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Effect of salinity and use of stress indices of morphological and physiological traits at the seedling stage in rice

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Rice (*Oryza sativa* L.) is the most important cereal crop and a major staple food for majority of the human populations worldwide. Rice crop is sensitive to salinity. In spite of large number of studies on salinity tolerance of rice, our knowledge on the overall effect of salinity on rice seedling growth is limited. Improvement in salt tolerance of crop plants remains indescribable, largely due to the fact that salinity is a complex trait which affects almost every aspect of the physiology, biochemistry and genomics of plants. The present investigation was conducted to establish the relationship between various morphological, physiological traits and stress indices. A set of 131 rice accessions was evaluated in two levels namely, non-stress (EC ~ 1.2 dS/m) and saline stress (EC ~ 10 dS/m) in hydroponics at seedling stage. Root length and shoot lengths were reduced by 52 and 50%, respectively in saline stress compared to non-stress conditions. There was a significant correlation between various morphological and physiological parameters in non-saline in addition to saline stress as well as non-stress. The effect of the increased Na^+ concentration in the medium is detrimental to root length and shoot length as observed by reduction in root length and a concomitant reduction in shoot length. Increased concentration of Na^+ led to augmented Na^+/K^+ ratio with increased stress in the medium and decreased expression of traits. A significant positive correlation (r=0.60) was noticed between stress tolerance index (STI) of root and shoot length. The stress susceptibility index (SSI) for root length was expressed significant positive correlation with SSI for shoot length (r=0.43). SSI for K^+ content was registered significant negative correlation with STI for Na^+ content (r=-0.43). The three accessions namely, IC 545004, IC 545486 and IC 545215 were found to be the best performers adjudged on the morphological and physiological criteria in saline stress situation. These three rice accessions could be used as a donor parent or for genotypic studies in future breeding programs.

Keywords: *Oryza sativa*, Paddy, Rice accessions, Stress susceptibility index (SSI), Stress tolerance index (STI)

Rice (*Oryza sativa* L.) is one of the most important cereal crops and a major staple food crop globally. Rice is considered as a crop sensitive to salinity. Sufficient genetic variation is available for salinity tolerance at seedling stage[1,2]. Rice is the single most important food item in terms of calorie intake, providing, on average, over 20 % of the human dietary energy[3]. Green revolution helped to solve the world's demand for food, but does not seem enough to meet the 21st century's exploding population requirements. Different concentrations of salt and duration of stress also have a varied impact on rice crop. The effects of salt stress on rice are highly dependent on developmental period. The younger seedling and reproductive stages are more responsive to salinity in contrast to the vegetative stage[4]. Na^+ and Cl^- accrual is negatively correlated with survival under saline condition[5,6].

Salt tolerance is controlled by multiple genes that allow plants to grow in the presence of elevated and relatively steady levels of salt, in particular NaCl[7]. Furthermore, ever rising demand for rice stress for enhancement of production at unprecedented levels within the fixed cultivable area. This is an overwhelming task but is certainly most promising.

Development of salt-tolerant varieties has been anticipated as a way of escalating agriculture into the regions influenced by salinity[8]. Propagating rice varieties, in a conventional manner, with in-built tolerance to salinity is realized as the most capable, less resource consuming, economically feasible and socially acceptable methodology.

Earlier studies carried out under controled conditions revealed that salt injury in rice plants is caused by both osmotic imbalance and buildup of chloride (Cl^-) ions[9]. Recent studies, however, indicated that injury is due to the unwarranted sodium (Na^+) uptake. The illustrative system of salinity tolerance in rice indicates barring out or decline of Na uptake and amplified absorption of K^+ to sustain a good ionic equilibrium in the shoot[10]. Screening of germplasm at the seedling stage is gladly

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accepted since it is based on a straightforward criterion of selection; it provides swift screening which is otherwise intricate at vegetative and reproductive stages. Quantization of salinity tolerance in the field poses grave intricacies owing to high field hetero-geneity and genotype/environment relations[11].

