (in 2 splits), single super phosphate (SSP), sulphate of potash (SOP) and zinc sulphate at 150 kg N, 90 kg P_2O_5, 50 kg K_2O and 7 kg $ZnSO_4$ ha^{-1}, respectively. The experiment was laid out in a completely randomized design with three repeats. Six 30-day old seedlings of each rice line (nine, see Table 4) were transplanted in each pot and thinned to three seedlings per pot after one week. Soil was kept submerged by adding demineralized water daily until maturity.

Screening under field conditions

A saline sodic soil (loamy clay) with an EC_e 7.2 dSm^{-1}; (5.2–8.3^b) pH_S 8.8; (8.5–9.7*; SAR 22.3; $CaCO_3$ 5.9% was puddled before transplanting of rice seedlings. The whole field was divided into 27 micro plots each measuring 1 × 2 m and thirty-day-old seedlings (2 per hill) of each rice line (nine, see Table 5) were transplanted in the field in the third week of June. (Maximum and minimum temperatures were 26–38°C and 14–24°C respectively, R.H. being 50–85% and total rainfall during the entire growth period was 150 mm). Plant to plant and row to row distance was 20 cm. The experiment was laid out in a randomized complete block design with three replications. Recommended doses of NPK and Zn fertilizers (as described earlier) were applied. Irrigation and other normal agronomic practices were carried out during the growth period. On maturity, paddy and straw yield data were collected.

Results and discussion

Effect of type of salinity

Shoot and root fresh weights were significantly reduced by different types of salinity: the differences in yield due to type of salt were also significant (Table 1). At this stage of plant growth, NaCl alone was found to be the most toxic, Na_2CO_3 alone the least harmful, and NaCl + $CaCl_2$ and the salt mixture were intermediate in terms of their effect on shoot weight: the two latter treatments were statistically alike. On the basis of growth under saline relative to the control soil, NIAB6 was found to be overall the most tolerant cultivar used while IR 1561 and Basmati 370 were rated salt sensitive lines.

*Range of the field.

Table 1. Effect of type of salts for 30 days on the growth (g FW per plant) of four rice lines (EC_e 10 dS m^{-1}).

Varieties/ Lines	Control	NaCl	NaCl + $CaCl_2$	Na_2CO_3	Salt mixture[a]	Mean
	Shoot					
Basmati 370	5.90 a	1.32 g–i (22)	2.20 e–g (37)	4.52 b (76)	2.40 d–f (41)	3.27 A
NIAB 6	3.30 c	1.35 g–i (41)	1.95 e–h (59)	2.20 e–g (67)	2.17 e–g (66)	2.20 C
BG 402–4	4.42 b	1.65 f–i (37)	2.05 e–h (46)	3.12 cd (71)	2.60 c–e (59)	2.77 B
IR 1561	3.22 c	0.65 j (20)	0.82 ij (25)	1.22 h–j (38)	0.92 ij (28)	1.37 D
Mean	4.22 A	1.22 D (29)	1.75 C (41)	2.77 B (65)	2.02 C (48)	
	Root					
Basmati 370	5.95 a	1.20 f–h (20)	1.50 d–g (25)	4.02 b (68)	2.12 de (36)	2.97 A
NIAB 6	3.10 c	1.17 f–h (38)	1.40 e–h (45)	1.52 d–g (50)	1.42 e–h (46)	1.72 C
BG 402–4	4.17 b	1.35 eh (32)	1.80 d–f (43)	2.30 d (55)	1.85 d–f (45)	2.30 B
IR 1561	3.55 bc	0.30 i (9)	0.62 hi (18)	0.87 g–i (25)	0.37 i (11)	1.15 D
Mean	4.20 A	1.00 D (24)	1.32 CD (32)	2.17 B (52)	1.45 C (34)	

Means with different letters differ significantly according to Duncan's Multiple Range Test ($p = 0.05$). Extra letters have been omitted except first and the last ones to simplify the Table.
Values in parenthesis represent percentages of respective controls.
[a]Salt mixture: NaCl: Na_2SO_4: $CaCl_2$: $MgSO_4$ = 5:9:5:1.

