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Assessing Salinity Tolerance of Rice Genotypes for Germination and Early Seedling Growth

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Abstract

Salinity is one of the most serious problems in rice cultivation. Salinity affects all growth stages of rice to varying degrees starting from germination up to maturation. The present study was conducted to evaluate the tolerance of 22 rice genotypes to salinity at both seed germination and seedling stages. The genotypes were evaluated for germination percentage and root and shoot growth at germination stage by soaking seeds in varying concentrations of NaCl solution and for 9 and 12 days in petri dishes. Under salt stressed conditions, the genotypes CSR-23, CSR-36, KMP-220 and FL-478 recorded higher germination percentage. These four rice genotypes that had better germination rate were also found to be moderately tolerant to salt stress at seedling growth stage. While salt stress had greater adverse effect on root growth at germination stage, the shoot growth was drastically affected at seedling stage. Further, majority of the genotypes under the present study were found to have high reduction in root to shoot ratio under salt stress. While the root to shoot ratio of MAS-26 and CSR-23 was not affected, the same was found to be increased in Bevu Bella and FL-478 under salt stress situation. Present study revealed significant variation between genotypes for all the traits under salt stress situations.

Keywords : Germination percentage, Shoot length, Salt stress, Root length

Biotic and abiotic stresses adversely affect crop growth and productivity. In crops, abiotic stresses, that limit the production worldwide, are generated by environmental factors such as drought, extreme temperatures, salinity and alkalinity that are complex and often interacting phenomena (Almeida *et al*., 2016). In rice, the productivity is adversely affected to the maximum extent by salinity what is next only to drought.

Salinity, as far as soils are concerned, refers to the presence of soluble salts above an arbitrary limit, commonly defined by the electrical conductivity (EC) of a saturated soil paste. According to most recent estimate, 20 per cent of total cultivated and 30 per cent of the world's rice growing land is affected by soil salinity (Hopmans *et al*., 2021). Around 6.727 million ha area in India, which is around 2.1 per cent of geographical area of the country, is salt affected, of which 2.956 million ha is saline and the rest 3.771 million ha is sodic (Arora *et al*., 2017). Salinity, at the seedling, early vegetative and reproductive stages is known to affect various traits such as spikelet number per panicle, number of primary and secondary branches per panicle, number of grains per panicle, number of filled grains per panicle and grain weight with increased spikelet sterility (Clermont-Dauphin *et al.,* 2010; Mojakkir *et al.,* 2015; Raghavendra *et al.,* 2018). Foggilatto *et al.* (2019) have also found adverse effect of salt on plant height, root, shoot and dry matter accumulation in rice genotypes. Further, salinity not only affects different growth parameters, but is also known to reduce seed germination, possibly due to osmotic effect or ion toxicity.

Salinity tolerance is a complex trait and phenotypic responses of plants to salinity stress are highly affected by the environment. Rice plants respond differently to salt stress at different growth stages (Singh *et al*., 2010). While the rice crop is relatively tolerant to salt stress during active tillering and maturity stages, it is highly sensitive during the early seedling and developmental stages (Hussain *et al*., 2017; Ologundudu *et al*., 2014). The symptoms due to salinity are reported to be more significant on the first and second leaves and were visualized by leaf rolling, formation of new leaf, brownish and whitish leaf tip, drying of leaves, reduction in root growth, stunted plant height and stem thickness leading to complete cessation of growth and mortality (Gregorio *et al*., 1997). Further, the effects of salinity are also manifested in the form of reduced seed germination, seedling survival, number of leaves, shoot weight, plant height and length and surface area of roots (Singh and Flowers, 2010).

The adverse effects of high levels of soil salinity on seed germination and seedling growth could be attributed to the combined effects of high osmotic potential and specific ion toxicity. Inhibition of seed germination, shoot and root elongation has been noticed as a result of sodium chloride treatments in rice (Senayake *et al*., 2017). According to the classification of crop tolerance to salinity, the rice crop was categorized as a sensitive crop with a threshold of 3 dsm^{-1} (Mohammadi-Nejad *et al*., 2010).

The salt affected soils distinguish themselves from their normal counter parts in various aspects, regardless of the region where they occur. Although not affected with respect to their physical properties, the salt affected soils contain sufficient quantities of neutral soluble salts to adversely influence the crop growth (Murthy *et al*., 2012). The cultural practices developed to manage and reduce soil salinity and alkalinity include incorporation of organic matter to soil, either by green manuring or application of farmyard manure, application of gypsum, sub surface drainage to remove excess salts, salt leaching with ponded fresh water, mulching between two irrigations and during fallow period, irrigation management and many more (Arora and sharma, 2017; Sharma *et al.,* 2014). Furthermore, the effects soil salinity can also be diminished by reducing the spacing, to maintain more plant population per unit area, planting aged seedlings, as well as more number of seedlings per hill (Singh *et al.,* 2016). Although there are several salinity management practices available, they involve additional cost and thereby reduce the profitability per unit area. Hence, development of salt tolerant varieties of rice offers simplest and sustainable method of over coming soil salinity associated problems.