In spite of large number of studies on salinity tolerance of rice, our knowledge of the overall effect of salinity on rice seedling growth is limited. Improvement in salt tolerance of crop plants remains indescribable, largely due to the fact that salinity is a complex trait which affects almost every aspect of the physiology, biochemistry and genomics of plants[12]. Screening of genotypes for tolerance to salt and incorporation of desirable traits into crop plants may mitigate the effects of salinity on productivity. Developing salinity tolerant plants may contribute to overcome food shortage issues in many countries. The present study was therefore, undertaken to establish the effects of salt stress on seedling growth and to analyze the salt sensitivity and its implications on various morphological and physiological traits in rice crop.

Materials and Methods

Plant material

A set of 131 indigenous collections (ICs) of rice (*Oryza sativa* L.) were obtained from DRR (Directorate of Rice Research, Hyderabad) and assessed for their responses to salinity (NaCl) stress in hydroponic conditions along with a sensitive check (IR 29) and a tolerant check (FL 478) in non saline and saline conditions (Table 1).

Table 1—List of 131 rice accessions (IC) and their vigour score in non saline (N) and saline (S) hydroponics study

S. No	IC	Vigour score		S. No	IC	Vigour score		S. No	IC	Vigour score		S. No	IC	Vigour score	
		N	S			N	S			N	S			N	S
1	461221	1	9	36	545005	1	9	71	545484	1	9	106	545526	3	9
2	459662	1	9	37	545194	1	9	72	545485	1	7	107	545300	1	9
3	545000	1	9	38	459667	1	9	73	545486	1	5	108	545528	1	9
4	545000	1	7	39	450164	1	9	74	545223	1	7	109	461283	1	5
5	545189	1	9	40	459669	1	9	75	545487	1	9	110	461281	1	9
6	455001	1	9	41	545195	1	9	76	545488	1	7	111	461288	1	9
7	545461	1	9	42	459677	1	9	77	545489	1	9	112	461286	3	9
8	545191	1	5	43	459672	1	9	78	545008	1	7	113	459775	1	5
9	545462	1	7	44	461231	1	9	79	545490	1	7	114	545268	1	9
10	545463	1	9	45	545203	1	9	80	545224	1	9	115	545022	1	9
11	545464	1	9	46	545204	1	9	81	545492	1	9	116	545270	1	7
12	545002	1	9	47	545205	1	9	82	545010	1	9	117	461275	1	7
13	450161	1	9	48	545476	1	9	83	545229	1	9	118	545518	1	9
14	545466	1	7	49	545206	1	9	84	545234	1	9	119	545023	1	9
15	545467	1	7	50	545477	1	7	85	545240	1	9	120	545519	1	9
16	545004	1	5	51	459690	1	7	86	545015	1	9	121	545284	1	9
17	545468	1	9	52	459684	1	9	87	461243	1	9	122	545024	1	9
18	545469	1	9	53	459685	1	9	88	461266	1	9	123	545513	1	9
19	450160	1	9	54	459689	1	9	89	459721	1	7	124	545276	1	9
20	461232	1	9	55	545006	1	9	90	450175	1	9	125	545277	1	9
21	545193	1	9	56	545212	1	9	91	459732	1	9	126	545278	1	7
22	545470	1	5	57	545479	1	9	92	459733	1	9	127	545514	1	7
23	461222	1	9	58	545214	1	9	93	461244	1	9	128	459752	1	9
24	461228	1	9	59	545480	1	9	94	459729	1	9	129	545515	1	7
25	545471	1	9	60	545215	1	5	95	459731	1	9	130	IR 29	1	9
26	461223	1	9	61	545217	1	9	96	461254	1	9	131	FL 478	1	5
27	461226	1	9	62	545007	1	7	97	461260	3	9				
28	545472	1	7	63	545218	1	9	98	461261	1	9				
29	545473	1	7	64	459693	1	9	99	461246	1	9				
30	461230	1	9	65	459692	1	9	100	461263	1	9				
31	461225	1	9	66	545219	1	9	101	461253	3	5				
32	459671	1	9	67	545481	1	9	102	461256	1	7				
33	461283	1	9	68	545482	1	9	103	545026	1	9				
34	461224	1	9	69	545222	1	9	104	545525	1	7				
35	459668	1	7	70	545483	1	7	105	545299	1	7				