Better shoot and root yields under Na_2CO_3 as opposed to the other salt mixtures appears to be a characteristic of rice which shows greater tolerance to sodicity than salinity (Verma and Abrol, 1980). In sodic soils rice seems to be affected chiefly by specific ion toxicity and nutrient imbalance (see Abrol, 1984). A relatively lower toxicity of calcium than sodium is obvious from the higher shoot and root yields in the case of salt mixture and NaCl + $CaCl_2$ treatments (see Aslam et al., 1990; Rengel, 1992).

In Pakistan, in many cases, soils contain exceptionally high sodium levels and, therefore, NaCl was preferred in later studies for developing salinity to represent the high sodium conditions. In addition, sodium chloride can be used safely in solution culture experiments without causing precipitation of different ions.

Table 2. Paddy and straw yields (g per plant) of four rice lines as affected by short term (10 day) salinity (100 mol m^{-3} NaCl) at various stages of plant growth

Varieties/ Lines	Control	Seedling stage	Tillering stage	Panicle initiation stage	Mean
	Paddy yield				
Basmati 370	8.2 cd	4.5 fg (55)	6.9 c–f (84)	4.2 f–h (52)	6.0 B
NIAB 6	12.9 a	9.0 bc (70)	11.1 ab (86)	7.4 c–e (58)	10.1 A
BG 402–4	9.1 bc	5.6 d–g (61)	6.3 c–f (69)	2.3 gh (25)	6.1 B
IR 1561	8.9 bc	2.9 gh (32)	5.3 e–g (59)	1.7 h (19)	4.7 B
Mean	9.8 A	5.5 C	7.4 B	4.2 D	
	Straw yield				
Basmati 370	18.3 a	9.9 de (54)	12.4 cd (68)	11.7 cd (64)	13.1 A
NIAB 6	17.7 ab	12.4 cd (70)	12.2 cd (69)	14.8 bc (83)	14.3 A
BG 402–4	11.0 d	4.9 f (44)	7.1 ef (64)	6.9 ef (62)	7.5 B
IR 1561	11.4 cd	4.4 f (39)	5.0 f (44)	6.3 f (56)	6.8 B
Mean	14.6 A	7.9 C	9.2 BC	9.9 B	

Means with different letters differ significantly according to Duncan's Multiple Range Test ($p = 0.05$). Extra letters have been omitted except first and the last ones to simplify the table.
Values in parenthesis represent percentages of respective controls.

Effect of short term (10 day) salinity at various growth stages

The four cultivars used in the previous experiment were exposed to 100 mol m^{-3} NaCl for a short time at various stages in their life cycle. The maximum adverse effect on paddy yield was observed when salinity was applied at the panicle initiation stage followed by the seedling stage (Table 2). In the case of straw yield, the early seedling stage proved to be the most sensitive. In terms of paddy yield, NIAB 6 gave a significantly higher value than all the other lines at all stages of growth while IR 1561 clearly proved to be the most sensitive line. BG 402–4 gave good paddy yield when the stress was imposed at seedling or tillering stages but was found as sensitive as IR 1561 or Basmati 370 when stressed at the panicle initiation stage. Basmati 370 was salt sensitive at both seedling and panicle initiation stages. Evidences regarding the variability in salinity tolerance of rice at different stages of its growth are available; rice is very tolerant at germination and tillering stages of its growth but is very sensitive at 1–2 leaf and flowering stages. Ripening appears to be little affected by salinity (Akbar and Ponnamperuma, 1982; Jones and Stenhouse, 1983; Maas and Hoffman, 1977; Pearson, 1961; Yoshida, 1981).

The straw yield of all the lines was affected similarly to paddy yield: the earlier the salinity was applied, the greater the effect. Furthermore, it is clear that the assessment of salt tolerance in rice, based on fresh shoot-weight at the early seedling stage, is related to the yield of paddy and thus could be used for mass screening purpose to reduce the time requirement. Nevertheless, some cultivers like BG 402–4 are exceptionally sensitive at the panicle initiation stage and this factor must also be considered for the final selection of rice cultivars. In addition, this information is also useful in determining the time at which saline water may be applied to irrigate a rice crop, if necessary to overcome water shortage, while minimising the loss of yield.