A number of Genes/QTLs have been mapped for several salt tolerance parameters such as Na+ and K+ uptake, Na+ and K+ concentration and Na+/K+ ratio in shoot on different chromosomes of rice. The candidate markers within *Saltol* QTL region in marker assisted breeding for increased salt tolerance have been identified (Thomson *et al*., 2010). Work on QTL introgression of *Saltol* in major rice varieties like BR11, BRRI Dhan 28, IR64, AS996, Swarna and basumathi varieties such as Pusa Basmati 1121 has been done (Linh *et al*., 2012; Nagarajan *et al*., 2014).

Reaction of different rice genotypes to different levels of salt stress can be assessed by screening the following appropriate screening procedures. As rice crop is more vulnerable to salt stress during germination and initial seedling stages, germination and seedling characteristics are the most viable and commonly used criteria used for selecting salt tolerant plants (Negrao *et al*., 2011). Planning a new breeding program to develop salt tolerant varieties requires us to understand the reaction of the present rice varieties for salt stress. Hence, the present study was undertaken to evaluate the response of 22 rice genotypes for salt stress at both germination and seedling stage.

Material and Methods

Plant Materials

The present investigation was carried out at Zonal Agricultural Research Station, V.C. Farm, Mandya. Seeds of 22 rice genotypes were obtained from Division of Rice Breeding, Zonal Agricultural Research Station, V.C. Farm, Mandya (Table 1). The rice genotypes studied composed of both land

TABLE 1
List of rice genotypes used in the study

Genotypes	Characteristics	Common cultivation / Development	Duration for maturity (days)	Yield (t/ha)
HJR	Landrace	Karnataka	120-130	4.1-4.4
GVT - 501	Improved variety	Karnataka	100-110	3.8-4.2
NLR - 3042	Improved variety	AndraPradesh	145-150	4.3-4.5
Sidda sanna	Landrace	Karnataka	120-130	4.2-4.6
Ratnachoodi	Landrace	Karnataka	140-150	6.6-6.8
JGL - 1798	High yielding variety	AndraPradesh/Karnataka	120-125	5.8-6.3
Jaya	High yielding variety	AndraPradesh/Karnataka	140-150	5.0-6.0
CSR - 36	Salt tolerant variety	CSSRI, Karnal	135-140	6.2-6.4
NMS - 2	High yielding variety	Karnataka	125-130	6.1-6.3
CSR - 23	Salt tolerant variety	CSSRI, Karnal	100-110	5.5-5.7
GVT - 503	Improved variety	Karnataka	130-135	3.8-4.2
Bevu Bella	Landrace	Karnataka	120-125	5.5-5.8
Mandya Vijaya	Variety	Karnataka	160-164	6.3-7.0
Binadhan - 8	Salt tolerant variety	Bangladesh	130-135	4.5-5.5
Pattanda Uthappa Belliyabba (PUB)	Landrace	Karnataka	145-150	6.4-6.6
KMP - 220	High yielding variety	Karnataka	125-130	7.4-7.6
FL - 478	Salt tolerant NIL of IR29	IRRI,Philippines	130-135	4.4-4.6
RNR - 15048	High yielding variety	Telangana	145-150	5.5-6.5
GVT - 514	Improved variety	Karnataka	130-135	5.2-5.5
Paduvanda Kuttappa Belliyabba (BKB)	Landrace	Karnataka	145-150	5.8-6.0
MAS - 26	Aerobic rice variety	Karnataka	115-120	4.0-5.0
GVT - 504	Improved variety	Karnataka	115-120	4.3-4.5

races and improved high yielding varieties of India. FL478 served as salinity tolerant check variety.

Screening Methodology

Before screening for salinity tolerance, unimbibed seeds of the 22 rice genotypes were incubated at 50°C for 5 days to break residual seed dormancy, if any.

a. Screening of Genotypes at Germination Stage

Germination Test : Germination, the process of emergence of seedling, was studied using petri dish method. Varieties were tested for the ability of their seeds to germinate under high salt concentrations and to screen for tolerance to salinity as proposed by Abesiriwardena (2004). Briefly, 25 seeds of each genotype were placed in a nine cm petri dish lined with a blotting paper. While the blotting paper imbibed either with 5 mL of deionised water served as control, the same with 5 mL saline solutions of different concentration served as treatments. Salt solutions with concentrations equal to 0mM (control), 50 mM, 100 mM and 150 mM were prepared by dissolving NaCl in deionised water. The emergence of seedlings was encouraged by placing the petri dishes at 25°C for 9 and 12 days. The petri dishes with the seeds were monitored regularly and the germination papers were ensured with sufficient moisture by topping up with the respective solutions whenever necessary. The experiment consisting of 22 genotypes, 4 levels of salt concentrations and 2 soaking periods, was laid out in a Completely Randomized Design (CRD). The experiment was repeated twice to obtain reliable results.

