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A study on the effect of salinity stress on the growth and yield of some native rice cultivars of Kerala state of India

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Abstract: Rice is the most importantcereal cropamong many ofthe low and middle income countries of the world. Natural phenomena and human activities have led to the loss of rice fields at an alarming speed. Utilization of marginal and critical habitats for cultivation is the only way to sustain the net cropping area available for the crop. Many of such areas are threatened by salinity stress. Screening of rice cultivars for salt tolerance and their conservation, improvement and utilization are the only solutions. Seven native rice cultivars of Kerala state of India have been screened presently for their performance under salt stress. Five of them were collected from a traditional saline habitat and two from non-saline areas. It has been observed that majority of the cultivars collected from the saline habitat and Veliyan, one cultivar collected from a non-saline area performed well under moderate salt stress. In all the cases, early flowering was induced by salt stress.

Keywords: Rice, Salt Stress, Native Cultivars, Early Flowering

1. Introduction

Among the low and middle income countries of the world rice is the most important cereal crop. The developing countries contribute 96.24% of the total world rice production [1]. Rising sea levels, salinization, erosion and human settlements lead to the loss of rice fields in an alarming speed [2]. Rice is a salt sensitive crop species for which soil salinity is a major factor restricting yield throughout substantial areas of Africa and south and south-eastern Asia [3, 4]. Salinity and drought stress are among the most serious challenges to crop production in the world today, particularly in developing countries [5, 6].

Salinity of soil or water is of increasing importance to agriculture because it causes a stress condition to crop plants. As far as rice is concerned, a species native to swamps and freshwater marshes, secondary salinization is becoming an increasingly serious production constraint [7]. Several physiological pathways like photosynthesis, respiration, nitrogen fixation and carbohydrate metabolism have been observed to be affected by high salinity [8]. Variations in sensitivity to salt during the life cycle increase the complexity of tolerance evaluation [9]. Some of the growth parameters such as root growth, seedling height, leaf area and tiller number have been proposed as morphological markers for the screening of tolerant genotypes in rice [10, 11, 12]. In rice, it has long been reported that grain yield is much more depressed by salt stress than vegetative growth [13, 14, 15]. The effects of salt stress on rice are highly dependent on plant phenology: young seedlings and plants at the flowering stage appear to be the most sensitive while tillering plants are less sensitive [3, 16]. Seed formation stage is also a sensitive stage and the effects of salinity on yield are more pronounced at this stage [16]. As in the case of other crops, yield is reduced progressively by low to sub lethal external salt concentrations [17]. Salinity applied at the seedling stage frequently induces premature senescence of leaves [18, 19, 20]. Plant height, total number of tillers, panicle length, grain weight per panicle, 1000seed weight and quality and quantity of grains decrease progressively with increase in salinity levels [21].

Yield losses due to salinity are amounted to 30-50%. Salinity can limit growth and plant yield in three ways including reducing osmotic potential, creating ion toxicity, causing disarrangement and imbalance of ion uptake causing disorders in enzyme activities and membrane and metabolic activities in the plant [22, 23, 24, 25]. These processes could affect morphological parameters and plant growth and will result in reduced vegetative growth [26, 27, 28], leaf area [29, 30], chlorophyll content [29, 30] and plant height [31, 32], consequently reducing plant dry weight [28, 33, 34, 35] and ultimately crop yield [33]. Reductions in growth rate occur because, in addition to toxicity by high salt concentration, the plants become unable to absorb enough water, because of the decrease in the osmotic component of soil water potential [36]. A prolonged stress causes wilting similar to that caused by drought, with a greenish-blue color, with thickened and greater waxed leaves [37, 38]. Some traditional cultivars and landraces of rice are more tolerant than many elite cultivars to various abiotic stresses. These resistant genotypes are considered to be good sources of tolerance traits. However, they generally have poor agronomic traits, such as tall plant stature, photosensitivity, poor grain quality and low yield. One example of a traditional genotype that is tolerant to high salinity is the Indian landrace Pokkali [39]. In salt levels above tolerable by rice plants, water salinity causes a decrease in tillering and increases spikelet sterility [40]. Studies with different genotypes and different locations and environments have shown a linear relationship between the increasing levels of salinity and the decrease in the number of tillers, in addition to increasing the number of non-productive tillers [41].

The present study has been carried out to assess the impact of salt stress on the growth and yield of some native rice cultivars which are used by the traditional farming communities of Kerala State of India.