Screening at seedling stage

For practical purposes, a good mass screening technique should be efficient, reproducible, reliable and simple, and for this purpose selection of a suitable criterion for assessing the relative salt tolerance is important. In the present study, three similar experiments (repeats) were conducted to determine the consistency in response of various cultivars grown in saline medium and the reproducibility of results of the rapid solution culture screening technique (Table 3).

Criterion for the assessment of salt tolerance and reproducibility of results

Both fresh and dry weight could be used as the criterion for assessing the relative salt tolerance. The determination of fresh weight is easier and simpler than dry weight measurements but requires greater care to avoid water loss during weighing. In all these experiments the mean fresh weight of the shoot (at various levels of salinity) was used as the criterion of salt tolerance. This seems to be more relevant to the field situation where there is a great heterogeneity in salinity, ranging from very low to highly saline patches. However, absolute shoot fresh weight or relative shoot yield (percent of control) at moderately high salinity (100 mol m^{-3} NaCl) gave almost similar results in all the three sets of solution culture experiments, these parameters could thus be used as the criterion of salt tolerance (Table 3). Some deviation in results in different experiments could be attributed to environmental factors as was indicated by Akbar and Ponnamperuma (1982), Maas and Hoffman (1977) and Panaullah (1980).

Ranking of the 7 selected lines according to their salt tolerance at 100 mol m^{-3} NaCl salinity in the three experiments are summarized in Table 3. It is apparent that although there was some deviation in the rank orders of lines with intermediate tolerance, particularly when the different criteria were used, the most tolerant and the most sensitive line occupied the top and the bottom position, respectively, in all the cases. This indicates that the technique had a satisfactory reproducibility. Except for the percentage mortality, none of the other criteria (root yield, shoot and root lengths and number of tillers) showed the same consistency in results as the shoot weight.

Table 3. Comparative salt tolerance in rice lines based on different growth criteria at 100 mol m^{-3} NaCl

Merit position	Absolute shoot yield Expt.			Relative shoot yield Expt.			Absolute root yield Expt.			Relative root yield Expt.			Absolute shoot length[a] Expt.			Relative shoot length Expt.			Absolute root length Expt.			Relative root length Expt.			Mortality Expt.		Absolute tillers Expt.	Relative tillers Expt.
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	III
1.	V_3[b]	V_3	V_3	V_3	V_6	V_3	V_6	V_3	V_3	V_6	V_3	V_3	V_3	V_3	V_3	V_3	V_3	V_3	V_3	V_3	V_2	V_6	V_2	V_3	V_3	V_3	V_3	V_3
2.	V_6	V_6	V_4	V_6	V_3	V_6	V_3	V_6	V_6	V_3	V_6	V_6	V_5	V_2	V_4	V_2	V_6	V_4	V_6	V_6	V_1	V_3	V_3	V_4	V_6	V_6	V_4	V_4
3.	V_4	V_2	V_5	V_5	V_5	V_4	V_5	V_2	V_5	V_4	V_5	V_5	V_6	V_6	V_6	V_7	V_4	V_6	V_2	V_5	V_3	V_5	V_5	V_6	V_4	V_4	V_5	V_2
4.	V_5	V_4	V_6	V_4	V_4	V_5	V_4	V_5	V_4	V_5	V_2	V_4	V_2	V_4	V_2	V_6	V_2	V_5	V_5	V_2	V_7	V_2	V_1	V_5	V_5	V_5	V_2	V_6
5.	V_2	V_5	V_2	V_7	V_2	V_2	V_2	V_4	V_1	V_7	V_4	V_1	V_4	V_5	V_5	V_5	V_5	V_2	V_4	V_4	V_4	V_4	V_6	V_2	V_2	V_2	V_6	V_5
6.	V_1	V_1	V_1	V_2	V_7	V_1	V_1	V_7	V_2	V_2	V_7	V_7	V_1	V_1	V_1	V_4	V_1	V_1	V_7	V_7	V_6	V_7	V_7	V_7	V_1	V_1	V_1	V_1
7.	V_7	V_7	V_7	V_1	V_1	V_7	V_7	V_1	V_7	V_1	V_1	V_2	V_7	V_7	V_7	V_1	V_7	V_7	V_1	V_1	V_5	V_1	V_4	V_1	V_7	V_7	V_7	V_7

[a]Shoot length = distance from root-shoot junction to the tip of the youngest leaf.
[b]Varieties are abbreviated as V_1 (Basmati 370), V_2 (Basmati 198), V_3 (NIAB 6), V_4 (IR 6), V_5 (KS 282), V_6 (BG 402–4), V_7 (IR 1561).