Data Collection

The observations were recorded on germination percentage (%), shoot length (cm) and root length (cm). The Petri dishes with seeds were examined, the number of germinated seeds counted and the germination percentage calculated. A seed was considered as germinated once the seed coat ruptured and the plumule and radicle emerged out of the seed coat. Observations on number of germinated seeds were recorded on 9 and 12 days of soaking period.

Root and shoot length measurement:

At 9th and 12th day of soaking period, the root and shoot length of ten randomly chosen seedlings in each petri dish was measured.

b. Screening of Genotypes at Seedling Stage

At the seedling stage, genotypes were screened for salt tolerance in a hydroponic system using International Rice Research Institute's (IRRI) standard protocol in two replications (Gregorio *et al*., 1997). The evaluation was carried out in a glass house under controlled conditions with ambient temperature between 30-35°C during the day and 20-24°C during night with a relative humidity in the range of 70–80%. Pre-germinated (3 days after germination) seeds were sown in wells punched on extruded polystyrene foam floats fitted with a nylon wire mesh on the bottom side and fixed on plastic crates. Each crate was filled with 8 litres of Yoshida nutrient solution (Yoshida *et al*., 1976). The crates were having punch holes of 10 rows and 10 coulmns, consisting of one genotype in each column along with highly tolerant genotype (FL478) in each crate. There were two replications for each set of genotypes. The resistant check FL478 was sown all along the borders to normalize competition for light and space. The salt stress was imposed by adding NaCl to nutrient solution to a final concentration of 100 mM, 14 days after germination and the same was maintained until final phenotypic scoring. The pH of 5.0 was maintained in the culture solution daily, with a replacement of entire nutrient solution after every 7 days. Sixteen days after imposing salt stress, the genotypes were visually scored using Standard Evaluation System for rice for salt stress symptoms (IRRI, 2013) as modified by Gregorio *et al*. (1997). The scores ranging from 1 (highly tolerant) to 9 (highly sensitive) is furnished in Table 2. In addition to scoring, the seedling root and shoot length of the genotypes were also recorded.

TABLE 2

Modified Standard Evaluation System (SES) of visual salt injury scoring at seedling stage (Gregorio *et al.* 1997)

Score	Observation	Tolerance
1	Normal growth, no leaf symptoms	Highly tolerant
3	Nearly normal growth; leaf tips or few leaves whitish and rolled	Tolerant
5	Growth severely retarded; most leaves rolled; only a few are elongating	Moderately Tolerant
7	Complete cessation of growth; most leaves dry; some plants dying	Susceptible
9	Almost all plants dead or dying	Highly Susceptible

Statistical Analysis

All the data collected was analyzed by analysis of variance (ANOVA). Data analysis was carried out according to the statistical procedure described by the SPSS (IBM. SPSS. Statistics, version 23). To check the difference among rice genotypes for salinity tolerance at seed germination and seedling stage, analysis of variance was performed using GLM procedure followed by separation of means by the Duncan Multiple Range Test (DMRT) and Least

Significant Differences (LSD) at 5 per cent level of significance.

Results and Discussion

Response of Rice Genotypes to Salt Stress for Germination

As high salt is known to affect rice crop at different stages, we were interested to know the effect of salt stress at germination stage. Therefore, we designed an experiment to determine the response of various rice genotypes to different salt concentrations. For this purpose, the seeds were exposed to different levels of salt stress for 9 and 12 days duration at germination stage. Following analysis of variance, two-way interaction effects of variety × salt concentration, soaking period × salt concentration and variety x soaking period were found to be significant at 0.05 probability levels (Table 3). As revealed by ANOVA, significant difference in germination percent was observed between the soaking duration of 9 and 12 days. The average germination percent of rice genotypes decreased with increasing duration of soaking irrespective of NaCl concentration. As expected, in control treatment where the seeds were soaked in water with no salts, the germination rate increased with time (Table 4). As 12 days of soaking resulted in higher inhibition of germination, we decided to consider 12 days of soaking period for analyzing the results henceforth.