2. Materials and Methods

2.1. The Experimental Poly House, the Design and the Cultivars used

The experiment was conducted in the experimental rainout poly house of Department of Botany, University of Calicut, Kerala, India located at 11°35'N latitude and 75°48'E longitude in the first crop season of 2012. Plants were grown in plastic pots of 25cm diameter in Randomized Block Design with three replications. Seven native cultivars of rice including five cultivars namely Orthadian, Orkazhama, Kuthiru, Kuttusan and Chovvarian collected from one of the saline rice habitats of Kerala and two native rice cultivars namely Kunhutty and Veliyan collected from one of the non-saline rice habitats of Kerala were used for the study. The collected seeds were sorted by hand to remove infected and unfilled grains. Healthy mature seeds from a single plant were used for the study.

2.2. Germination of Seeds and Seedling Growth

Enough number of good caryopses were taken and washed in running tap water to remove dust and dirt particles. The seeds were soaked in distilled water, allowed to germinate in 10cm diameter Petri dishes covered with lid under room temperature. The water was changed every day. The seeds started to germinate from the third day. On 10th day, required numbers of the germinated seedlings were transferred to colored plastic pots of 25cm diameter filled with paddy soil mixed with enriched compost in 3:1 ratio. Two seedlings were initially planted per pot and after establishment of the seedlings the smaller among the two were removed. The plants were maintained in the experimental poly house of the Department under wetland conditions, always maintaining 3cm of water above the soil level. The soil was fertilized with 1g N: P: K =18: 18: 18 per pot at fortnightly intervals starting from the 30th day. Weeding was done manually whenever required.

2.3. Experimental Treatments and Observations

The experimental treatment was started from the 45th day onwards starting from 10mM (0.91dSm^{-1}) aqueous solution of Sodium Chloride as detailed in Table 1. Major growth and yield characters of the control and treated plants were observed and analyzed at the time of harvest (Table 2). Analysis of variance was carried out to find out the significance of variations induced by the treatments in the case of the different cultivars.

Table 1. *Details of experimental treatments applied.*

Sl. No.	Treatment
T1	Control
T2	10mM (0.91dSm^{-1}) on 45th day
T3	10mM (0.91dSm^{-1}) on 45th day & 30mM (2.74 dSm^{-1}) on 53rd day
T4	10mM (0.91dSm^{-1}) on 45th day, 30mM (2.74 dSm^{-1}) on 53rd day & 50mM (4.57 dSm^{-1}) on 61st day
T5	10mM (0.91dSm^{-1}) on 45th day, 30mM (2.74 dSm^{-1}) on 53rd day, 50mM (4.57 dSm^{-1}) on 61st day & 70mM (6.39 dSm^{-1}) on 69th day
T6	10mM (0.91dSm^{-1}) on 45th day, 30mM (2.74 dSm^{-1}) on 53rd day, 50mM (4.57 dSm^{-1}) on 61st day, 70mM (6.39 dSm^{-1}) on 69th day & 100mM (9.13 dSm^{-1}) on 77th day
T7	10mM (0.91dSm^{-1}) on 45th day, 30mM (2.74 dSm^{-1}) on 53rd day, 50mM (4.57 dSm^{-1}) on 61st day, 70mM (6.39 dSm^{-1}) on 69th day, 100mM (9.13 dSm^{-1}) on 77th day & 200mM (18.26 dSm^{-1}) on 90th day

3. Results and Discussion

Progressive application of salinity stress in rice as described above induced variations in different morphological characters as presented in Tables 2, 3 and 4. Among the growth and yield characters studied, plant height showed significant reduction under salt stress in two cultivars among the seven cultivars studied. Flag leaf length showed no significant variation under salt stress in any of the cultivars. Number of total tillers produced showed significant reduction in three cultivars due to salt stress. The character showed significant increase in one of the cultivars at 100mM salt concentration. Number of ear bearing tillers showed significant reduction in two out of the seven cultivars studied. Days to flower got reduced significantly in all the cultivars under salt stress. In two of the cultivars, it got reduced starting from 30mM of salt concentration and in others it got reduced starting from 10mM of salt concentration itself. Total duration of the crop also showed the same trend of variation. Panicle length showed significant reduction in one of the cultivars starting from 50mM salt concentration onwards. Number of spikelets per panicle showed significant reduction in only one of the cultivars studied and seeds per panicle showed significant reduction in three of the cultivars studied. Fertility percentage was affected adversely only in one cultivar. 100 seed weight got significantly reduced in three cultivars out of the seven studied and yield per plant showed significant reduction in five of the cultivars studied. Panicle density showed significant reduction in two cultivars and significant increase in one cultivar.

The above analysis showed that length of flag leaf was not affected by salt stress. Characters like plant height, panicle length, spikelets per panicle and fertility percentage were reduced significantly in one cultivar each. EBT number and panicle density were reduced in two cases and number of total tillers, seeds per panicle and 100 seed weight were reduced in three cases. Yield per plant was reduced in five cultivars out of the seven studied. The cultivars Kuttusan and Veliyan did not show significant yield reduction even under higher concentration of salt in the medium. Days to flower and total duration were reduced significantly in all the cases. This shows that flowering is induced earlier under salt stress.