Validity of results

Although direct screening under field conditions is difficult (takes more time, energy and space than screening seedlings in solution culture), the final assessment is made in terms of paddy yield in the field; consequently this must be tested before any recommendation can be made for the authenticity of a screening technique or recommendations of selected lines for general cultivation in salt-affected areas be made. To determine the authenticity of the solution culture screening technique as the general procedure for mass screening of rice lines against salinity, various techniques of screening, e.g. solution culture, pot culture and soil culture, were compared using a number of rice lines. Since field heterogeneity for salinity is high (Richards, 1983) the

Table 4. Relationship of shoot fresh weight with paddy yield of rice grown under saline conditions

	Mean fresh shoot weight[a] Average of solution culture Expt. I, II, III (g per plant)	Mean paddy yield[b] pot culture (g per pot)	Paddy yield salt-affected field (kg ha^{-1})	Paddy:straw ratio salt-affected field
Basmati 370	1.19 B	33.4 BC	336.9 B	0.24
Basmati 198	1.22 B	34.2 BC	219.7 B	0.11
Basmati 6129	1.11 BC	30.5 C	000.0 C	0.00
IR 6	1.50 A	37.3 B	1069.1 A	0.30
IR 1561	0.81 C	30.5 C	175.8 B	0.06
BG 402–4	1.52 A	33.8 BC	483.3 B	0.14
KS 282	1.39 AB	42.0 A	1083.8 A	0.30
NIAB 6	1.67 A	44.7 A	1127.7 A	0.31
Pokkali	–	37.5 B	439.4 B	0.14

Means with different letter(s) differ significantly according to Duncan's Multiple Range Test ($p = 0.05$).
Correlation coefficient:
Fresh shoot weight vs Paddy yield (pot culture) = 0.77*;
Fresh shoot weight vs Paddy in salt-affected field = 0.78*;
Paddy yield (pot culture) vs Paddy yield, in salt-affected field = 0.91**.
*Significant ($p = 0.001$).
**Highly significant ($p = 0.001$).

[a]Mean = control + 50 + 100 m*M* NaCl.
[b]Mean = control + 5 + 10 dSm^{-1}.

means (shoot fresh weight of solution culture experiments and paddy yield of pot culture experiment) were used (Table 4) for the purpose of comparison and determining co-relations between solution culture, pot culture and field experiment. Although there is heterogeneity in artificially salinized soils, variation is small compared with naturally salt-affected fields. Little variation was found in solution culture experiments. There were significant relationships between shoot fresh weight and paddy yield determined amongst the various experiments (Table 4).

In the pot culture experiment, both at EC_e of 5 and 10 dSm^{-1}, NIAB6 gave the highest absolute paddy yield. The yield of NIAB6 was significantly greater than the salt sensitive rice lines: IR1561, Basmati 370, Basmati 198 and Basmati 6129 as well as BG402-4 and Pokkali at EC_e of 10 and on pooled mean basis (Tables 4 and 5). The behaviour of BG402-4 was striking and like salt-sensitive cultivars. Its absolute and relative yield at EC_e of 10 dSm^{-1} was the same as in the case of Basmati 370. The cause of sensitivity to stress at maturity stage may be the participation of different genes for salt tolerance for different plant developmental stages (Akbar, 1986; Iwaki, 1956). Relative yields (% of control) at EC_e 5 dSm^{-1} for various cultivars were comparable but were quite different at EC_e of 10 dSm^{-1}. Like absolute paddy yield, relative yield of NIAB6 at EC_e of 10 dSm^{-1} was also the highest (Table 5). The results obtained for paddy yield from salt-affected field experiment for NIAB6, KS282 and IR6 were significantly better compared to the other lines. The maximum paddy yield being in the case of NIAB6: BG 402-4, once again, proved salt sensitive under natural field conditions by producing poor paddy yield, i.e. 42.8% of the paddy yield of NIAB6; Basmati 6129 failed to develop any grain. The yield of IR1561 was also low and only 15.6% of the NIAB6 yield (Tables 4 and 5).