As shown in Table 4, in general, the germination percent at 100mM NaCl was less than that of 50 mM NaCl concentration. Further, the average germination percentage reached minimum at highest concentration of 150 mM NaCl. At 100 mM NaCl concentration, the lowest germination percentage was recorded by the rice genotype HJR (4%) which further decreased to zero percent germination at 150 mM NaCl concentration (Plate 1). Similar to that of HJR, complete inhibition of germination at 150 mM NaCl post 12 days of soaking was also recorded by seven genotypes. Therefore, we decided to analyse the germination per cent of different rice genotypes at 100 mM NaCl concentration at 12 days after soaking. The seeds incubated with distilled water, with no NaCl added, served as control. In control

TABLE 3

Variance analysis (ANOVA) for germination showing the significant difference between the variety, soaking period, and salt concentration in response to salinity stress

Source	Type III Sum of Squares	df	Mean Square	F-value	P value
Corrected Model	15.125 [a]	112	.135	99.351	.000
Intercept	53.064	1	53.064	39037.636	.000
Variety	4.219	21	.201	147.801	.000
Soaking period	.328	1	.328	241.433	.000
Salt concentration	9.135	3	3.045	2240.232	.000
Variety * Soaking period	.083	21	.004	2.908	.001
Variety * Salt concentration	1.281	63	.020	14.953	.000
Soaking period * Salt concentration	.079	3	.026	19.413	.000
Error	.086	63	.001		
Total	68.275	176			
Corrected Total	15.211	175			

a. R Squared = 0.994 (Adjusted R Squared = 0.984)

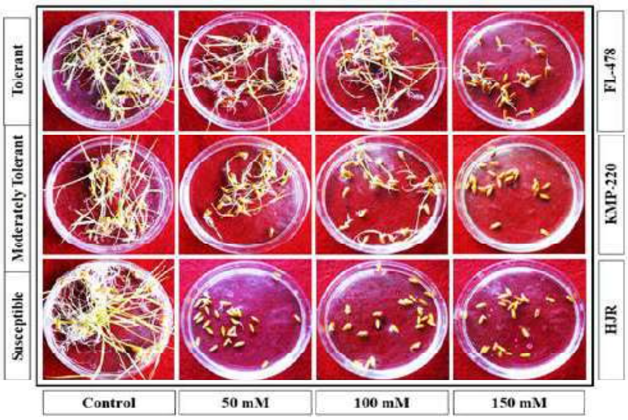

Plate 1: Germination, root and shoot growth of rice genotypes in response to different levels of salt concentrations at germination stage

Briefly, the seeds of different rice genotypes were placed on blotting paper soaked in water and NaCl solutions of indicated concentrations in petri dishes. The petri dishes were incubated at room temperature for 12 days with constant moisture level. The seeds were then transferred to other petri dishes without blotting paper for taking photographs.

treatment, the average germination percent was found to be 88 per cent with highest and lowest germination percent of 96 (Jaya, BKB and GVT-501) and 80 (Rathnachoodi, Bevu Bella and GVT-514), respectively. In this study, the rice genotype FL-478 harbouring *Saltol* QTL was used as a tolerant check. In accordance to our expectation, FL-478 was found to be most tolerant rice genotype for salt stress by recording highest germination of 80 per cent (Table 4). Similar to our observation, FL-478 was also previously reported to be salt tolerant at germination stage (Kumar *et al.,* 2017).

Following the criteria suggested by earlier work (Senanayake *et al*., 2017), based on mean separation score percentage, the rice genotypes were categorized in to six different salinity response groups. As shown in Table 5, the highly tolerant and highly susceptible category consisted of only one rice genotype each with FL-478 (resistant check) and HJR, respectively. While eight genotypes were grouped under moderately tolerant category, three rice genotypes *viz*., CSR-23, CSR-36 and KMP-220 were categorized as tolerant to salt stress. In contrast, 9 genotypes were categorized as either moderately susceptible or susceptible rice genotypes for germination at high salt concentrations.

Root and Shoot Growth of Rice Genotypes to Salt Stress at Germination Stage

The germination stage comprises not only emergence of root and shoot from the seed, but also includes initial root and shoot growth. Having studied the response of rice genotypes for root and shoot emergence, corresponding to germination process, we were interested to also know their root and shoot growth in response to salt stress. Due to the reasons quoted earlier, we resorted to measure the root and shoot growth of rice genotypes at germination stage following soaking of seeds for 12 days in 100mM NaCl solution. Further, seeds soaked in water without any salt for 12 days served as negative control.

The average root length of 22 rice genotypes in control was found to be 6.96 cm with a range of 4.6 cm and 9.4 cm. Similarly, the seeds soaked in 100mM NaCl resulted in average root growth of 6.8 cm ranging between 4.5 cm and 8.8 cm. As shown in Table 6, there was no significant difference between root growth in control and seeds soaked in salt solution. However, there was a significant difference between individual rice genotypes for root growth in both within and between control and salt stress conditions. Following soaking of seeds in 100mM NaCl, the highest and lowest root growth was recorded by MAS-26 (8.8 cm) and BKB (4.5 cm), respectively. After MAS-26, the highest root growth at germination stage was recorded by the rice genotypes JGL-1798 (8.6 cm) and RNR-15048 (8.5 cm), respectively (Table 6). Further, the rice genotypes FL-478, CSR-36, CSR-23 and KMP-220, that were earlier found to have better germination rate under salt stress, exhibited contrasting response to salt stress. Among these, the rice genotypes FL-478 and CSR-36 showed enhanced root growth under salt stress compared to that of control with increase of root growth by 41 and 3 percent, respectively. The possible reason for the increase in root length of these genotypes could be due to lower uptake of

