Screening of Rice Varieties for Salt Stress at Reproductive Stage Based on Phenotypic Responses

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Abstract
Salinity affects all growth stages of rice at varying degrees starting from germination up to maturation. The present study was conducted to screen the commonly cultivated rice varieties against salt stress and to identify best varieties at reproductive stage that can address the problem of salt stress in Sri Lanka. Screening of 21 newly improved rice varieties and check variety Pokkali was performed at reproductive stage in soil-filled pots. A factorial experiment laid out in a completely randomized design was conducted. Rice varieties were tested for the ability to sustain growth performance and yield performances at the reproductive stage under salt stress. Most of the varieties were significantly affected beyond the EC 4 dS/m salt stress. At the 12 dS/m salt stress level, only 6 varieties namely Pokkali, At 354, Bg 369, At 353, Bg 406, At 402 and Bg 379-2 survived. Based on the phenotypic observations, Pokkali , At 354, Bg 369, At 353, Bg 406 and At 402 identified as salinity tolerant and Bg 379-2 identified as moderately salinity tolerant at reproductive stage.

***Keywords*:** Phenotypic response, Rice, Salt stress, Varieties
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Introduction

Rice (*Oryza sativa* L.*)* is one of the most important cereal crops and serves as the staple food for nearly half of the world's population (Mohammadi *et al.*, 2010). However, the productivity of rice is greatly affected due to soil salinity which is the second most widespread soil problem next to drought in rice growing areas of the world (Islam *et al.*, 2011).

Rice is very sensitive to salinity during early seedling and reproductive stages compared to germination, active tillering and at maturity stages (Lafitte *et al.*, 2007). Salinity affects yield components such as panicle length, spikelet number per panicle, grain yield and also delays panicle emergence and flowering (Flowers and Yeo, 2000).

In agriculture, a soil having a salt concentration exceeding an Electrical Conductivity (EC) value of 4 dS/m is classified as saline (USDA-ARS, 2008). It has been observed that the yield of most crops is reduced at salinity levels above 4 dS/m. In Sri Lanka, approximately 13% of the irrigated lands are affected by salinity stress (Gregorio *et al.*, 1997) and this percentage increases gradually in both coastal regions and inlands. Salinity is gradually increasing in the rice lands of Sri Lanka both in the coastal regions and inlands (Sirisena & Herath, 2009).

Even though there are agronomical practices like improved field drainage, maintenance of adequate amount of water around 2 to 3 cm height until early reproductive stage establishment of crop by transplanting and use of organic manure instead of inorganic fertilizer are used to address salinity, these practices are not cost-effective, efficient and favorable for a long-term solution. Hence, cultivation of durable resistant rice varieties appears more appropriate as a long-lasting solution. Hence, the present study was conducted to screen twenty-two most popular rice varieties grown in salinity affected areas in Sri Lanka against salt stress and to identify mega varieties that can address the problem of salt stress.

Materials and Methods

Plant Materials

This study was carried out at Rice Research and Development Institute (RRDI, Batalagoda) which comes under low country intermediate zone. Seeds of twenty-one improved rice varieties namely Bg 379-2, Bg 450, At 402, Bg 403, Bg 406, Bg 94-1, Bg 352, At 353, At 354, Bg 357, Bg 358, Bg 359, Bg 360, At 362, Ld 365, Bg 366, Bg 369, Bg 300, Bg 310, At 307, At 308 and Pokkali as salinity resistant check variety were collected from rice research station Batalagoda.

Response to salt stress at reproductive stage

The study was conducted during 2014/15 *Maha* season (add months) in a greenhouse at RRDI. The varieties were evaluated for their tolerance to salinity in a pot experiment based on the performance of the mature plants under saline conditions. Soil was collected from RRDI paddy field (EC - 0.04 dS/m) air dried, sieved through 4 mm sieves and filled into pots at the rate of 5 kg per pot. Soil in pots was mixed with water and allowed to settle for 2 weeks; fertilizers were added and mixed with the soil at the time of planting at the rate of 0.3 g of urea, 0.75 g of concentrated super phosphate and 25 g of Muriate of Potash according to department recommendation. Three weeks old rice seedlings of 22 varieties (21 newly improved + *Pokkali* check) were planted at the rate of 3 plants per pot. At the booting stage NaCl was added at the rates of 0, 6, 12 and 18g per pot to get the salinity levels of 0, 4, 8, 12 dS/m, respectively. Saturated moisture level was maintained in each pot throughout the growing season. The experiment was a 22 (variety) X 4 (salinity levels) two factorial laid out in a CRD with three replications. Data were recorded on Plant Height (PH), Panicle Length (PL), Root Dry Weight (RDW), Shoot Dry Weight (SDW), Panicle No. per plant (PN), Fill Grain % (FG%), Grain Yield per plant (GY) and Plant Survival % (PS%).