The similarity of results among the three sets of the solution culture experiments (Table 3) indicated a high reproducibility of results, and their close association (significant correlation) with the results of the experiments conducted in salinised soil (pot culture; Tables 4 and 5) and saline field (Table 4) authenticated the validity of the technique. The distribution pattern of various lines into various salinity tolerance groups (Table 6) indicates that, in spite of some variations, the overall pattern of behaviour of the lines tested remained fairly constant under different situations, particularly with respect to the most salt tolerant and the most salt sensitive lines. The line NIAB6 proved to be the most tolerant while IR 1561 and Basmati 370 were relatively the most sensitive to salinity. The line BG 402-4 appeared promising at the seedling stage but exhibited poor salt tolerance at maturity during field and pot culture experiments. All the lines exhibited greater sensitivity to salts in

Table 5. Relative performance of nine rice varieties/lines in pot culture and the salt-affected field (g per plant)

Varieties/ Lines	EC_e dSm^{-1}			Relative yield from salt affected field
	1.1 (Control)	5.0	10.00	
	pot culture			
Basmati 370	49.9 bc	67*	33*	29.9**
Basmati 198	44.3 c–e	75	60	19.5
Basmati 6129	45.5 cd	66	35	0.0
NIAB 6	56.2 ab	74	64	100.0
IR 6	49.4 bc	68	58	94.8
IR 1561	46.2 c	75	23	15.6
BG 402–4	48.8 bc	71	33	42.8
KS 282	58.5 a	64	52	96.1
Pokkali	55.0 ab	55	49	39.0
Mean	50.3 A	69	46	

Relative performance * a, For pot culture; % of control.
**b, For field; % of the maximum yield.

Table 6. Rating of rice varieties for salt tolerance* at different stages of growth

Varieties/ Lines	Germination	Seedling stage Experiment			Maturity stage			Final grade
		I	II	III	Pot trial	Shocks at various stages of plant growth	Field trial	
Basmati 370	MS	S	S	S	S	S	S	S
Basmati 198	MS	MS	MS	MS	MT	–	S	MS
NIAB 6	T	T	T	T	T	T	T	T
IR 6	T	MS	MT	T	MT	–	T	T
KS 282	T	MT	MS	MS	MT	–	T	T
BG 402–4	MT	T	T	MT	S	S	S	MS
IR 1561	S	S	S	S	S	S	S	S

Tolerance class: S (Sensitive); MS (Moderately sensitive); MT (Moderately tolerant); T (Tolerant).
*Salt tolerance class was determined according to statistical order and on the basis of following criteria at different stages of plant growth.
a) Germination stage = % germination;
b) Seedling stage = absolute and relative fresh shoot weight;
c) Maturity stage = absolute paddy yield.
A line with greater than 50% score was finally rated as the tolerant, 40–50% score as moderately tolerant, 30–40% score as moderately sensitive, and less than 30% score as the sensitive one.

the rooting medium during panicle initiation stage as compared to the seedling stage and the other stages of plant growth.

Conclusions

From the data we conclude that screening at the seedling stage was a convenient and fairly reliable technique for determining differences with respect to salt tolerance in a large number of rice genotypes. There are some exceptions, such as the case of BG 402–4, and these must be taken into account. Field screening techniques encounter/confront the biggest problem of high degree of soil heterogeneity and only a limited number of genotypes can be handled. Development of the time saving evaluation and selection technique appears to be greatly useful in accelerating the progress towards the improvement of salt tolerance in rice.

Acknowledgement

Authors would like to acknowledge Professor T J Flowers, University of Sussex, for valuable comments and critically reviewing the draft of this paper.

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Section editor: H Lambers