TABLE 4

Germination percentage (%) of 22 rice genotypes with various salt concentrations at two soaking periods

	Control	50 mM	100 mM	150 mM	Control	50 mM	100 mM	150 mM
HJR	80	40	20	8	92	32	4	0
GVT-501	88	48	36	12	96	40	28	0
NLR-3042	84	72	52	40	88	64	44	32
Sidda sanna	88	36	24	4	84	20	12	0
Ratnachoodi	88	60	40	16	80	48	24	4
JGL-1798	88	56	36	20	84	48	28	0
Jaya	100	84	76	60	96	72	48	44
CSR-36	88	76	68	52	88	72	64	56
NMS-2	96	64	48	32	92	52	32	8
CSR-23	96	88	84	56	92	84	68	64
GVT-503	92	64	56	44	92	60	48	40
Bevu Bella	84	56	36	16	80	40	20	0
Mandya Vijaya	80	60	32	4	88	48	16	0
Binadhan-8	92	64	60	48	92	60	48	40
PUB	92	64	44	12	88	52	36	0
KMP-220	92	84	76	68	84	80	64	56
FL-478	94	92	84	76	88	84	80	68
RNR-15048	88	44	24	0	84	32	12	0
GVT-514	88	56	40	12	80	40	20	0
BKB	100	92	80	68	96	76	48	44
MAS-26	88	52	32	8	88	44	24	0
GVT-504	88	68	60	48	84	64	48	44
Mean	89.7	64.5	50.4	32.0	88.0	55.1	37.1	22.7
Maximum	100	92	84	76	96	84	80	68
Minimum	80	36	20	0	80	20	4	0

Na^+. In line with this, in an earlier work tolerant genotypes have been reported to have lower uptake of Na^+ than sensitive genotypes do. Similar results of varied genotype response showing increased root growth with increased NaCl concentration reported by Kumar *et al.* (2017). However, to our curiosity, salt stress led to reduction in root length of the genotypes CSR-23 and KMP-220 by 30 and 39 per cent, respectively (Table 6). This contrasting reduction in root length under salt stress, in otherwise geno types with better germination, has also been reported in several earlier studies (Meghana *et al.,* 2015; Puvanitha *et al.,* 2017). The possible reason for reduction in root length of CSR-23 and KMP-220 could be due to increased influx of Na^+ leading to reduction of root cell size, the rate of cell production and elongation, consequently resulting in shorter roots (Seo *et al.,* 2020).

Unlike root growth, we found significant reduction in average shoot growth in 100 mM salt solution-soaked seeds (4.56 cm) than that of seeds soaked in water (6.39 cm). The shoot length ranged between 4.6 cm and 7.6 cm and 2.9 cm and 6.5 cm in control and seeds soaked in 100 mM NaCl solution, respectively (Table 6). Following soaking of seeds in 100 mM NaCl, the highest and lowest shoot growth was recorded by Binadhan-8 (6.5 cm) and

TABLE 5

Rice genotypes grouped into different groups at germination stage for salinity tolerance

Salinity tolerance	Genotypes	Germination rate
Highly tolerant	FL-478[a]	>70 %
Tolerant	CSR 23[b], KMP-20[bc], CSR 36[d],	*51-70 %*
Moderately tolerant	BKB[bc], Jaya[cd], GVT-503[e], Binadhan-8[e], GVT-504[e], NLR-3042[e], NMS-2[f], PUB[fg],	31-50 %
Moderately Susceptible	JGL-1798[gh], Ratnachoodi[gh], MAS-26[h], GVT-501[h],	21-30 %
Susceptible	Bevu Bella[h], GVT-514[h], Mandya Vijaya[h], Sidda sanna[i], RNR-15048[i]	11-20%
Highly susceptible	HJR[i]	0-10%

Note : The mean followed by the same letter are not significantly different at p=0.05

