

SCREENING RICE VARIETIES FOR SALINITY TOLERANCE: COMPARISON OF DIFFERENT METHODS

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ABSTRACT

Cultivation of rice varieties tolerant to salinity is considered to be a suitable low cost option available for increasing the rice production in salt-affected rice lands in inland valleys and coastal plains of Sri Lanka. As such, necessity has arisen to find out better screening methods to select rice varieties tolerant to salinity. Therefore, experiments were conducted to study the performance of rice varieties under salt conditions at germination and maturity stages. Rice varieties, Pokkali, Nona Bokra, At 354 and At 401 were selected as salinity tolerant, BW 400 and Bg 94-1 were selected as moderately tolerant and Bg 450, Bg 304, Bg 300 and Bg 750 as salinity susceptible. Screening was done at germination and at maturity. Performance of rice crop under saline condition varied with the stages of the crop growth. Varieties tolerant at seedling stage at 8 dS m^{-1} were not tolerant at germination stage and as such varietal ability to germinate under the salinity level of 8 dS m^{-1} could not be taken as a good indicator to differentiate the varieties sensitive to salinity. Yield reduction at the salinity level of 8 dS m^{-1} is a suitable method to distinguish susceptible, moderately tolerant and tolerant varieties. According to the results, it could be suggested that yielding ability under saline conditions is a good indicator to measure salt tolerance but germination under saline condition could not be taken as a reliable criterion to select rice varieties tolerant to salinity.

KEYWORDS: Rice, Salinity tolerance.

INTRODUCTION

The annual per capita consumption of rice in Sri Lanka is around 100kg and rice is the major source of energy and protein (Abey Siriwardena, 2003). Therefore, with the estimated increase in population from the current level of 19 to 23 million by the year 2025, annual rice production has to be increased from 3.08 million t to 3.83 million t within the next two decades to feed the growing population. To achieve this target, all possible ways to increase rice production have to be explored. In addition, it is also necessary to protect the present extent under rice lands.

One of the major constraints that limit the cultivated extent and diminish productivity of rice lands is salinity. Saline soils occur mostly in arid and semi arid channel irrigated areas and in the coastal belts. In the dry zone of Sri Lanka, salinity has become a major factor limiting rice production in areas under major irrigation schemes where drainage facilities are insufficient (Jeganathan and Adamplan, 1980; Balasooriya, 1987). In addition, inland salinity occurs in areas where drainage is poor and evaporation exceeds precipitation. The source of salt is weathered rocks and irrigation water

(Handawela, 1982). Some rice lands in the costal plains receive tidal water ranging between 45 and 60cm during spring tide and between 10 and 25cm during neap. In addition, during dry weather, salt water intrudes the lands up to 50cm above mean sea level (Panabokke, 1977). As a result, rice growing soils in the coastal belt of Sri Lanka are salinized every year and converted into conditions in which rice growing is difficult (Dimantha, 1977). The area affected by coastal salinity was estimated to be around 0.112 million ha. (Alwis and Panabokke, 1972). Electrical conductivity values of saturated soil paste exceeding 4 dS m^{-1} are not uncommon in these areas (Panabokke, 1978). In addition, approximately 4000 ha of costal rice soils in Sri Lanka were flooded with salt water during the 2004 Tsunami making them unsuitable for rice cultivation. Besides, extreme environmental conditions and rising sea levels within the next few years due to forecasted climate changes might result in making more rice lands saline.

Since demand for water is on the increase in Sri Lanka, there will be comparatively less water available to wash off the accumulated salt in the soils. On the other hand, saline soils vary widely in their chemical and physical properties and hydrology. The variables include content and nature of salts, distribution of salts in the surface horizon, soil pH, nature and content of clay, organic matter content, nutrient content, water regime, relief and temperature (Ikehashi and Ponnampereuma, 1978). As such, measures that were identified to reclaim paddy lands affected by salinity are difficult to practice. In addition, most of these measures cause extra expenditure to the farmer and their impacts are not long lasting. As such, farmers usually pay little attention to reclaim those lands. Therefore, genetic improvement of salt tolerance in rice plays a vital role in improving the rice production in salt-affected rice lands in the country.

Most of the rice varieties widely grown in the island at present are not tolerant to salinity and thus the genetic improvement of rice tolerant to saline conditions is expected to provide a greater benefit. Production of rice varieties tolerant to salinity has no advantage if the response to salinity is unknown. Thus, knowledge on performance of rice varieties under saline conditions is necessary to evaluate varieties suitable for saline conditions. Therefore this paper reports result of some studies conducted at the Rice Research and Development Institute (RRDI) to evaluate the performance of rice varieties under saline conditions.

MATERIALS AND METHODS

Ten rice varieties having different yielding abilities were collected from four maturity groups. Their potential yield, maturity age and other promising characters are given in Table 1.

Table 1. Detailed description of rice varieties selected for the study*.