Earlier workers have reported reduction of plant height in rice under salt stress [42, 43, 44]. Differential variation of tiller number under salt stress has also been reported [26, 43]. Akbar *et al.* (1972) have reported reduction of EBT under salt stress [45]. Differential behaviour of panicle length under salt stress in different varieties of rice has been reported by Marassi*et al*. (1989) [46]. Reduction of spikelets per panicle in rice [42, 47, 48] and number of seeds per panicle [49, 50] have also been reported. Reduction in yield due to salt stress has been reported by Zeng and Shannon (2000) [33] and Cha-um and Kirdmanee (2010) [51]. Salinity reduces yield by reducing the number of filled grains per panicle. Reduction in seed weight may be possibly due to decreased pollen viability or decreased receptivity of the stigmatic surface or both [14, 21, 48]. It has been reported that reduction in spikelet number per panicle is the major cause of yield loss due to salinity [33].

Among the seven native rice cultivars of Kerala state of India studied presently, five were collected from one of the traditional saline rice tracts of Kerala. Earlier, it has been reported that these cultivars perform well under non saline conditions also [52]. However, some of these cultivars and one cultivar Veliyan which is traditionally cultivated under non-saline conditions in Kerala State of India have proved to be potentially capable of growing and performing well under moderately saline conditions.

Table 2. *Impact of salt stress on morphological characters in the case of the different rice cultivars studied.*

Characters/ Treatments	Cultivars													
	Chovvarian		Kuttusan		Kuthiru		Orkazhama		Orthadian		Kunhutty		Veliyan	
	Mean ± SE	CD (5%)	Mean ± SE	CD (5%)	Mean ± SE	CD (5%)	Mean ± SE	CD (5%)	Mean ± SE	CD (5%)	Mean ± SE	CD (5%)	Mean ±SE	CD (5%)
1. Plant height (cm)														
T1 (Control)	156.33 ±1.03		163.17 ±1.59		201.67 ±2.96		152.67 ±1.2		177.00 ±0.38		104.17 ±0.66		150.67 ±0.45	
T2	153.67 ±1.24		158.67 ±1.45		199.33 ±3.60		153.83 ±1.17		193.00 ±3.30		98.33 ±0.45		150.50 ±0.50	
T3	185.33 ±2.23		163.00 ±1.09		158.67 ±0.77		152.67 ±1.91		184.33 ±3.22		100.17 ±0.54		150.17 ±0.27	
T4	153.00 ±0.95	12.26	158.50 ±0.72	NS	194.67 ±2.31	17.66	153.17 ±0.93	NS	184.33 ±3.22	NS	102.17 ±0.54	NS	150.67 ±0.45	NS
T5	153.67 ±1.40		157.33 ±1.75		191.67 ±1.33		148.83 ±0.93		185.67 ±1.91		96.67 ±1.58		151.00 ±0.22	
T6	153.00 ±1.53		150.00 ±0.44		187.00 ±1.65		148.17 ±0.38		184.33 ±2.41		98.00 ±1.31		150.17 ±0.54	
T7	151.00 ±1.86		158.67 ±0.70		192.00 ±1.31		148.00 ±1.36		186.33 ±1.45		96.83 ±1.48		150.67 ±0.55	
2. Flag leaf length (cm)														
T1 (Control)	95.50 ±0.72		105.00 ±0.65		102.67 ±0.88		100.17 ±1.11		89.50 ±0.33		82.33 ±0.55		70.83 ±0.41	
T2	93.67 ±1.03	NS	101.50 ±0.87	NS	101.00 ±0.61	NS	102.67 ±1.45	NS	85.33 ±1.53	NS	81.67 ±0.88	NS	71.00 ±0.22	NS
T3	97.00 ±0.58		102.17 ±0.60		103.50 ±0.85		98.00 ±3.39		79.00 ±2.10		82.67 ±0.33		70.83 ±0.23	
T4	90.33 ±0.33		100.17 ±0.89		108.67 ±0.55		96.33 ±0.60		79.00 ±2.10		82.00 ±0.58		71.50 ±0.50	