BKB (2.9 cm), respectively. Following Binadhan-8, the highest shoot growth at germination stage was recorded by the rice genotypes PUB (5.5 cm) and GVT-504 (5.5 cm), respectively (Table 6). This contrasting reduction in shoot length under salt stress, has also been reported in several earlier studies (Meghana *et al.,* 2015; Kumar *et al.,* 2017; Puvanitha *et al.,* 2017). The rice genotypes FL-478, CSR-36, CSR-23 and KMP-220 that were earlier found to have better germination rate and MAS-26, JGL-1798 and RNR-15048 that had recorded highest root growth under salt stress, exhibited reduced shoot growth. Further, the most salt sensitive genotypes for shoot growth at germination stage were BKB, Sidda Sanna and CSR-23 with 49, 47 and 37 per cent reduction, respectively. In contrast, the least salt sensitive genotypes were found to be Binadhan-8, PUB and HJR, with mere 7, 11 and 17 per cent reduction in shoot growth. The inhibitory effect of salt on shoot and root growth has been observed by earlier research workers (Puvanitha *et al.*, 2017; Hakim *et al.,* 2010). The reduced root and shoot growth due to salinity has been attributed to delayed differentiation of root and shoot. However, similar to our findings, greater inhibitory effect of salt stress on shoot growth rather than root growth has also been reported (Hussain *et al.,* 2017).

Response of Rice Genotypes to Salt Stress at Seedling Stage

Having studied the root and shoot growth at germination stage, we were interested to assess the root and shoot growth response of 22 rice genotypes to elevated levels of salt concentration. As with the germination stage experiments, the root and shoot growth of rice genotypes was studied by growing seedlings in hydroponic system of nutrient solution comprising 100 mM NaCl and the results were compared to that of seedling growth in nutrient solution without any added salts and scoring was done based on visual symptoms of salt injury according to the modified standard evaluation system (SES) of IRRI (Gregorio *et al.,* 1997) (Table 2).

In control where the seedlings were grown on mere nutrient solution, all the rice genotypes under study displayed robust growth with uniform green colour and height. Upon growing under salt stress, the genotypes showed varied responses ranging from score 1 (Highly tolerant) to score 9 (Highly susceptible). The resistant check variety FL-478, with a score of 1, was the only genotype found to be highly tolerant to salt stress (Table 7). Another rice genotype, CSR-36 recorded a score of 3 and was the lone genotype in the tolerant category. While seven genotypes with a score of 5 were grouped under moderately tolerant category, majority of the genotypes (10) were grouped as susceptible to salt stress and recorded a score of 7. In contrast three rice genotypes comprising of Jaya, GVT-514 and HJR recorded a score of 9 and were found to be highly susceptible to salt stress. In addition to scoring 16 days after induction of salt stress, the genotypes were also measured for root and shoot length. As shown in Table 8 on an average, the induction of salt stress at the seedling stage resulted in 30.36 per cent reduction in root length

TABLE 6

Root and shoot length of rice genotypes at germination stage in response to control and 100mM NaCl concentration at 12 days soaking period

Genotypes	Root length			Shoot length		
	Control	100mM	% Change over control	Control	100mM	% Change over control
FL-478	5.4	7.6	41	6.7	4.8	-28
CSR-23	8.9	6.2	-30	6.2	3.9	-37
CSR-36	7.3	7.5	3	6.3	4.7	-25
KMP-220	9.3	5.7	-39	7.3	5.3	-27
Jaya	6.9	7.5	9	7	5.1	-27
GVT-503	5.8	7.6	31	6.8	4.9	-28
Binadhan-8	5.7	6.8	19	7	6.5	-7
BKB	8.6	4.5	-48	5.7	2.9	-49
GVT-504	6.8	5.8	-15	7.3	5.5	-25
NLR-3042	7.2	5.4	-25	5.8	4	-31
PUB	6.8	7.7	13	6.2	5.5	-11
NMS-2	8.8	6.1	-31	6.6	4.2	-36
GVT-501	6.4	6	-6	6.9	5.1	-26
JGL-1798	7.8	8.6	10	7.6	5	-34
Ratnachoodi	5.1	7.7	51	5.7	4.2	-26
MAS-26	7.5	8.8	17	7.4	5.2	-30
Bevu Bella	4.6	6.6	43	5.5	4	-27
GVT-514	5.6	7.6	36	6.5	4.4	-32
Mandya Vijaya	7	5.3	-24	5.5	4.1	-25
Sidda sanna	6.5	6.2	-5	5.7	3	-47
RNR-15048	9.4	8.5	-10	6.3	4.1	-35
HJR	5.8	5.9	2	4.6	3.8	-17
Mean	6.96	6.80	2	6.39	4.55	-29
Minimum	4.60	4.50	-48	4.60	2.90	-49
Maximum	9.40	8.80	51	7.60	6.50	-7

when compared to that of control. Among genotypes, highest reduction in root length was observed in HJR (73 %), followed by Jaya (62 %) and Ratnachoodi, PUB and BKB (50%), corresponding to higher sensitivity to salt stress. In contrast, the lowest reduction in root length, that indicate higher tolerance to salt stress, was found in rice genotypes FL-478 (6%), CSR 36 (9%) and MAS-26 (9%) (Table 8). The differential genotypic responses observed in the study could be due to the effect of salinity on root cell size, the rate of cell production and elongation, consequently leading to shorter roots in susceptible rice genotypes. Similar report was made by Seo *et al.* (2020) that root length reduction was due to the effect of high concentration of salt.