<i>Variety</i>	<i>Maturity period (months)</i>	<i>Potential yield (t/ha)</i>	<i>Remarks</i>
Bg 750	2½	4	
Bg 300	3	10	
Bg 304	3	9	Tolerant to Zn deficiency
Bg 94-1	3 ½	10	Moderately susceptible to Zn deficiency
At 354	3 ½	10	Moderately tolerant to Zn deficiency
At 401	4	10	Moderately tolerant to Zn deficiency
Bw 400	4	8	Moderately tolerant to Zn deficiency
Bg 450	4	10	Moderately susceptible to Zn deficiency
Pokkali	4	3-4	Moderately tolerant to Zn deficiency
Nona Bokra	4	3-4	Moderately susceptible to Zn deficiency

* Ikehashi and Ponnampuruuma, 1978; RRDI, 2006.

Screening at germination stage

A green house experiment was conducted at RRDI to screen the above ten rice varieties at their germination stage. Soils from Plinthudults group of Kurunegala series having an electrical conductivity of 0.123 dS m^{-1} were air-dried and sieved through 4mm sieve and packed into plastic trays at the rate of 5kg per tray. Each tray was treated with solid NaCl to raise the electrical conductivity of the soil to 8 dS m^{-1} (Zeng and Shannon, 2000; Ikehashi and Ponnampuruuma, 1978; IRRI, 1987).

Fertilizers were added to the soil at the rate of 0.3g urea, 0.75g concentrated super phosphate and 0.25g muriate of potash to ensure normal growth of the seedlings. Seeds were moistened for 24 hours in petrydishes and twenty seeds of each variety placed in trays with one row per variety. There were 3 replicates and each replicate had 20 seeds. To avoid the changing of salt concentration due to evapo-transpiration, water level of the trays was maintained daily. After one week, the germinated seeds of all the varieties were counted.

Screening during the growth stage up to harvesting

Pots of 10 litre capacity were filled with 5kg air dried sieved soil. Solid sodium chloride was added and mixed with soil in each pot to raise the salinity level to 8 dS m^{-1} (DOA, 1987, IRRI, 1987). Then soils were mixed with water up to saturation and allowed to settle for 2 weeks. N, P, K and Zn fertilizers were added and mixed with the soil at the time of planting as per the rates recommended by the Department of Agriculture (5kg N ha^{-1} , $45\text{kg P}_2\text{O}_5 \text{ ha}^{-1}$ and $20\text{kg K}_2\text{O ha}^{-1}$) Three weeks old rice seedlings of the above ten varieties were planted at 4 plants per pot. Fertilizer top dressings were done as recommended by the Department of Agriculture (35kg N ha^{-1} at

2 WAP, 50kg N ha⁻¹ at 5 WAP and 15kg N ha⁻¹ and 20kg K₂O ha⁻¹ at 7WAP). At maturity, grains were harvested and yield per plant was recorded.

RESULTS AND DISCUSSION

Sirisena and Abeysiriwardena (2005) reported that seeds soaked in a solution having Electrical Conductivity of 40 dS m⁻¹ for 9 days made a considerable difference in the normal (seeds having both root and coleoptiles) seed germination among rice varieties. According to them the reduction in germination varied among the varieties. Bg 450, Bg 750, Bg 300 and Bg 304 showed very low level of normal seed germination while Bw 400 and Bg 94-1 had a medium level of normal seed germination. However, At 401, At 354, Pokkali and Nona Bokra had a high level of normal seed germination. Therefore, this test can be used to differentiate varieties that are susceptible and tolerant. Ikehashi and Ponnampereuma, (1978) indicated that differences among rice varieties in the count of dead leaves of the seedlings grown in salt and soil mixture were another option to differentiate varieties that are susceptible and tolerant. According to Sirisena and Abeysiriwardena (2005) the increase in the number of dead leaves with increasing level of salinity was comparatively higher in Bg 300, Bg 304 and Bg 450 and Bg 750 than Bw 400, At 354, At 401, Bg 94-1, Nona Bokra and Pokkali.

Accordingly, the above ten varieties were ranked as susceptible, moderately tolerant and tolerant as given in Table 2.

Table 2. Varietal ranking for reaction to salinity based on seed viability when seeds were soaked in salt solutions having EC 40 dS m⁻¹ for 9 days and on count of dead leaves at 4 weeks after planting in soil having salinity levels of 8 dS m⁻¹.

<i>Variety</i>	<i>Varietal ranking based on reaction to salinity</i>
<i>Bg 450</i>	Susceptible
<i>Bg 750</i>	Susceptible
<i>Bg 300</i>	Susceptible
<i>Bg 304</i>	Susceptible
<i>Bg 94-1</i>	Moderately tolerant
<i>BW 400</i>	Moderately tolerant
<i>Nona Bokra</i>	Tolerant
<i>At 354</i>	Tolerant
<i>At 401</i>	Tolerant
<i>Pokkali</i>	Tolerant

Source: Sirisena and Abeysiriwardena, 2005.

