Yield and yield components of selected rice (*Oryza sativa* L.) Cultivars as affected by salinity

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Abstract— *Salinity is an important agricultural constrain which retards crop production. An experiment was conducted at the Agronomy farm of the Eastern University to find out the yield and yield attributes of selected rice cultivars which were exposed to salinity. The saline soil was collected from a saline tract of Batticaloa district. Three rice cultivars viz. "Pachaiperumal", "At 307"and "At 308" were used as the test materials. 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. Non saline soil was used as the control treatment. With regard to the yield attributes, cultivar "At 307" showed the best results compared to the rest of the cultivars under saline condition. "At 307" maintained highest number of productive tillers (15.5) per plant, highest number of filled grains (146.5) per panicle, lowest number of unfilled grains (50.8), highest value of 1000-grain weight (18.4 g) and highest yield (2 t ha^{-1}) than the rest of the cultivars. Rice cultivars "Pachaiperumal" and "At 308" showed their susceptibility to salinity stress. Thus, "At 307" was identified as the most salt tolerant rice cultivar compared to the others.*

Keywords— **Rice cultivars, Salt stress, Yield, *Oryza sativa***

I. INTRODUCTION

Among the factors that limit rice yield, salinity is one of the most serious environmental problems both globally and as well as in Sri Lanka. As reclamation of saline soils is laborious, development or selection of salt tolerant crop species is one of the possible means for salt prone areas. Generally, salinity affects the growth of rice plant at all stages of its life cycle as it is the most salt sensitive crop but more distinct on reproductive than vegetative stage. Thus, decreases the grain yield. Excessive soluble salts in soils may reduce the efficiency of water uptake by plants. Plant height, total number of tillers, number of productive tillers, filled grains per plant, unfilled grains per plant and 1000-seed weight are the yield contributing components. Yield and quantity of grains decreased progressively with increasing level of salinity (Abdullah *et al*., 2001). Rice is susceptible to salinity, since most rice plants are severely injured at an EC of 6-10 dSm^{-1}. Yield losses due to salinity amount to 30-50 percent and farmers normally grow local varieties due to unavailability of salt tolerant high yielding varieties (Islam *et al*., 2007). Appropriate salt tolerant high yielding varieties can fit into the rice-growing saline tracts and boost up the country's rice production. Study on the response of rice to salinity stress will help in selection of salt tolerant cultivars by identifying physiological features of salinity tolerance. Hence, the present study was conducted to assess the yield and yield attributes of selected rice cultivars grown under saline condition.

II. MATERIALS AND METHODS

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 seedlings were irrigated continuously until they were ready for transplanting. Saline soil was collected at a saline tract of 'Pankudaveli' and non-saline soil was collected from a nearby area. Three weeks later, healthy vigorous, two rice seedlings were transplanted in polyethylene bags (30 cm in diameter and 60 cm in height) filled with 3 Kg of sun dried saline and 3 Kg of non – saline soils. Urea, Sulphate of potash and Triple super phosphate were used as basal and top dressing according to the recommendation of the Department of Agriculture. A quantity of 1000 mL of distilled water was irrigated to each polyethylene bag when needed to maintain the required soil moisture and salt concentrations and all other agronomic practices were done according to the recommendation of the Department of Agriculture.

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 experimental design was two factor in a factorial Completely Randomized Design which includes 6 treatments (3 cultivars x saline soil and non-saline soil) with 4 replications. A total number of 240 bags were used for this experiment. Each bag consisted of two plants. Each replication consisted of 20 plants. (The experiment was arranged in a Factorial Completely Randomized Design in the following Figure:)