Characters/ Treatments	Chovvarian Mean ± SE	Chovvarian CD (5%)	Kuttusan Mean ± SE	Kuttusan CD (5%)	Kuthiru Mean ± SE	Kuthiru CD (5%)	Orkazhama Mean ± SE	Orkazhama CD (5%)	Orthadian Mean ± SE	Orthadian CD (5%)	Kunhutty Mean ± SE	Kunhutty CD (5%)	Veliyan Mean ±SE	Veliyan CD (5%)
T5	95.83 ±0.83		97.33 ±0.70		102.17 ±1.87		91.17 ±0.23		81.33 ±1.24		81.00 ±0.58		70.67 0.45±	
T6	92.83 ±1.28		93.50 ±1.05		100.50 ±0.98		89.33 ±0.25		84.67 ±1.65		78.67 ±1.20		70.00 ±0.38	
T7	91.50 ±0.61		98.67 ±1.03		103.17 ±0.82		87.83 ±1.10		84.67 ±1.20		78.00 ±0.44		70.33 ±0.45	
3. Panicle length (cm)														
T1 (Control)	27.17 ±0.17		32.67 ±0.45		31.00 ±0.58		27.50 ±0.29		28.67 ±0.45		26.33 ±0.33		31.33 ±0.454	
T2	27.67 ±0.33		30.67 ±0.45		31.83 ±0.66		27.67 ±0.33		29.33 ±0.7		24.17 ±0.17		31.00 ±0.218	
T3	27.00 ±0.58		29.67 ±0.33		29.00 ±0.22		27.00 ±0.58		28.33 ±0.33		26.33 ±0.23		29.83 ±0.227	
T4	25.33 ±0.13	NS	29.00 ±0.29	3.38	28.67 ±0.55	NS	25.33 ±0.13	NS	28.33 ±0.33	NS	26.13 ±0.39	NS	30.33 ±0.333	NS
T5	27.67 ±0.67		26.33 ±0.60		29.83 ±0.41		27.67 ±0.67		28.67 ±0.13		25.50 ±0.33		30.50 ±0.189	
T6	25.50 ±0.48		25.83 ±0.35		28.17 ±0.06		25.50 ±0.48		28.33 ±0.45		24.83 ±0.23		30.00 ±0.289	
T7	25.67 ±0.33		26.67 ±0.38		28.83 ±0.35		25.67 ±0.33		29.17 ±0.23		24.83 ±0.06		30.33 ±0.333	
4. EBT number														
T1 (Control)	6.00 ±0.22		5.00 ±0.22		6.33 ±0.33		6.00 ±0.22		6.33 ±0.33		6.00 ±0.22		5.67 ±0.25	
T2	5.33 ±0.33		6.00 ±0.58		6.00 ±0.22		5.33 ±0.33		6.33 ±0.45		5.67 ±0.45		7.00 ±0.22	
T3	5.67 ±0.13		4.67 ±0.33		7.00 ±0.38		5.67 ±0.13		5.33 ±0.13		4.67 ±0.33		6.00 ±0.22	
T4	4.67 ±0.13	NS	5.67 ±0.33	NS	5.67 ±0.13	1.87	4.67 ±0.13	NS	5.33 ±0.13	NS	4.33 ±0.33	NS	5.33 ±0.13	1.62
T5	5.00 ±0.58		3.67 ±0.25		5.00 ±0		5.00 ±0.58		5.00 ±0		4.33 ±0.25		4.00 ±0.22	
T6	4.00 ±0.22		4.00 ±0.22		5.00 ±0.22		4.00 ±0.22		4.33 ±0.13		4.33 ±0.45		5.00 ±0.22	
T7	4.00 ±0		3.00 ±0.22		3.67 ±0.13		4.00 ±0		4.67 ±0.33		3.67 ±0.13		4.33 ±0.13	
5. Total number of tillers														
T1 (Control)	8.33 ±0.13		7.00 ±0.22		9.33 ±0.13		8.33 ±0.13		8.00 ±0.22		7.67 ±0.13		7.00 ±0.22	
T2	7.33 ±0.25		7.00 ±0.38		6.33 ±0.33		7.33 ±0.25		7.33 ±0.25		8.00 ±0.38		7.33 ±0.13	
T3	6.67 ±0.25	1.71	7.00 ±0.22	NS	9.67 ±0.33	2.13	6.67 ±0.25	1.71	7.00 ±0.22	NS	7.33 ±0.25	NS	8.00 ±0	
T4	7.00 ±0.22		7.67 ±0.13		8.00 ±0.22		7.00 ±0.22		7.00 ±0.22		7.00 ±0.22		6.00 ±0.22	1.32
T5	7.67 ±0.33		6.00 ±0.22		6.00 ±0.38		7.67 ±0.33		6.67 ±0.13		6.00 ±0.38		7.00 ±0.22	
T6	5.00 ±0		6.00 ±0.22		7.00 ±0.22		5.00 ±0		6.00 ±0.22		6.67 ±0.45		8.33 ±0.13	
T7	5.33 ±0.13		6.00 ±0.22		5.67 ±0.13		5.67 ±0.13		6.00 ±0.22		5.67 ±0.13		6.33 ±0.13	
6. Days to flower														
T1 (Control)	131.33 ±0.67		128.33 ±1.20		135.00 ±0.87		110.33 ±0.77		127.33 ±0.55		129.33 ±1.10		153.33 ±2.33	
T2	125.33 ±2.43	13.06	110.00 ±4.36	20.71	119.33 ±1.12	12.45	97.00 ±0.79	9.62	92.33 ±1.20	11.06	125.33 ±1.03	5.40	125.33 ±1.91	26.27
T3	102.33 ±1.28		107.00 ±2.48		81.00 ±1.22		85.67 ±0.55		81.33 ±0.45		85.33 ±2.59		108.33 ±4.43	