Statistical analysis

To check the difference among rice varieties for salinity tolerance analysis of variance was performed using Proc GLM procedure followed by the Duncan Multiple Range Test (DMRT). Plant survival percentage was calculated by using survival plants per pot. For the preparation of dendogram PH, PL, RDW, SDW, PN, FG%, GY and PS% were considered. Cluster analysis was performed using Statistical Analysis System (SAS).

Results and Discussion

The two-way interaction effect of variety X salt concentration were significant with PH, PL, RDW, SDW, PN, FG%, GY and PS% (Table 1). PH and PL of the tested varieties decreased with the increasing salt levels. Influence of different salinity levels at reproductive stage on the height (*mean*=66.47295, R^2=0.958129, p <0.0001) of the rice varieties and PL (*mean*=16.6837, R^2=0.951901, P <0.0001) were significant beyond the 4 dS/m salt stress, whereas some literature said that the height of rice in different levels of salinity (3.6 to 8.3 dSm^{-1}) decreased but not statistically significant (Gridhar, 1988: Flash, 2010).

The influence of salinity on the height has been reported by many researchers (Gridhar, 1988). RDW (*mean*=1.338788, R^2=0.782539, P <0.0001) and SDW (*mean*=6.542618, R^2=0.88832, P <0.0001) of the tested varieties decreased with the increasing salt levels. It was significant beyond the 4 dS/m salt stress. The influence of salinity on the dry weight of straw was reported (Zeng and Shannon, 2000); whereas some studies have shown that salinity does not effect on the weight of straw before heading stage (Zeng and Shannon, 2000).

PN (*mean*=7.710985, R^2=0.862459, P <0.0001), FG% (*mean*=0.421136, R^2=0.862459, P <0.0001) and GY (*mean*=30.89989, R^2=0.9972676, P <0.0001) of the tested varieties decreased with the increasing salt levels. Influence of different salinity levels on the yield data of the rice varieties was significant beyond the 4 dS/m. Salinity has a significant influence on grain yield. Significant impacts of salinity on the number of filled panicles were reported. Salt sensitive varieties showed higher reduction in yield per plant compared to tolerant varieties. High influence of salinity on rice yield and rice sensitivity to salinity was reported by several researchers (Kadda et al, 1973; Shahdy, 1994).

PS %(*mean*=0.80703, R^2=0.9972776, P <0.0001) was highly significant at the 12 dS/m salt stress. At the 12 dS/m salt stress 6 varieties namely *Pokkali*, At 354, Bg 369, At 353, Bg 406, At 402 and Bg 379-2 survived (Table 1). Remaining varieties at 12 dS/m salinity level were analyzed further by using dendrogram based on the influence of salinity on percentage reduction of the PH, PL, RDW, SDW, PN, FG%, GY and PS%. Clustering was done at 21.62 similarity level. Significantly different two clusters were identified. As a result, *Pokkali,* At 354, Bg 369, At 353, Bg 406 and At 402 identified as salinity tolerant verities whereas Bg 379-2 identified as moderately salinity tolerant variety among the selected rice varieties at reproductive stage.

Table 1: Percentage reduction of the phenotypic traits due the salinity stress.