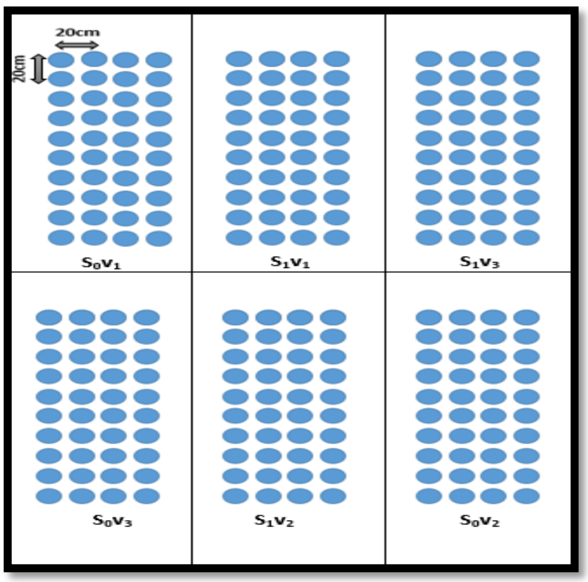

Figure 1: Layout of the experiment

A. Soil analysis

Soil analysis was carried out after soil filling and at the end of the study to determine the electrical conductivity 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.

B. Determination of soil electrical conductivity (EC)

The following procedure was adopted to determine the EC of soil samples of both saline and non-saline soils. A quantity of 20 g of soil sample was mixed with 50 mL of distilled water for the preparation of soil water filtrate. Then, soil water suspension was shaken for a period of 1 hour and filtrate was collected. Digital EC meter was used to determine the EC of the filtrate collected from the soil samples.

C. Yield and yield attributes

Yield and yield attributes for the plants exposed to saline and non-saline conditions were taken during the ripening stage of paddy plants. The sampled plants from each treatment, were used to collect the data. The yield and yield contributing parameters such as total number of tillers, number of productive tillers, number of filled grains per panicle, unfilled grains per panicle, 1000 grain weight, and yield were recorded.

D. Total number of tillers and productive tillers per plant

Two plants were randomly selected from each replicate of the treatments from separate polyethylene bags during the ripening stage. The total number of tillers and productive tillers were counted from the selected plants.

E. Number of filled grains per panicle

Two plants were randomly selected from each treatment replicate from separate polyethylene bags during the ripening stage. The number of filled and unfilled grains and 1000 grain weight was recorded from the selected plants

F. Yield

Two plants were randomly selected from each treatment replicate during the ripening stage from separate polyethylene bags. The yield was determined from the selected plants.

G. Analysis

The data were statistically analyzed and differences between treatment means were compared by Duncan's Multiple Range Test (DMRT).

III. RESULTS AND DISCUSSION

A. Soil analysis results of saline and non-saline soil

Formation of white crust and irregular emergence of crop seedlings were noticed on plants exposed to salinity. Salinity causes reduction in the rate of infiltration and hydraulic conductivity by surface crusting. According to the soil test results, EC of soil was ranged from 5.2 to 8.1 dSm^{-1} with an average of 6.6 dSm^{-1} classified as a moderately saline soil. The EC of non – saline soil ranged from 1.9 to 1.7 dSm^{-1} with an average of 1.8 dSm^{-1}.

The pH of non - saline soil was ranged from 6.9 to 6.5 with an average of 6.7 and pH of saline soil was ranged from 7.6 to 7.9 with an average of 7.8.

Salinity becomes a problem when enough salts accumulate in the root zone to affect plant growth. Excess salts in the root zone hinder plant roots by withdrawing water from surrounding soil. This lowers the amount of water available to the plant, regardless of the amount of water actually in the root zone. The excess salinity in soil water can decreases plant available water and cause crop stress.

Wahome *et al.,* (2000) 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. When roots are injured due to salinity; nutrient uptake is impaired thereby causing various nutrient deficiency symptoms and salinity can affect all the major processes that play a key role in plant growth and development such as photosynthesis, lipids and synthesis of proteins etc. Reduction in plant growth due to salinity has been denoted by salt induced osmotic stress, specific ion effect, nutritional imbalance and salt induced oxidative stress (Ashraf and Akram, 2009; Munns and Tester, 2008). The outcome of these effects cause membrane damage, nutrient imbalance, altered levels of growth regulators, enzymatic inhibition and metabolic dysfunction including photosynthesis which ultimately leads to plant death (Hasanuzzaman *et al*. 2012).