The average reduction in shoot length of all the genotypes (11.77%) was much lesser than the average reduction of root length (30.36%). This suggests, in the set of genotypes studied under present investigation, greater effect of salt stress

TABLE 7

Evaluation of rice genotypes for salinity tolerance at seedling stage

Genotypes	Salinity injury score	Reaction to salinity
FL-478	1	Highly tolerant
CSR-36	3	Tolerant
CSR-23, KMP-220, GVT-503, Binadhan-8, NLR-3042, PUB and Ratnachoodi	5	Moderately tolerant
BKB, GVT-504, NMS-2, GVT-501, JGL-1798, MAS-26, Bevu Bella, Mandya Vijaya, Sidda sanna and RNR-15048	7	Susceptible
Jaya, GVT-514 and HJR	9	Highly susceptible

on root growth rather than shoot growth. In support to our finding, Rahman *et al.* (2001) also reported greater effect of salinity on root length than shoot length. This difference might be due to the effect of NaCl being more inhibitory on root growth than shoot growth. However, this observation contradicted greater effect of salt stress on shoot length rather than root length at germination stage (Table 6). Among genotypes, RNR-15048 (39%), PUB (37%) and Jaya (30%) recorded highest reduction in shoot length at seedling stage and were found to be highly sensitive to salt stress (Table 8). Similar to these, Mandya Vijaya, Bevu Bella and BKB were also found to have reduced shoot growth to a greater extent, in comparison to control, with more than 20 per cent reduction. In line with our finding, salt was found to inhibit plant growth at seedling stage resulting in reduction of plant biomass (Jamil *et al.,* 2012). In contrast, the salt stress had absolutely no effect on the root growth of NLR 3042 under salt stress condition. To our interest, the genotypes KMP-220 and Binadhan-8 recorded higher shoot growth under salt stress condition. Apart from these genotypes, the other varieties that were found to have least reduction (3-5%) in shoot growth upon salt stress induction included CSR-36, GVT-504, GVT-501, JGL-1798, Sidda sanna and HJR.

As we have already evidenced greater inhibitory effect of salt on root growth than that of shoot growth at seedling stage (Table 8), root to shoot ratio is expected to have more role in obtaining higher yield following rice cultivation in salt affected soils. Therefore, root to shoot ratio forms an important criterion while evaluating for salt tolerance. Because of this reason, we also determined root to shoot

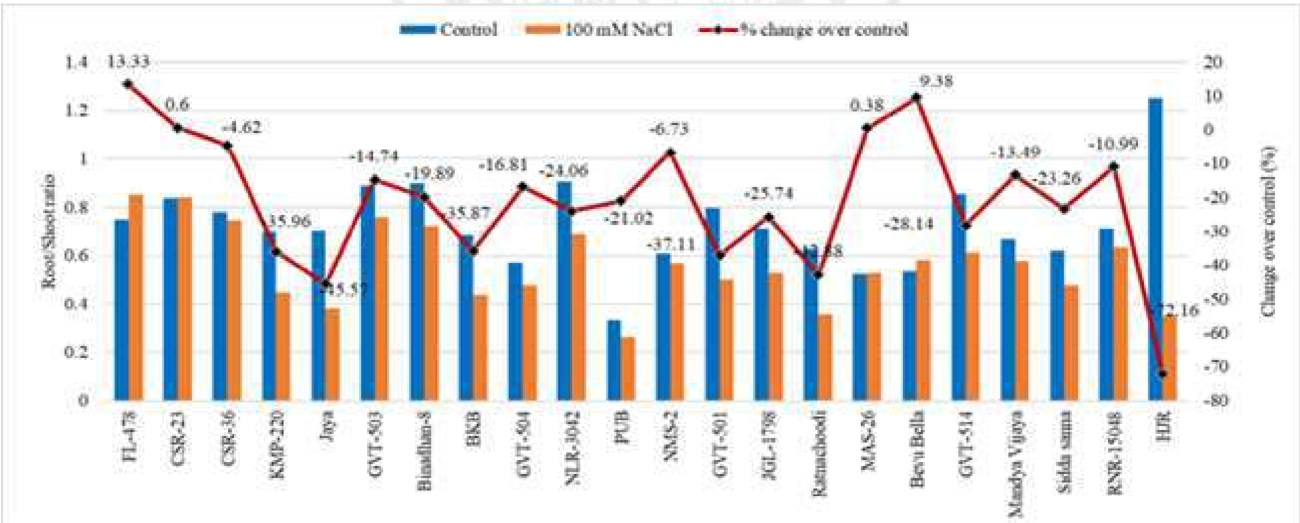

Fig 1: Effect of salinity on root and shoot length and root to shoot ratio in rice genotypes at seedling stage

Briefly, a set of 22 rice genotypes were screened in hydroponic system of nutrient solution with and without added NaCl to a final concentration of 100 mM. Following their growth in this setup as explained for 16 days observations on root and shoot length were recorded.

