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Effect of Salinity on Plant Height, Shoot and Root Dry Weight of Selected Rice Cultivars

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Abstract: Salinity becomes a serious concern when soluble salts occur in excessive concentrations in the soil or water. NaCl is the most common salt causing salinity stress. Salinity is a major yield-reducing factor in coastal and arid irrigated rice production systems. Selection of salt tolerant rice varieties has huge impact on global food supply chain. Therefore three rice varieties namely 'Pachaiperumal', 'At 307', 'At 308' were tested in a pot experiment to find out their responses against salt stress in terms of plant height, shoot and root dry weight. The experiment was conducted using polyethylene bags and was laid out in the Factorial Completely Randomized Design with six treatments and four replications. Salt stress was imposed for the three weeks old rice seedlings after transplanting them in the polyethylene bags which were filled with saline soil (EC 6.6 dSm^{-1}). Non saline soil (1.8 dSm^{-1}) was used as the control treatment. The saline soil was collected from a saline tract of Batticaloa district. Plant height, Root and shoot dry weights and yield of the tested cultivars were significantly($P<0.05$) reduced by salinity. Rice cultivar "At 307" showed the highest plant height (68.5 cm, 86.3 cm and 82.38 cm) during the growth stages respectively when exposed to salinity and the lowest plant heights (52.1,69.8 and 66.6) were found in "Pachaiperumal" under salt stress. Cultivar "At 307" showed the highest root dry weights (0.4 g, 10.1 g and 26.3g) when exposed to salinity during the growth stages and the lowest weights (0.1g, 5.1g and 19.4g) were found in "Pachaiperumal". The highest shoot dry weight (0.21g, 26.1g, and 40.2g) was recorded in "At 307" meanwhile lowest shoot dry weight (0.8g, 12.7g, and 24.4g) was observed in "Pachaiperumal" under the saline condition. The highest yield (2.2 $t.ha^{-1}$) was obtained in "At 307" and the lowest one (0.4 $t.ha^{-1}$) was recorded in "Pachaiperumal" under saline condition. Thus the physiological responses of rice plants to salinity at various developmental stages are therefore critical for identifying salinity tolerance in the cultivars.
Keywords: Plant Height, Rice Cultivars, Salinity, Shoot and Root Dry Weight

INTRODUCTION

Rice (*Oryza sativa*), as one of the world's most important cereal crops, provides the primary source of food and calories for about half of mankind [1] .Soil salinization is a global threat that causes a huge reduction of agricultural yield worldwide. More than 20% of all irrigated land on earth is affected by salinization. Rice as a so-called glycophyte is very sensitive to salinity stress. Height, root length, shoots and root dry matter of rice plant were affected significantly by salinity. Salinity stress is generally defined as the presence of excessive amounts of soluble salt that hinder or negatively affect the functions needed for normal plant growth and development [2]. Soil contains soluble salts of multifarious nature. High concentrations of salt impose both osmotic and ionic stresses on the plants which lead to several morphological and physiological changes. High salt content, especially chloride and sodium sulphates, affects plant growth by modifying their morphological, anatomical and physiological traits [3]. Many researchers reported that with an increase in salinity there was a decrease in the development of the xylem. Many studies have shown that the fresh and dry weights of the shoot system are affected, either negatively or positively, by changes in salinity concentration, type of salt present, or type of plant species [4] and decrease in dry matter content at the highest salinity levels might be due to the inhibition in hydrolysis of reserved foods and their translocation to the growing shoots. The only way to control the salinization process and to maintain the sustainability of landscape and agricultural fields is to combat the salinization problems by environmentally safe and clean technique is the use of salt-tolerant species [5]. Identification of salt tolerant varieties and development of management strategies are very important to reduce the salinity impacts and enhance the productivity from agricultural lands. It can be done by screening rice varieties for salt tolerance and identification of traits associated with salt tolerance which could be incorporated into breeding programmes to develop tolerant varieties. Therefore the present study was conducted to assess the effects of salinity on the growth attributes of selected paddy cultivars grown on a saline tract of Batticaloa. It has become important to study the performance of different paddy cultivars under saline conditions which may lead to varietal improvement to be effective for salinity tolerance.

METHODOLOGY

This experiment was conducted at the Agronomy farm of the Eastern University which is located in the Batticaloa district of Sri Lanka. The experiment was carried out during the "*Yala"* 2015. Rice (*Oryza sativa* L.) cvs. "Pachaiperumal", "At 307" and "At 308" were used for this study and the certified rice seeds were collected from different sources ("Pachaiperumal" from the seed and planting material office, Vavuniya and "At 307" and "At 308" from the government seed farm, Karadiyanaru). The seeds of these cultivars were washed thoroughly and were soaked in water for 24 hours and then incubated for 48 hours. A quantity of 100 g seeds of each of these cultivars were placed in petri dishes. These dishes were watered daily with equal amount of sterilized distilled water. The seeds were sprouted after five days in petri dishes. The seedlings were irrigated continuously until they were ready for transplanting. Saline soil was collected at a saline tract of 'Pankudaveli' and the non-saline soil was collected from a nearby area. Three weeks later, healthy vigorous rice seedlings were transplanted in polyethylene bags filled with sun dried saline and non – saline soils.