Phenotyping for salinity tolerance at seedling stage

These rice accessions were grown in hydroponics using Yoshida nutrient solution and screened for salinity tolerance at the seedling stage (14 days after sowing) using IRRI standard protocol. The experiment was conducted in a controlled glasshouse at Central Soil Salinity Research Institute (CSSRI), Karnal (Latitude: 29° 43’ N, Longitude: 76° 58’ N) under two salinity stress situations, namely salinity stress (EC ~ 10 dS/m) and non saline (EC ~ 1.2 dS/m) hydroponics at seedling stage. Nutrient solution was salinized by adding NaCl to obtain the desired levels of salinity. Salinity (EC ~ 10 dS/m) was induced at the seedling stage and the desired level of salinity was maintained for the next 14 days. The modified standard evaluation system (SES) was used in rating the visual symptoms of salt toxicity[13] and genotypes scored after two weeks of salinization.

Evaluation of salt tolerance scores

The visual symptoms of salt injury on individual seedlings were observed and the salinity tolerance (ST) score on a scale of 1–9 based on the Standard Evaluation System (SES) was assigned.

Estimation of Na^+ and K^+ content

The shoot samples were oven dried (70°C to constant weight), ground and analyzed by flame photometer (PFP7, Staffordshire United Kingdom) for sodium and potassium.

Correlations, indices and statistical analysis

Mean absolute and relative root/shoot lengths of the replicates of each accession in saline were calculated where,

$$\text{Relative root/shoot length} = \frac{\text{root/shoot length in saline solution}}{\text{root/shoot length in control solution}} \times 100$$

The stress susceptibility index (SSI) for each genotype was calculated for all the traits[14].

Stress susceptibility index (SSI) = $1-(Y_s/Y_p)/SI$

where, Y_s is the stress yield and Y_p is the non-stress yield.

SI was calculated as: $1-(X_s/X_p)$

X_s is the mean stress yield over genotypes and X_p is the mean non-stress yield over genotypes.

Stress tolerance index (STI) for each genotype was calculated[15].

Stress tolerance index (STI) = $(Y_p \times Y_s)/(X_p)^2$

where Yp and Ys are the grain yield of a genotype under non stress and stress conditions, respectively and Xp is the mean yield of all genotypes under non stress conditions.

Statistical analysis

The correlation coefficients between stress indices and plant traits for all possible comparisons were computed. Coefficients of determination were also computed for the same trait and indices. Mean comparisons, ANOVA and other statistical analyses were performed using SAS 9.3 software (SAS Institute Inc., Cary USA). Analysis of variance (ANOVA) for all the seven traits was estimated.

Results

Morphological and physiological behavior of rice accessions in saline stress and stress indices

Analysis of variance (ANOVA) for all the morphological and physiological parameters was estimated. The genotypic variation were highly significant (P <0.01) as evident from the analyses of variances of the characters investigated (Table 2). The mean squares due to treatments were highly significant for all the characters thus indicating the variation within genotypes. Analysis of variance illustrated significant differences among accessions used in this study.

Growth indices and ionic analysis were employed to study the effect of salt stress at the seedling stage.

Table 2—Analysis of variance of morphological and physiological traits for salinity stress tolerance at seedling stage

Source of Variance	Environments	df	Root length	Shoot length	Vigor	Na^+ content	K^+ content	Na uptake	K uptake
	Non saline	2	2.95	11.18	2.00E-05	1.00E-02	5.00E-02	0.052	2.00E-05
Replication	Saline		2.31	3.39	1.00E-04	2.00E-04	1.00E-05	0.0751	5.00E-05
	Non saline	130	57.33**	112.19**	0.09**	0.48**	1.91**	0.001**	0.001**
Treatments	Saline		24.87**	79.44**	3.29**	0.02**	0.40**	0.02**	0.002**
	Non saline		1.32	2.86	1.00E-04	2.00E-03	2.00E-02	1.00E-05	5.00E-05
Error	Saline	260	1.82	2.98	2.00E-04	1.00E-04	9.00E-04	9.00E-05	2.00E-05