Characters/ Treatments	Cultivars													
	Chovvarian		Kuttusan		Kuthiru		Orkazhama		Orthadian		Kunhutty		Veliyan	
	Mean ± SE	CD (5%)	Mean ± SE	CD (5%)	Mean ± SE	CD (5%)	Mean ± SE	CD (5%)	Mean ± SE	CD (5%)	Mean ± SE	CD (5%)	Mean ±SE	CD (5%)
T4	83.67 ±2.19		95.33 ±2.10		80.00 ±0.22		80.67 ±0.45		88.33 ±0.55		82.33 ±0.25		105.67 ±5.03	
T5	81.67 ±0.83		84.33 ±2.23		85.33 ±1.91		84.67 ±0.77		84.33 ±1.55		78.33 ±1.24		82.00 ±1.96	
T6	87.33 ±2.19		87.67 ±1.61		88.67 ±2.19		87.33 ±2.31		83.00 ±1.65		80.00 ±0.87		94.67 ±3.92	
T7	84.67 ±1.67		86.33 ±2.84		92.00 ±2.21		81.67 ±1.55		87.33 ±2.43		94.00 ±1.36		105.33 ±1.32	
7. Total duration														
T1 (Control)	162.67 ±0.70		157.33 ±1.33		165.00 ±0.87		140.33 ±0.77		157.33 ±0.55		159.33 ±1.10		181.00 ±1.53	
T2	152.33 ±3.50		140.67 ±4.48		149.67 ±1.03		127.33 ±0.98		123.33 ±1.24		156.33 ±0.67		155.33 ±1.91	
T3	133.67 ±1.20		137.67 ±2.53		111.00 ±1.22		116.00 ±0.65		112.33 ±0.25		116.00 ±2.46		140.00 ±4.35	
T4	117.67 ±3.39	17.51	126.67 ±1.91	20.95	111.00 ±0.22	12.13	110.67 ±0.45	10.87	118.33 ±0.55	11.19	112.33 ±0.25	9.77	136.67 ±4.81	24.82
T5	112.00 ±0.79		116.00 ±2.31		116.67 ±1.88		115.00 ±0.79		115.67 ±1.42		110.00 ±0.65		112.00 ±1.96	
T6	118.67 ±2.07		118.33 ±1.55		121.00 ±2.08		117.33 ±2.81		113.00 ±1.65		113.33 ±0.67		126.33 ±3.76	
T7	116.00 ±1.65		117.67 ±2.84		124.33 ±2.19		114.33 ±1.45		119.33 ±2.59		125.33 ±1.32		136.33 ±0.98	
8. Seeds per panicle														
T1 (Control)	96.67 ±1.97		99.00 ±2.30		110.33 ±2.98		96.67 ±1.97		118.00 ±2.36		103.67 ±1.12		113.33 ±2.41	
T2	90.33 ±4.06		95.00 ±1.73		104.00 ±1.75		90.33 ±4.06		96.00 ±2.00		107.33 ±3.10		113.00 ±3.00	
T3	86.33 ±2.45		94.33 ±2.53		97.00 ±1.75		86.33 ±2.45		106.33 ±1.53		94.67 ±2.10		116.33 ±0.70	
T4	90.67 ±2.10	NS	92.67 ±1.64	NS	96.67 ±0.88	NS	90.67 ±2.10	NS	106.33 ±1.53	16.64	95.00 ±1.43	15.89	100.67 ±1.75	18.71
T5	85.33 ±2.39		80.67 ±2.88		97.00 ±2.08		85.33 ±2.39		99.67 ±3.30		95.00 ±1.22		106.33 ±1.40	
T6	75.00 ±1.79		85.67 ±1.42		92.33 ±1.08		75.00 ±1.79		92.67 ±1.03		82.67 ±1.55		84.33 ±2.56	
T7	77.00 ±3.51		83.33 ±0.83		88.67 ±2.07		77.00 ±3.51		90.33 ±1.96		75.67 ±2.48		104.33 ±3.34	
9. Spikelets per panicle														
T1 (Control)	114.00 ±2.84		116.33 ±1.42		126.33 ±1.64		114.00 ±2.84		141.00 ±1.96		129.00 ±1.96		140.33 ±2.39	
T2	107.67 ±3.60		107.00 ±1.57		122.67 ±1.32		107.67 ±3.60		119.33 ±3.09		125.00 ±4.60		139.67 ±4.58	
T3	103.33 ±2.84		111.00 ±3.61		119.67 ±3.07		103.33 ±2.67		123.67 ±3.28		114.67 ±1.65		145.00 ±1.00	
T4	108.67 ±2.95	NS	110.67 ±1.39	NS	121.33 ±2.03	NS	108.67 ±2.95	NS	123.67 ±3.28	NS	115.67 ±2.56	NS	124.33 ±3.33	24.56
T5	98.67 ±2.62		101.00 ±1.79		125.00 ±2.94		98.67 ±2.62		118.67 ±2.53		116.67 ±1.12		122.67 ±2.15	
T6	89.67 ±2.40		103.67 ±0.33		105.33 ±0.88		89.67 ±2.40		114.00 ±2.00		107.67 ±2.03		96.33 ±3.92	
T7	99.00 ±3.59		105.67 ±1.58		118.33 ±2.40		99.00 ±3.59		112.67 ±1.98		96.00 ±3.02		121.67 ±2.59	
10. Fertility %														
T1 (Control)	84.97 ±0.90	NS	84.94 ±0.93	NS	87.12 ±1.22	6.39	84.97 ±0.90	NS	83.60 ±0.59	NS	80.44 ±0.41	NS	80.72 ±0.76	NS
T2	83.52 ±1.73		88.76 ±0.76		84.71 ±0.53		83.52 ±1.73		80.64 ±0.70		86.23 ±0.72		81.17 ±0.70	