This experiment was carried out with six treatments and four replications and the treatments were as follows:

- T_1 (S_0V_1) = "Pachaiperumal" rice cultivar grown in non -saline soil (Control).
- T_2 (S_1V_1) = "Pachaiperumal" cultivar grown in saline soil.
- T_3 (S_0V_2) = "At 307" cultivar grown in non-saline soil (Control).
- T_4 (S_1V_2) = "At 307" cultivar grown in saline soil.
- T_5 (S_0V_3) = "At 308" cultivar grown in non -saline soil (Control).
- T_6 (S_1V_3) = "At 308" cultivar grown in saline soil.

The experiment was laid out in the Completely Randomized Design with two factor (salinity * cultivar) in a factorial arrangement. The data were statistically analyzed and differences between treatment means were compared by Duncan's Multiple Range Test (DMRT).

SOIL ANALYSIS

Soil analysis was carried out after soil filling and at the end of the study to determine the electrical conductivity and pH of both saline and non-saline soils. After the harvest, soil from the bags was removed separately, gently powdered with a wooden mallet to break the clods. The soil was air-dried, sieved and stored for analysis.

PLANT HEIGHT (cm)

Plant heights for the plants exposed to saline and non-saline treatments were taken at two weeks interval. The heights of the plants were recorded in centimeters from the ground level to the apex of the top most leaf.

SHOOT AND ROOT DRY WEIGHT(g)

Two plants were randomly selected from each replicate of the treatments during the vegetative, panicle initiation, heading and ripening stages different cultivars of paddy. Selected plants were uprooted and washed with tap water to remove the adhering sand. The shoots and roots were separated and kept in paper bags and dried in a drying oven at 80^0c until the weight was stable. The oven dried samples were taken and their dry weights were recorded.

Yield

Two plants were randomly selected from each replicate of the treatments during ripening stage. The yield was determined from the selected plants.

RESULTS AND DISCUSSION

Soil analysis results of saline and non-saline soil

Salinity causes reduction in the rate of infiltration and hydraulic conductivity by surface crusting. According to the soil test results pH in this area ranged from 7.6 to 7.9 with an average of 7.8 and the electrical conductivity of soil was ranged from 5.18 to 8.13 dSm^{-1} with an average of 6.6 dSm^{-1} classified as a moderately saline soil. The pH of non-saline soil was ranged from 6.9 to 6.5 with an average of 6.6 dSm^{-1} and the electrical conductivity of soil was ranged from 1.9 to 1.7 dSm^{-1} with an average of 1.8 dSm^{-1}. Non saline soil was loam textured in nature and saline soil was clay loam textured in nature.Wahome *et al.* [6] reported that high concentrations of salts in the growth medium cause undesirable effects on plant growth and development. Necrosis of tips, margins and laminae of leaves are symptoms observed due to salinity at early growth stages. Reduction in plant growth due to salinity has been denoted due to the following processes: salt induced osmotic stress, specific ion effect, nutritional imbalance, and salt induced oxidative stress [7]. The outcome of these effects may cause membrane damage, nutrient imbalance, altered levels of growth regulators, enzymatic inhibition and metabolic dysfunction, including photosynthesis which ultimately leads to plant death [8].

Effects of salt stress on the heights of paddy plants at different growth stages

It was found that there were significant ($P < 0.05$) differences between treatments on the heights of all the three paddy cultivars at the vegetative and reproductive stages and there was no significant interaction effect between the treatments on plant height among the tested cultivars at ripening stage (Table 1). Subjecting paddy plants to salt stress caused a significant reduction in the heights at the vegetative, reproductive and ripening stages compared to the control treatment .Cultivars had a significant effect ($P < 0.05$) on plant height when treated with salinity. Cultivar "Pachaiperumal" exhibited the lowest heights when exposed to salinity while "At 307" showed highest height at all three growth stages. Salinity has significantly reduced the heights of all the paddy cultivars during the above growth stages compared to control treatments. Less impact for salinity during the vegetative and reproductive stages led to better yield at the ripening stage. Hence "At 307"is could be identified as a suitable paddy cultivar for salt prone areas than the rest of the cultivars. The results indicated the effect of salinity on plant height of different cultivars which might be due to genetic potentiality of the varieties. Shalhevet [9] stated that salinity generally reduces shoot growth of crops more than root growth. Islam *et al*. [10] also witnessed the differences in plant height of rice varieties with different salinity levels. Other results those have supported what has been shown here, are those by Dantus *et al*. [11] in their study on cowpea, (*Vigna unguiculata* L.), and on *Brassica campestris* L. where they indicated that the zero level of salinity (< 4dsm^{-1}) led to increase in plants heights whereas higher concentrations (>4dsm^{-1}) caused reduction. Similar results were noted as well including the study done by Mathur *et al*. [12] on moth bean *Vigna aconitifolia* L.; Jamil *et al*. [13] on radish plant (*Raphanus sativus* L.), Taffouo *et al*. [4] on cowpea (*Vigna unguiculata* L.). They found that increasing the concentrations of salinity developed a decline in the heights of these plants.

