Effects of NaCl induced Salinity on the Growth and Yield of Selected Rice (*Oryza sativa* L.) Cultivars

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Abstract
Salinity induced by NaCl is one of the serious abiotic stresses that reduce plant growth, development and productivity worldwide. This experiment was conducted to assess the effects of different salinity levels (100 and 150 mM NaCl) on the growth and yield of selected rice cultivars namely, At 307 and At 308. The rice plants were grown in plastic pots (30 × 30 cm) and the experiment was laid-out in a Completely Randomized Design with six treatments and four replications. Shoot and root length, plant dry weight and yield were significantly reduced by salinity stress. At 307 showed the highest shoot length (35.6 cm) under 100 mMNaCl concentration while the lowest (21.4 cm) was found in At 308 at 150 mM salinity. The highest root length (14.9 cm) was found in At308 at 150 mM salinity and the same was lowest (6.8 cm) in At 307 at 150 mMNaCl concentration. At307 showed the highest plant dry weight (25.2 g) at 100 mM salinity and the lowest (11.5 g) was found in At308 under 150 mM salinity. Salt stress also significantly reduced the yield of tested rice cultivars. The highest yield (3.5 t ha^{-1}) was obtained in At 307 at 100 mMNaCl concentration and the lowest (1.3tha^{-1}) was recorded in At308 under 150 mM salinity. Based on the tested parameters, At 307 was found to grow and produce well at 100 mMNaCl concentration and At 308 did not perform well under the tested salinity levels. Hence, At 307 was identified as the salt tolerant rice genotype among the tested cultivars.

Keywords: Salinity, Rice cultivars, Tolerance, Yield
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Introduction

Salinity is a major environmental stress affecting plant productivity and is a problem in many areas, particularly in hot and dry climatic conditions. Salinity is gradually spreading in the rice lands of Sri Lanka, both in the coastal regions and inlands (Sirisena and Herath, 2009). Among the low and middle income countries of the world, rice is the most important cereal crop. Rising sea levels, salinization, erosion and human settlements lead to the loss of rice fields in an alarming rate. Salinity and drought stress are among the most serious challenges to crop production in the world today, particularly in developing countries.

Salinity exerts its undesirable effects through osmotic inhibition and ionic toxicity. Osmotic inhibition is the result of the salt presented in the soil solution which reduces the ability of the plant to take up water and leads to slower growth. Ionic toxicity is caused by an excessive amount of salt entering the transpiration stream which eventually injures cells in the transpiring leaves and may further reduce growth. Reduction in growth and photosynthesis are among the most conspicuous effects of salinity stress.

The ability of plants to cope with salinity stress is an important determinant of crop distribution and productivity in many areas. Therefore, it is important to understand the mechanisms that confer tolerance to saline environment. Some of the growth parameters such as root growth, plant height, leaf area and plant dry weight have been proposed as morphological markers for the screening of tolerant genotypes in rice. The estimation of total dry weight is viewed as a valuable index for monitoring the vegetative growth of plant (Hakim *et al.*, 2014).

Hence, the present study was conducted with the objectives of investigating the effects of salt stress on the shoot and root length, plant dry weight and yield of selected rice cultivars which are commonly cultivated in the Batticaloa District, to compare the growth performance of these cultivars at different salinity levels and to select the salt tolerant rice cultivar which can thrive and produce well under saline condition.

Materials and methods

This experiment was conducted on a farmer's field near the Eastern University where the climate was warm (28-32ºC) with an average annual rainfall of 1250 mm. Hundred grams of seeds of each of these cultivars (At 307 and At 308) were placed in petri dishes and were watered daily. The sprouted seedlings were transplanted in plastic pots (3 plants/pot) having the height (30 cm) and diameter (30 cm) and filled with paddy soil: sand: compost (1:1:1 v/v). Three NaCl levels such as 0 (control), 100 and 150 mM were used. Control plants were watered with 100 ml distilled water whereas salinity-stressed plants were irrigated with 100 and 150 mM NaCl solutions which were prepared by using analytical NaCl. The experiment was laid out in the Completely Randomized Design in 2 x 3 factorial arrangements with four replications. Two cultivars and three salinity levels were the experimental factors.

Four weeks after transplanting, shoot and root length were measured. Five plants from each replicate were used for these measurements. The shoot length was measured from the base of the stem to the apex of the longest leaf and the root length was determined from the base of the stem to the tip of the longest root. Dry weight of plants was measured after drying at 80ºC for 2 days in an electric oven. The roots of the uprooted plants were washed thoroughly with distilled water before drying.