Characters/ Treatments	Cultivars													
	Chovvarian		Kuttusan		Kuthiru		Orkazhama		Orthadian		Kunhutty		Veliyan	
	Mean ± SE	CD (5%)	Mean ± SE	CD (5%)	Mean ± SE	CD (5%)	Mean ± SE	CD (5%)	Mean ± SE	CD (5%)	Mean ± SE	CD (5%)	Mean ±SE	CD (5%)
T3	83.52 ±0.39		85.21 ±0.51		81.29 ±0.67		83.52 ±0.39		86.38 ±1.08		82.54 ±1.28		80.24 ±0.30	
T4	83.58 ±0.53		83.70 ±0.84		79.83 ±0.76		83.58 ±0.53		86.38 ±1.08		82.34 ±0.89		81.24 ±0.75	
T5	86.47 ±0.83		79.52 ±1.42		77.70 ±0.64		86.47 ±0.83		83.73 ±1.08		81.42 ±0.63		86.85 ±1.08	
T6	83.92 ±1.35		82.61 ±1.21		87.71 ±1.08		83.92 ±1.35		81.41 ±0.54		76.81 ±0.61		88.21 ±1.42	
T7	77.41 ±1.00		79.00 ±0.87		74.86 ±0.23		77.41 ±1.00		80.13 ±0.78		78.81 ±0.63		85.47 ±1.03	
11. 100 seed weight (g)														
T1 (Control)	2.07 ±0.05		2.02 ±0.03		2.79 ±0.02		2.07 ±0.05		2.28 ±0.02		3.01± 0.01		2.28 ±0.07	
T2	2.02 ±0.06		1.97 ±0.01		2.59 ±0.03		2.03 ±0.06		2.08 ±0.04		3.08 ±0.03		2.62 ±0.07	
T3	1.84 ±0.01		2.06 ±0.03		2.51 ±0.02		1.84 ±0.01		2.11 ±0.03		2.93 ±0.01		2.45 ±0.02	
T4	1.98 ±0.04	NS	1.95 ±0.01	NS	2.64 ±0.01	0.16	1.98 ±0.04	NS	2.11 ±0.03	0.22	2.91 ±0.02	0.13	2.66 ±0.02	NS
T5	1.77 ±0.01		1.96 ±0.01		2.69 ±0.01		1.77 ±0.01		1.98 ±0.03		2.92 ±0.01		2.60 ±0.08	
T6	1.76 ±0.01		1.94 ±0.04		2.61 ±0.02		1.76 ±0.01		1.91 ±0.01		2.78 ±0.02		2.58 ±0.05	
T7	1.81 ±0.02		1.90 ±0.01		2.53 ±0.01		1.81 ±0.02		1.89 ±0.01		2.74 ±0.01		2.28 ±0.01	
12. Yield per plant														
T1 (Control)	11.84 ±0.13		9.87 ±0.26		19.35 ±0.96		11.84 ±0.13		17.11 ±1.02		18.65 ±0.55		14.67 ±0.78	
T2	9.30 ±0.12		10.92 ±0.90		16.47 ±1.05		9.48 ±0.51		13.17 ±1.28		19.11 ±1.79		21.14 ±1.54	
T3	9.02 ±0.38		8.94 ±0.62		16.77 ±0.63		9.02 ±0.38		11.92 ±0.16		12.63 ±0.62		17.15 ±0.68	
T4	8.54 ±0.55	3.70	10.34 ±0.74	NS	14.52 ±0.46	5.28	8.54 ±0.55	3.99	11.92 ±0.16	5.53	11.73 ±0.64	7.52	14.33 ±0.51	NS
T5	7.53 ±0.95		5.79 ±0.43		13.07 ±0.30		7.53 ±0.95		9.93 ±0.51		11.91 ±0.59		11.03 ±0.73	
T6	5.16 ±0.13		6.57 ±0.31		11.96 ±0.40		5.16 ±0.13		7.71 ±0.36		10.29 ±1.20		11.14 ±0.83	
T7	5.63 ±0.32		4.75 ±0.34		8.23 ±0.37		5.63 ±0.32		7.84 ±0.45		7.52 ±0.22		11.89 ±0.59	
13. Panicle density														
T1 (Control)	4.19 ±0.08		3.58 ±0.08		4.11 ±0.13		4.19 ±0.08		4.95 ±0.13		3.95 ±0.09		14.67 ±0.78	
T2	3.88 ±0.11		3.49 ±0.03		3.87 ±0.06		3.88 ±0.11		4.09 ±0.12		4.46 ±0.27		21.14 ±1.54	
T3	3.82 ±0.04		3.76 ±0.16		4.13 ±0.12		3.82 ±0.04		4.39 ±0.17		3.60 ±0.12		17.15 ±0.68	
T4	4.28 ±0.10	NS	3.82 ±0.05	NS	4.25 ±0.09	NS	4.28 ±0.10	NS	4.39 ±0.17	NS	3.65 ±0.13	0.75	14.33 ±0.51	0.81
T5	3.56 ±0.02		3.84 ±0.04		4.19 ±0.07		3.56 ±0.02		4.14 ±0.08		3.73 ±0.01		11.03 ±0.73	
T6	3.56 ±0.15		4.02 ±0.04		3.74 ±0.04		3.56 ±0.15		4.05 ±0.14		3.34 ±0.12		11.14 ±0.83	
T7	3.84 ±0.10		3.96 ±0.03		4.10 ±0.04		3.84 ±0.10		3.86 ±0.05		3.04 ±0.13		11.89 ±0.59	