TABLE 8

The root length, shoot length and root: shoot length of rice genotypes at the seedling stage

Genotypes	Root length (cm)		% Change over control	Shoot length (cm)		% Change over control	Root / Shoot Ratio		% Change over control
	Control	100 mM NaCl		Control	100 mM NaCl		Control	100 mM NaCl	
FL-478	36	34	-6	48	40	-17	0.750	0.850	13.33
CSR-23	36	32	-11	43	38	-12	0.837	0.842	0.60
CSR-36	32	29	-9	41	39	-5	0.780	0.744	-4.62
KMP-220	30	21	-30	43	47	9	0.698	0.447	-35.96
Jaya	21	8	-62	30	21	-30	0.700	0.381	-45.57
GVT-503	32	25	-22	36	33	-8	0.889	0.758	-14.74
Binadhan-8	36	31	-14	40	43	8	0.900	0.721	-19.89
BKB	28	14	-50	41	32	-22	0.683	0.438	-35.87
GVT-504	24	19	-21	42	40	-5	0.571	0.475	-16.81
NLR-3042	29	22	-24	32	32	0	0.906	0.688	-24.06
PUB	20	10	-50	60	38	-37	0.333	0.263	-21.02
NMS-2	28	25	-11	46	44	-4	0.609	0.568	-6.73
GVT-501	31	19	-39	39	38	-3	0.795	0.500	-37.11
JGL-1798	27	19	-30	38	36	-5	0.711	0.528	-25.74
Ratnachoodi	30	15	-50	48	42	-13	0.625	0.357	-42.88
MAS-26	22	20	-9	42	38	-10	0.524	0.526	0.38
Bevu Bella	16	14	-13	30	24	-20	0.533	0.583	9.38
GVT-514	29	19	-34	34	31	-9	0.853	0.613	-28.14
Mandya Vijaya	24	15	-38	36	26	-28	0.667	0.577	-13.49
Sidda sanna	26	19	-27	42	40	-5	0.619	0.475	-23.26
RNR-15048	22	12	-45	31	19	-39	0.710	0.632	-10.99
HJR	30	8	-73	24	23	-4	1.250	0.348	-72.16
Min	16.00	8.00	-73.00	24.00	19.00	-39.00	0.72	0.56	-20.70
Max	36.00	34.00	-6.00	60.00	47.00	9.00	0.33	0.26	-72.16
Mean	27.68	19.55	-30.36	39.36	34.73	-11.77	1.25	0.85	13.33
Stdev	5.39	7.47	18.74	7.75	7.87	12.99	0.18	0.16	19.76

ratio of the genotypes under investigation. As shown in Table 8, induction of salt stress resulted in reduced root to shoot ratio in 18 genotypes. Among these, the highest decline was recorded in HJR (72.16%), followed by Jaya (45.57 %), Ratna choodi (42.88%), GVT-501 (37.11%), KMP-220 (35.96%) and BKB (35.87%). Similarly, Blaha and Pazderu (2013) have also observed remarkable reduction in root and shoot ratio at seedling stage under salinity stress in rice genotypes. In stark contrast, an increased root to shoot ratio, following induction of salt stress at seedling stage, was recorded in FL-478 (13.33%) and Bevu Bella (9.38%) (Fig. 1). With increased root to shoot ratio under salt stress condition, FL-478 and Bevu Bella seem to be tolerant to salt stress. Further, two more genotypes MAS-26 and CSR-23 experienced least inhibitory effect of salt on their root to shoot ration and proved to be promising genotypes for cultivation in salt affected soils.

Assessing the response of genotypes to salt stress is essential before deploying any rice variety for cultivation in saline soils. Hence, the present investigation was conducted to determine the reaction of 22 rice genotypes for salt stress at seed germination and seedling growth stages. Based on the overall performance of these genotypes at germination and seedling stage for several growth parameters, FL-478, CSR-23, CSR-36, KMP-220 and Binadhan-8 displayed high tolerance to salt stress at both germination and initial seedling growth stages. As these genotypes were found to have better germination rate, root and shoot growth and root to shoot ratio in salt stress situation, they can be directly recommended for cultivation in salt affected areas following their evaluation for yield. Alternately, these genotypes can also be recommended for their use in breeding program as donors of salt tolerance traits. In this regard, FL-478, CSR-23 and CSR-36 have already been evaluated for their salt tolerance at different levels and released for commercial cultivation in salt affected areas in different states of India (Krishnamurthy *et al.,* 2020; Singh *et al.,* 2016). In addition to these, other genotypes under this study have recorded varying responses for different growth parameter which needs further characterization under salt stress induced conditions.

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