At the maturity stage, five plants were randomly selected from each replicate of the treatments of the selected rice cultivars and the grains were collected and their weights were also recorded. The data were statistically analysed using ANOVA and the difference between treatment means was compared using DMRT.

Results and discussion

Under saline condition, the shoot length of the selected rice cultivars was significantly ($p<0.05$) lower than the control values (Table 1). As pointed out by Pattanagul and Thitisaksakul (2008), growth reduction is generally observed in plants exposed to salinity stress. This may partly be due to lower water potential in the cells which in turn causes stomatal closure and limits CO_2 assimilation.

At307 showed significantly ($p<0.05$) higher shoot length than At 308 in the tested salinity levels. Besides, At 307 in 100 mMNaCl solution exhibited the highest shoot length and the lowest was found in At 308 in 150 mMNaCl treatment. From these observations, At 307 was proven to grow to a substantial height, despite saline environment which could be a salt tolerant feature of this cultivar.

Under saline condition, the root length was significantly lower than the control values (Table 1). The highest root length was observed in At 308 at 150 mM NaCl solution and the lowest was found in at 307at 150 mM NaCl solution. This indicates that At 308 which showed low shoot length under saline condition exhibited high root length in the similar situation. As reported by Pattanagul and Thitisaksakul (2008), salt-sensitive cultivars of rice showed an increase in root length in response to salinity stress.

Table 1: Effects of different NaCl concentrations on the shoot length, root length and plant dry weight of the selected rice cultivars

Salinity level	Cultivars	Shoot length (cm)	Root length (cm)	Dry weight g plant^{-1}
0	At 307	42.3 a	16.3 a	28.7 a
	At 308	38.1 a	15.8 a	24.1 a
100 mM	At 307	35.6 b	10.1 b	25.2 b
	At 308	26.7 c	13.2 c	18.6 c
150 mM	At 307	30.2 d	6.8 d	19.3 c
	At 308	21.4 e	14.9 e	11.5 d

*Values in the same column followed by the same letter do not differ significantly ($P< 0.05$).

* Values are the means of 20 plants in 4 replications.

The root length of At 307 was reduced by salinity stress. While an increase in root growth in order to increase water influx is usually documented as a general response to salinity, experimental evidence indicates that reduced root and increased shoot growth may improve salinity tolerance by resisting the flux of toxic ions to the shoot (Maggio *et al.*, 2007). Among the twenty-three rice (*Oryza sativa* L.) varieties when screened for salt tolerance showed a decrease in the average root length with increased salt level of 4, 8, 12 and 24 dSm^{-1}. The gradual decrease in root length with increase in salinity might be due to inhibitory effect of NaCl to root elongation by restricting cell division and expansion of root.

Plant dry weights in saline condition were significantly (*p<0.05*) lower than the control values. Increased salinity level caused a greater reduction in plant dry weights. Total plant dry weights of three rice varieties showed a significant (*p<0.05*) variation among different experimental rounds under both un-stressed and salt-stressed conditions (De Costa *et al.*, 2012). According to Asha and Dhingra (2007), plant dry weight was decreased with increasing salinity levels. At 307 showed significantly (p<0.05) higher dry weight than At 308 in the tested salinity levels. Besides, At 307 in 100 mMNaCl showed the highest dry weight and the lowest was found in At 308 under 150 mM NaCl. From these results, At 307 produced a substantially high dry weight under saline condition which could be asalt tolerance feature of this cultivar. As stated by De Costa *et al.* (2012), a higher total plant dry weight under salt-stress, indicates a combination of salt-tolerance and inherent genetic capacity for higher biomass growth.

The yield of At 307 and At 308 rice cultivars at 0 mM (Control) salinity level were 4.3 and 3.2 tha^{-1} respectively. The yields of At 307 and At 308 at 100mM salinity were 3.5 and 2.5 tha^{-1} respectively. At 307 and At 308 showed 2.7 and 1.3 tha^{-1} as yield at 150mM salinity, respectively. Increased salinity level caused greater reduction in grain yield. The reduction in yield under saline condition is also due to reduced growth as a result of decreased water uptake, toxicity of sodium and chloride in the shoot cell as well as reduced photosynthesis. Rice cultivar At 307 showed significantly (p<0.05) higher yield than At 308 in the tested salinity levels. These results showed that At 307 was able to withstand and produce markedly well than At 308 under saline environment. Cultivars which are believed to be salt resistant usually maintain higher yield under salinity stress.

Conclusions

Rice cultivar At 307 showed the better growth attributes and yield than At 308 under saline condition. Hence, out of two rice varieties tested, At 307 was identified as the salt tolerant rice cultivar which can be cultivated in the saline areas of the Batticaloa district.

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