C. Effects of salt stress on the total number of tillers per plant and the number of productive tillers per plant during ripening stage

The results (Table 1) revealed that the total number of tillers were not significantly affected and the number of productive tillers per plant were significantly ($P<0.05$) affected by salinity stress. It was found that there were significant ($P<0.05$) differences between treatments and cultivars on the total number of productive tillers per plant at the ripening stage. There was no significant interactions between treatments and cultivars on the total number of tillers and number of productive tillers per plant at the ripening stage.

The highest number of productive tillers was obtained in “At 307” rice cultivar and the lowest number was found in “Pachaiperumal” under salt stressed condition. Hence “At 307” was able to maintain substantial number of productive tillers under salt stress condition. This is the salt tolerant feature of this cultivar.

Salinity has significantly reduced the total number of tillers per plant and the number of productive tillers per plant during the growth period of rice. The number of tillers per plant is an important yield parameter under salinity because it determines the grain bearing panicles. High effectiveness of salinity on the total number of tillers and the number of productive tillers per plant has been reported by many researchers. Zeng *et al*. (2001) reported that salinity decreases the number of tillers when imposing before panicle emergence and reduction in the number of tillers decrease the yield. Farshid Aref (2013) and Zeng and Shannon (2000) showed that productive tiller number per plant was significantly reduced at 4.5 dSm^{-1} and higher than the non-saline condition.

Table 1: Effects of salt stress on the total number of tillers and number of productive tillers per plant at ripening stage

	Cultivars	Treatment	Total tillers	CV %	Productive tillers	CV %
Non saline	Pachai-perumal	T_1 (S_0V_1)	22.0 ±0.81a	6	20.0 ±0.65a	7
	At 307	T_2 (S_0V_2)	18.4 ±0.28b	4	13.7 ±0.85a	11
	At 308	T_3 (S_0V_3)	16.0 ±0.4b	6	12.0 ±0.75a	10
Saline	Pachai-perumal	T_4 (S_1V_1)	18.0 ±0.4a	4	12.5 ±0.28c	10
	At 307	T_5 (S_1V_2)	16.3 ±0.3b	6	15.5 ±0.28a	6
	At 308	T_6 (S_1V_3)	13.3 ±0.85b	11	10.0 ±0.40b	9
Salinity			**<.0001**		**<.0001**	
Cultivar(V)			**<.0001**		**0.0213**	
Interaction(S*V)			**0.1830**		**0.0449**	

*Values with the same letter(s) within each column are not significantly different.

*Values are the means of 8 plants in 4 replications.

D. Effects of salinity on the filled grains and unfilled grains per panicle of rice at the ripening stage

It was found that there were significant ($P<0.05$) differences between treatments in the total number of filled grains and empty grains per panicle. It was also found that there were significant interactions between treatments and cultivars on the total number of filled grains and empty grains per panicle. Salinity has significantly reduced the number of filled grains and increased the total number of empty grains per panicle. Results (Fig 2) showed that the lowest number of filled grains and the higher number of empty grains per panicle were obtained in the cultivar "Pachaiperumal" while the highest number of filled grains and the lowest number of empty grains per panicles were obtained in the cultivar "At 307" under salinity stress.

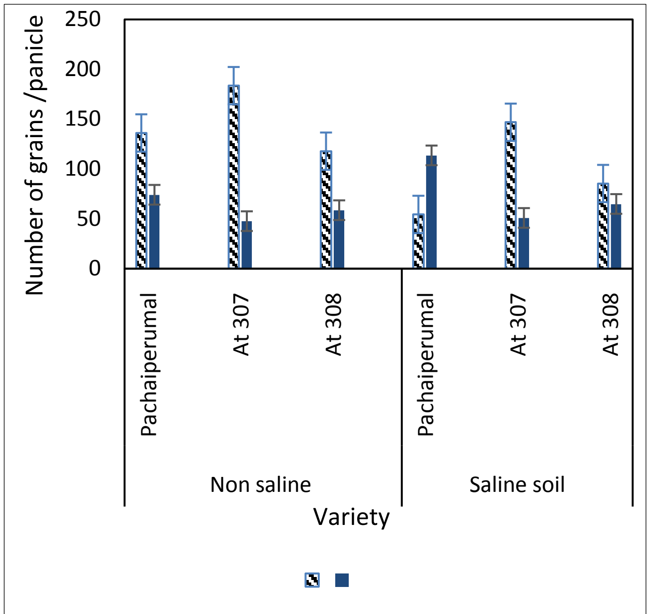

Figure 2: Effects of salt stress on the filled and unfilled grains of rice at the ripening stage