Screening at germination

It appears from the results in Table 3 that the effect of salinity on germination of rice seeds was significant for salinity tolerant as well as salinity susceptible varieties. At 354 and Nona Bokra were identified as

tolerant varieties (Ikehashi and Ponnampereuma, 1978; Siriwardena, 1999; RRDI, 2006). In addition, experiments conducted by Sirisena and Abeysiriwardena (2005) also showed that At 354 and Nona Bokra were more tolerant to salinity than Bg 300, Bg 304, Bg 750, Bg 94-1 and Bw 400.

Table 3. Percentage seed germination of the selected rice varieties under saline and non saline conditions and varietal ranking for salinity reaction.

Variety	% Germination*		Decrease in %** germination	Varietal ranking on the basis seed germination
	Control	8 dS m ⁻¹		
Bg 450	87a	68b		Susceptible
Bg 94-1	88a	73b	15	Susceptible
Bg 300	85a	82.5a	2.5	Tolerant
Bg 304	85a	82.5a	2.5	Tolerant
Bg 750	85a	82.5a	2.5	Tolerant
Bw 400	82.5a	82.5a	0	Tolerant
At 401	95a	92.5a	2.5	Tolerant
At 354	87.5a	70b	17.5	Susceptible
Nona Bokra	85a	72.5b	12.5	Susceptible
Pokkali	92.5a	90a	2.5	Tolerant

*Values followed by same letter in each column are not significantly different at $p=0.05$.

**Difference between control and 8 dS m⁻¹.

Contrary to the above, results of the germination count revealed that Bg 300, Bg 304, Bg 750, Bg 94-1 and Bw 400 are tolerant to salinity at germination while At 354 and Nona Bokra are susceptible. Ikehashi and Ponnampereuma (1978) also reported that seed germination in saline condition is not well correlated with tolerance at seedling stage, and as such seed germination in saline condition cannot be considered as a good indicator to select rice varieties for salinity tolerance.

Screening at maturity stage

Even though seedlings were 3 weeks old when planting in salt treated pots, no plants survived in pots of Bg 300, Bg 304, Bg 450 and Bg 750 under saline conditions. Therefore, grain yield per panicle could not be counted for Bg 300, Bg 304, Bg 450 and Bg 750 (Table 4). The highest grain yield per panicle under saline conditions was observed in At 401 and followed by At 354, Bw 400, Pokkali and Nona Bokra. Pokkali and Nona Bokra were the lines which had lower yields even under normal conditions (Ikehashi and Ponnampereuma, 1978). Yield levels under salinity conditions were moderate in Bg 94-1. The highest reduction in grain yield due to salinity was observed in Bg 94-1 and Bw 400. This agrees with the findings of Zeng and Shannon (2000) who disclosed that grain filling of susceptible rice varieties diminish at higher salinity levels due to high pollen sterility.

Table 4. Grain yield per panicle of rice varieties grown in saline condition and varietal ranking for salinity reaction.

<i>Variety</i>	<i>Grain yield per panicle (g)*</i>		<i>Decrease in yield ** (seed weight in g)</i>	<i>Varietal ranking on the basis of grain yield</i>
	<i>Control</i>	<i>Soil treated with NaCl to make EC 8 dS m⁻¹</i>		
<i>Bg 450</i>	3.76a	NR		Susceptible
<i>Bg 750</i>	2.75b	NR		Susceptible
<i>Bg 300</i>	3.96a	NR		Susceptible
<i>Pokkali</i>	2.34b	1.91ab	0.43	Tolerant
<i>At 354</i>	3.80a	2.08ab	0.72	Tolerant
<i>BW 400</i>	3.76a	2.17ab	1.59	Moderate tolerant
<i>Bg 94-1</i>	2.92ab	1.30c	1.62	Moderate tolerant
<i>Nona</i>	2.13b	1.75b	0.38	Tolerant
<i>Bokra</i>				
<i>At 401</i>	2.98a	2.76a	0.12	Tolerant
<i>Bg 304</i>	3.98a	NR		Susceptible

NR- not recorded.

*Values followed by same letter in each column are not significantly different at $p=0.05$.**Difference between control and 8 dS m^{-1} .

Ranking of varieties for salinity reaction on the basis of grain yield presented in Table 4 are almost similar to the rankings in Table 2. Therefore, yield reduction at saline condition is a suitable indicator to distinguish susceptible, moderately tolerant and tolerant rice varieties.

CONCLUSIONS

Performance of rice varieties under saline conditions varied with the growth stage of rice seedling. Seed viability test after emersion of seeds in a salt solution with an electrical conductivity of 40 dS m^{-1} for 9 days and visual scoring of seedlings at 4 weeks after transplanting in a saline soil have been identified as good measure of testing rice varieties for salt tolerance. The results of the present studies showed that the germination test in saline soils is not a good indicator to distinguish salinity susceptible and tolerant rice varieties, but yield reduction under saline condition is a suitable indicator to distinguish susceptible, moderately tolerant and tolerant rice varieties. Therefore, the understanding of plant response from seed to maturity stage is necessary to get a better understanding about the rice varieties for their reaction to salinity.

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