Table-1: Effects of salt stress on the height of paddy plants at different growth stages

			Growth Stages		
	Cultivar	Treatment	Vegetative	Reproductive	Ripening
Non Saline	Pachaiperumal	S_0V_1	80.9a	142.6a	132.5a
	At 307	S_0V_2	74.5b	90.6b	86.2b
	At 308	S_0V_3	67.5c	86.9c	78.9c
Saline	Pachaiperumal	S_1V_1	52.1c	69.8c	66.6c
	At 307	S_1V_2	68.5a	86.3a	82.38a
	At 308	S_1V_3	59.7b	73.1b	68.28b
Salinity(S)			<.0001	<.0001	<.0001
Cultivar(V)			<.0001	<.0001	<.0001
Interaction(S*V)			<.0001	0.0010	0.2177

*Values with the same letter within the same column are not significant (P< 0.05) according to the Duncan Multiple Range Test at 5% significant level.

* Values are the means of 48 plants in 8 replications.

Effects of salinity on the root dry weights of paddy at different growth stages

The root dry weights of paddy plants were significantly affected by salinity stress during the growth period as P value was less than 0.05. It was found that there were significant ($P<0.05$) differences between treatments in the root dry weights of paddy during the vegetative and reproductive stages. It was also found that there were no significant interactions between salinity stress and cultivars on the root dry weights of paddy plants at the ripening stage.

Table-2: **Effects of salinity on the root dry weights of selected paddy cultivars at different growth stages**

			Growth Stages		
	Cultivar	Treatment	Vegetative	Reproductive	Ripening
Non Saline	Pachaiperumal	S_0V_1	0.2±0.05a	14.5±0.40ab	49.2±0.66a
	At 307	S_0V_2	0.6±0.05a	16.9±0.98a	41.1±1.46b
	At 308	S_0V_3	0.4±0.01a	11.8±0.95b	29.8±0.33c
Saline	Pachaiperumal	S_1V_1	0.1±0.01a	5.1±0.65a	19.4±2.27a
	At 307	S_1V_2	0.4±0.01a	10.1±0.40a	26.3±1.20a
	At 308	S_1V_3	0.2±0.01b	8.7±0.54b	21.1±7.00a
Salinity(S)			<.0001	<0.0001	<0.0001
Cultivar(V)			0.0004	0.0061	<.0001
Interaction(S*V)			0.0015	0.0012	0.2084

***Values with the same letter within the same column are not significant (P< 0.05) according to the Duncan Multiple Range Test at 5% significant level.

*Values are the means of 48 plants in 8 replications.

Salinity has significantly reduced the root dry weights of all the three paddy cultivars compared to the control treatment. Cultivar "At 307" exhibited the highest root dry weights when exposed to salinity at all three growth stages than the rest of the cultivars. The lowest amount was observed in "Pachaiperumal". Comparable results were obtained in sorghum and spider plants and in white seed coat bambara at high-salt treatment (200 mM NaCl) and the reduction of the plant root dry weight due to increased salinity may be a result of a combination of osmotic and specific ion effects of Cl^- and Na^+ [4]. Root injury and death due to ionic toxicity may have affected water uptake by the plants and as a result increased water deficit in the plants leading to decreased net photosynthesis, which in turn may have affected shoot growth. Water deficit may as well occur as the result of lowered water potential of the soil solution and restricting root water uptake. Reduction in dry weight of plant tissues reflects the increased metabolic energy cost and reduced carbon gain, which are associated with salt adaptation [14].