Table 3.*Variation of characters over control in different rice cultivars under conditions of salt stress.*

Cultivars/Treatments	Characters showing	
	Significant reduction	**Significant increase**
1. Chovvarian		
10 mM/0.91 dSm-1	Nil	Nil
30 mM/2.74 dSm-1	Days to flower	Plant height
50 mM/4.57 dSm-1	Days to flower	Nil
70 mM/6.39 dSm-1	Yield per plant, Days to flower	Nil
100 mM/9.13 dSm-1	Yield per plant, Total number of tillers, Days to flower	Nil
200 mM/18.26 dSm-1	Yield per plant, Total number of tillers, Days to flower	Nil
2. Kuttusan		
10 mM/0.91 dSm-1	Nil	Nil
30 mM/2.74 dSm-1	Days to flower	Nil
50 mM/4.57 dSm-1	Panicle length, Days to flower	Nil
70 mM/6.39 dSm-1	Panicle length, Days to flower	Nil
100 mM/9.13 dSm-1	Panicle length, Days to flower	Nil
200 mM/18.26 dSm-1	Panicle length, Days to flower	Nil
3. Kuthiru		
10 mM/0.91 dSm-1	Total number of tillers, 100 seed weight, Days to flower,	Nil
30 mM/2.74 dSm-1	Days to flower, Plant height	Nil
50 mM/4.57 dSm-1	Fertility %, Days to flower	Nil
70 mM/6.39 dSm-1	Total number of tillers, Fertility %, Yield per plant, Days to flower	Nil
100 mM/9.13 dSm-1	Total number of tillers,100 seed weight, Yield per plant, Days to flower	Nil
200 mM/18.26 dSm-1	EBT number, Total number of tillers, Fertility %,100 seed weight, Yield per plant, Days to flower	Nil
4. Orkazhama		
10 mM/0.91 dSm-1	Days to flower	Nil
30 mM/2.74 dSm-1	Days to flower	Nil
50 mM/4.57 dSm-1	Days to flower	Nil
70 mM/6.39 dSm-1	Yield per plant, Days to flower	Nil
100 mM/9.13 dSm-1	Total number of tillers, Yield per plant, Days to flower	Nil
200 mM/18.26 dSm-1	Total number of tillers, Yield per plant, Days to flower	Nil
5. Orthadian		
10 mM/0.91 dSm-1	Seeds per panicle, Days to flower	Nil
30 mM/2.74 dSm-1	Days to flower	Nil
50 mM/4.57 dSm-1	Days to flower	Nil
70 mM/6.39 dSm-1	Seeds per panicle,100 seed weight, Yield per plant, Days to flower	Nil
100 mM/9.13 dSm-1	Seeds per panicle,100 seed weight, Yield per plant, Days to flower	Nil
200 mM/18.26 dSm-1	Seeds per panicle,100 seed weight, Yield per plant, Days to flower	Nil
6. Kunhutty		
10 mM/0.91 dSm-1	Nil	Nil
30 mM/2.74 dSm-1	Days to flower	Nil
50 mM/4.57 dSm-1	Days to flower	Nil
70 mM/6.39 dSm-1	Days to flower	Nil
100 mM/9.13 dSm-1	Seeds per panicle,100 seed weight, Yield per plant, Days to flower	Nil
200 mM/18.26 dSm-1	Seeds per panicle,100 seed weight, Yield per plant, Panicle density, Days to flower	Nil
7. Veliyan		
10 mM/0.91 dSm-1	Days to flower	Panicle density
30 mM/2.74 dSm-1	Days to flower	Panicle density
50 mM/4.57 dSm-1	Days to flower	Nil
70 mM/6.39 dSm-1	EBT number, Panicle density, Days to flower	Nil
100 mM/9.13 dSm-1	Seeds per panicle, Spikelets per panicle, Panicle density, Days to flower	Total number of tillers
200 mM/18.26 dSm-1	Panicle density, Days to flower	Nil