Variety	PL		PN		PH		RDW		SDW		GY		FG%		PS%	
	8 dS/m	12 dS/m	8 dS/m	12 dS/m	8 dS/m	12 dS/m	8 dS/m	12 dS/m	8 dS/m	12 dS/m	8 dS/m	12 dS/m	8 dS/m	12 dS/m	8 dS/m	12 dS/m
Bg379-2	11.4 ±(5.9)	66.8 ±(33.1)	67.5 ±(5.9)	87.5 ±(12.4)	10.9 ±(2.2)	74.3 ± (25.6)	90.5 ±(1.9)	96.6 ± (3.3)	88.05 ± (0.8)	93.1 ± (6.8)	88.4 ± (0.7)	96.5 ± (3.4)	31.4 ±(19.1)	82.3 ± (17.6)	0 ± (0)	66.6 ±(33.3)
At402	12.8 ±(0.8)	44.7 ±(27.6)	58.6 ±(6.1)	59.4 ±(20.2)	5.8 ±(1.9)	37.4 ±(10.2)	61.0 ± (9.5)	80.3 ±(10.4)	65.5 ± (5.2)	80.3 ±(10.4)	57.6 ± (5.90)	86.4 ± (7.1)	9.1 ±(2.0)	47.0 ± (8.9)	0 ± (0)	33.3 ±(33.3)
Bg406	20.3 ±(2.4)	23.4 ± (3.1)	52.6 ±(14.3)	45.5 ±(20.4)	14.1 ±(1.9)	33.9 ± (1.3)	73.0 ± (7.0)	92.6 ± (0.3)	73.4 ± (7.2)	92.7 ± (0.4)	78.6 ± (3.8)	91.2 ± (4.0)	11.5 ± (8.0)	34.7 ± (30.8)	0 (±0)	0 ± (0)
At353	11.2 ±(6.9)	21.5 ± (2.4)	57.7 ± (9.1)	51.1 ± (6.8)	11.2 ±(1.5)	14.1 ± (2.5)	69.3 ±(10.1)	70.4 ± (7.0)	69.3 ±(10.1)	50.4 ±(25.0)	77.2 ± (3.9)	91.9 ± (0.9)	47.4 ±(18.1)	28.9 ± (25.5)	0 ± (0)	0 ± (0)
Bg359	12.0 ±(4.5)	19.8 ± (9.8)	48.7 ± (3.7)	55.1 ± (6.9)	3.4 ±(2.5)	9.6 ± (1.2)	52.4 ±(19.1)	85.7 ± (1.4)	52.4 ±(19.1)	89.3 ± (4.9)	64.0 ± (8.3)	87.3 ± (5.4)	10.4 ± (6.4)	15.1 ± (5.4)	0 ± (0)	0 ± (0)
Bg369	6.1 ±(1.7)	0.2 ±(0.1)	39.8 ±(11.5)	41.3 ± (7.2)	0.4 ±(0.2)	24.8 ± (24.7)	50.2 ± (2.4)	70.8 ± (7.7)	54.6 ± (9.3)	76.6 ± (2.3)	64.4 ± (1.4)	79.2 ± (1.4)	0.9 ± (0.6)	2.7 ± (1.2)	0 ± (0)	0 ± (0)
At354	18.1 ±(5.2)	3.2 ± (2.7)	60.4 ± (7.4)	68.1 ± (7.9)	22.3 ±(2.3)	17.1 ± (2.5)	64.5 ±(28.2)	94.4 ± (1.3)	64.5 ±(28.2)	93.1 ± (1.2)	79.7 ± (3.8)	94.1 ± (2.7)	31.3 ±(10.0)	48.5 ± (7.1)	0 ± (0)	0 ± (0)
Pokkali	4.3 ±(2.8)	23.2 ± (5.3)	68.5 ± (9.2)	83.3 ± (3.9)	8.0 ±(3.7)	8.8 ± (2.4)	29.2 ± (7.9)	55.4 ± (4.0)	29.2 ± (7.9)	55.4 ± (4.0)	84.3 ± (1.0)	95.4 ± (1.2)	86.6 ± (4.9)	91.7 ± (1.8)	0 ± (0)	0 ± (0)

Conclusion

At the reproductive stage, the phenotypic traits of the varieties were significantly affected beyond the EC 4 dS/m salinity level. Significant reduction was observed in PH, PL, RDW, SDW, PWT, PNO and YLD in response to increasing salt level. *Pokkali*, At 354, Bg 369, At 353, Bg 406 and At 402 are identified as salinity tolerant and Bg 379-2 is identified as moderately salinity tolerant variety at reproductive stage.

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