Strong effect of salinity on the total number of filled grains and the total number of empty grains per panicle has been reported by many researchers. Increased number of incompletely filled grains might be the results of assimilate shortage during grain filling, brought about by early leaf senescence caused by salinity (Fabre *et al*., 2005). Salinity decreases yield through decreasing filled grains per rice panicle.

E. Effects of salinity on 1000 grain weight and yield of rice at the ripening stage

It was found that there were significant ($P<0.05$) differences between treatments in the 1000 grain weight (Table 2) and the yield (Table 3) of rice. It was also found that there were significant ($P<0.05$) interactions between salinity and cultivars on 1000 grain weight and yield of rice. The highest amount (18.4 g) of 1000 grain weight was obtained in the cultivar "At 307" and the lowest (14.3 g) amount was recorded in "Pachaiperumal" under salinity stress. Salinity has significantly reduced the 1000 grain weight of rice. Fabre *et al*. (2005) stated that salinity decreases yield through decreasing 1000 grain weight.

Table 2: Effects of salinity on 1000 grain weight of paddy at the ripening stage

	Cultivar	Treatments	1000grain weight(g)	CV%
Control	Pachai-perumal	T_1 (S_0V_1)	22.9±0.43a	3.7%
	At 307	T_2 (S_0V_2)	21.6±0.49a	4.5%
	At 308	T_3 (S_0V_3)	17.6±0.94b	12%
Salinity	Pachai-perumal	T_4 (S_1V_1)	14.3±0.50b	7%
	At 307	T_5 (S_1V_2)	18.4±0.41a	5%
	At 308	T_6 (S_1V_3)	15.5±0.53b	4%
Salinity(S)			**<.0001**	
Variety (V)			**<.0001**	
Interaction(S*V)			**<.0001**	

*Means followed by the same letter(s) are not significantly different ($P<0.05$).

*Values are the means of 8 plants in 4 replications.

F. Yield

It was found that there were significant differences between treatments in the yield of selected rice cultivars (Table 3). Salinity has 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.

Table 3: Effects of salinity on the yield of selected rice cultivars during the maturity

Soil	Cultivars	Treat ment	Yield (tha^{-1})	CV%
Control	Pachai-perumal	T_1 (S_0V_1)	3.3 ± 0.07b	6%
	At 307	T_2 (S_0V_2)	4.3 ± 0.04a	3%
	At 308	T_3 (S_0V_3)	1.9 ± 0.04c	9%
Saline	Pachai-perumal	T_4 (S_1V_1)	0.4 ± 0.01c	11%
	At 307	T_5 (S_1V_2)	2.2± 0.065a	7%
	At 308	T_6 (S_1V_3)	0.8± 0.052b	10%
Salinity (S)			**< 0.0001**	
Cultivar (V)			**< 0.0001**	
Interaction (S*V)			**< 0.0001**	

*Means followed by the same letter(s) are not significantly different (P<0.05).

*Values are the means of 8 plants in 4 replications.

Crop yield reduction in salt affected soils results primarily from alterations of various metabolic processes in plants under salinity stress (Eynard *et al*., 2005). 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 (Juan *et al*., 2005). 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.

IV. CONCLUSIONS

The experiment was conducted to find out the effects of salinity on the yield and yield components of selected rice cultivars during the ripening stage. All the tested attributes were affected by salinity. With regard to the yield attributes, the performance of rice cultivar "At 307" was performed better than to the rest of the cultivars under salt stress. "At 307" was able to maintain highest number of productive tillers per plant, highest numbers of filled grains per panicle, highest panicle length, highest number of grains per panicle, lowest number of unfilled grains, highest amount of 1000-grain weight and yield than the rest of the cultivars. The result indicate that the 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 salt tolerant rice cultivar which could be cultivated in the salt prone coastal belt of Batticaloa district.

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