Effects of salinity on the shoot dry weights of paddy at different growth stages

The shoot dry weights of paddy were significantly affected by different treatments during the growth period as the P value is less than 0.05 (Table 3).It was found that there were significant (P<0.05) differences between treatments on the shoot dry weights of tested paddy cultivars during the vegetative and reproductive stages while there was no significant (P<0.05) interaction on the shoot dry weights of paddy cultivars at the ripening stages. Salinity has significantly reduced the shoot dry weights of all the tested paddy cultivars. Cultivar "At 307" exhibited the highest shoot dry weights when exposed to salinity at the vegetative, reproductive and ripening stages compared to the rest of the cultivars and the lowest shoot dry weight was noticed in "At 308". Salinity has significantly reduced the shoot dry weights of all the tested paddy cultivars. Jamil *et al.* [13] observed that shoot length, root lengths and dry weights of paddy were decreased with increasing salt stress. The reduction in root and shoot development may be due to toxic effects of NaCl as well as unbalanced nutrient uptake by the seedlings [15].

Table-3: Effects of salinity on the shoot dry weights of paddy at different growth stages

			Growth Stages		
	Cultivar	Treatment	Vegetative	Reproductive	Ripening
Non Saline	Pachaiperumal	S_0V_1	0.52±0.05a	26.9±0.22c	46.4±0.77b
	At 307	S_0V_2	0.26±0.02b	30.2±1.14a	57.1±2.33a
	At 308	S_0V_3	0.18±0.01c	27.8±0.33b	42.2±0.6b
Saline	Pachaiperumal	S_1V_1	0.8±0.01c	12.7±0.35c	24.4±0.93c
	At 307	S_1V_2	0.21±0.02a	26.1±0.27a	40.2±1.54a
	At 308	S_1V_3	0.18±0.01b	15.8±0.64b	33.6±0.5b
Salinity(S)			<.0001	<.0001	<.0001
Cultivar(V)			0.0004	0.0061	<.0001
Interaction(S*V)			0.0015	0.0062	0.2084

*Values with the same letter within the same column are not significant (P< 0.05) according to the Duncan Multiple Range Test at 5% significant level.

*Values are the means of 48 plants in 8 replications.

High salinity may inhibit the root and shoot elongation due to slowing down the water uptake by the plant. Neumann [16] indicated that salinity can rapidly inhibit the root growth and its capacity to water uptake and essential mineral nutrition from soil .The reduction in shoot dry weight could also be associated with reduced rate of leaf production, hence low number of leaves leading to reduced photosynthesis and accumulation of dry matter

Yield

It was found that there were significant differences between treatments in the yield of selected rice cultivars (Table 4).Salinity have significantly reduced the yield of all the tested rice cultivars. The highest yield (2.2 $t.ha^{-1}$) was obtained in "At 307" and the lowest one (0.4 $t.ha^{-1}$) was recorded in "Pachaiperumal" under saline condition.

The reduction in yield under saline condition was 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 [17]. Based on this observation it could be stated that "At 307" rice cultivar was able to show relatively high yield than the other two cultivars under saline condition. This is a favourable feature with regard to salt tolerance of this cultivar. Cultivars which are believed to be more salt resistant usually maintain high yield under salinity stress. The lowest yield found in "Pachaiperumal" exhibits its susceptibility to salt stress.

Table-4: Effects of salinity on the yield of selected rice cultivars during the maturity

Soil	Cultivars	Treatments	Yield (tha^{-1})
Control	Pachaiperumal	T_1 (S_0V_1)	3.3 ± 0.07b
	At 307	T_2 (S_0V_2)	4.3 ± 0.04a
	At 308	T_3 (S_0V_3)	1.9 ± 0.04c
Saline	Pachaiperumal	T_4 (S_1V_1)	0.4 ± 0.01c
	At 307	T_5 (S_1V_2)	2.2± 0.065a
	At 308	T_6 (S_1V_3)	0.8± 0.052b
Salinity (S)			< 0.0001
Cultivar (V)			< 0.0001
Interaction (S*V)			< 0.0001

*Values with the same letter within the same column are not significant (P< 0.05) according to the Duncan Multiple Range Test at 5% significant level.
*Values are the means of 48 plants in 8 replications.

CONCLUSIONS

All the tested attributes were affected by salinity. Salt stress reduced the plant heights, shoot and root dry weight during the growth period of these cultivars. Paddy cultivar "At 307" was able to maintain the highest heights at all three growth stages. Salinity caused a reduction in the shoot and root dry weights of selected paddy cultivars. "At 307" showed the highest root and shoot dry weights compared to rest of the cultivars. With regard to the yield, cultivar "At 307" performed better than the rest of the cultivars under salt stress. When comparing the overall performance of these selected paddy cultivars "At 307" performed better than "Pachaiperumal". All these results indicated that cultivar "At 307" was able to withstand salinity stress much better than the others and may be considered as a salt tolerant cultivar. Based on the study, "At 307" was identified as the most salinity tolerant paddy cultivar which could be cultivated in the salt affected areas of Batticaloa.

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