Table 4.*Variation of characters as induced by salt stress in the rice cultivars studied.*

Variety	Characters												
	Plant height	**Flag leaf length**	**Total tiller number**	**EBT Number**	**Days to flower**	**Duration**	**Panicle length**	**Number of spikelets per panicle**	**Number of seeds per panicle**	**Fertility %**	**100 seed weight**	**Yield per plant**	**Panicle density**
Chovvarian	Significant increase at 30mM	No significant variation	Significant reduction from 100mM onwards	No significant variation	Significant reduction from 30mM onwards	Significant reduction from 30mM onwards	No significant variation	No significant variation	No significant variation	No significant variation	No significant variation	Significant reduction from 50mM onwards	No significant variation
Kuttusan	No significant variation	No significant variation	No significant variation	No significant variation	Significant reduction from 30mM onwards	Significant reduction from 30mM onwards	Significant reduction from 50mM onwards	No significant variation	No significant variation	No significant variation	No significant variation	No significant variation	No significant variation
Kuthiru	Significant reduction at 30mM	No significant variation	Significant reduction from 70mM onwards	Significant reduction at 200mM	Significant reduction from 10mM onwards	Significant reduction from 10mM onwards	No significant variation	No significant variation	No significant variation	Significant reduction at 50mM and 200 mM	Significant reduction at 10mM, 100Mm and 200 mM	Significant reduction from 70mM onwards	No significant variation
Orkazhama	No significant variation	No significant variation	Significant reduction from 100mM onwards	No significant variation	Significant reduction from 10mM onwards	Significant reduction from 10mM onwards	No significant variation	No significant variation	No significant variation	No significant variation	No significant variation	Significant reduction from 70mM onwards	No significant variation
Orthadian	No significant variation	No significant variation	No significant variation	No significant variation	Significant reduction from 10mM onwards	Significant reduction from 10mM onwards	No significant variation	No significant variation	Significant reduction at10mM, 70mM, 100mM and 200mM	No significant variation	Significant reduction from 70mM onwards	Significant reduction from 70mM onwards	No significant variation
Kunhutty	No significant variation	No significant variation	No significant variation	No significant variation	Significant reduction from 10mM onwards	Significant reduction from 10mM onwards	No significant variation	No significant variation	Significant reduction from 100mM onwards	No significant variation	Significant reduction from 100mM onwards	Significant reduction from 100mM onwards	Significant reduction at 200mM
Veliyan	No significant variation	No significant variation	Significant increase at 100mM	Significant reduction at 70mM	Significant reduction from 10mM	Significant reduction from 10mM	No significant variation	Significant reduction at100mM	Significant reduction at 100mM	No significant variation	No significant variation	No significant variation	Significant reduction from 70mM

	onwards	onwards		onwards and significant increase at 10 Mm and 30mM

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