*and ** Significant at 0.05 and 0.01 probability level, respectively

Plant height at seedling stage was significantly reduced under salinity stress. Root length and shoot lengths were reduced by 52 and 50%, respectively in saline stress in comparison to non-stress conditions (Table 3). Root length in non-stress and saline stress ranged from 12 to 31 cm and 4.33 to 18.0 cm, respectively. Shoot length ranged from 37 to 61 cm in non-stress to 12 to 40 cm in saline stress. The concentration of Na^+ increased but that of K^+ decreased. The Na^+ content shoot was increased from 1.13 mmol g^{-1} dry wt. in non-stress to 2.11 mmol g^{-1} dry wt. in saline stress, which was 86 % increment. The K^+ content was reduced by 64% in stress as compared with non stress conditions (Table 2) decreasing from 2.35 mmol g^{-1} dry wt. in non-stress to 0.83 mmol g^{-1} dry wt. in saline stress. Relative root length ranged from 18.00 to 97.00 cm. However, relative shoot length ranged from 26.63 to 73.47 cm (Table 3).

Salinity stress caused lesser effects on the morphological characters shoot and root length in three rice accessions *viz*., IC 545004, IC 545486 and IC 545215. Mean squares due to the treatments were highly significant for all the characters indicating presence of variation within genotypes (Table 3). The per cent reduction of root and shoot was minimal in IC 545004 (30.77 and 39.05%, vigor 5) followed by IC 545486 (34.88 and 27.63%, vigor 5) and IC 545215 (35.07 and 30.22%, vigor 5) in saline stress over non stress. The upper limit of damage in shoot was evident by a maximum reduction of 62% in the accession IC 459731. The low values of stress susceptibility index (SSI) indicate those genotypes which perform well under stress and possess sufficient plasticity to respond to the potential environment. Accessions ICs 545004, 545486 and 545215 were amongst the bottom 10 candidates for SSI root length, shoot length and Na^+ content. Higher values of STI indicate the superiority of genotypes due to both high yield potential and stress tolerance. The accession 545004 appeared among the top five contenders for STI root length, shoot length and vigor. Likewise, accession 545486 had the lowest SSI for shoot length and Na^+ content and had maximum STI for root length amongst all the accessions. Hence, accessions 545486 followed by accession 545004 and 545215 performed well under saline stress and were superior over other accessions.

Correlations analysis

The simple correlation was estimated among the morphological and physiological parameters (Table 4a). Significant and positive correlation was found between root and shoot length in non stress (r=0.35) and saline stress conditions both (r=0.64). Strong and negative correlation between Na content and K uptake was observed in saline stress (r=-0.53) as well as in non stress conditions as well (r=-0.35). A strong

Table 3—Comparisons of mean, range and per cent change of morphological, physiological and stress indices of 131 rice accessions in saline (EC~ 10 dS/m) over non stress

Traits	Mean		Range		% Reduction/Increase
	Non stress	Saline stress	Non stress	Saline stress	Saline stress
Root length	23.55	11.31	12.00-31.00	4.33-18	-52
Shoot length	50.11	24.86	37.00-61.00	12.00-40.00	-50
Na^+ content	1.13	2.11	0.44-2.54	0.60-4.32	+86
K^+ content	2.35	0.83	0.58-3.94	0.32-2.26	-64
Na uptake	0.09	0.15	0.001-0.11	0.03-0.45	+66
K uptake	0.09	0.05	0.01-0.26	0.002-0.09	-44
Vigour score	1.02	8.47	1-3	3-9	-
Relative root length	-	49.48	-	18.00-97.00	-
Relative shoot Length	-	50.04	-	26.63-73.47	-
SSI root length	-	0.98	-	0.04-1.59	-
SSI shoot length	-	0.99	-	0.53-1.46	-
SSI Na^+ content	-	-1.1	-	(-6.62)-(0.01)	-
SSI K^+ content	-	0.26	-	0.02-0.58	-
STI root length	-	0.49	-	0.15-0.97	-
STI shoot length	-	2.03	-	0.78-3.69	-
STI Na^+ content	-	1.97	-	0.21-6.94	-
STI K^+ content	-	0.35	-	0.05-1.13	-

negative correlation exists between K content and Na uptake in both the presence and absence of stress (r=-0.51 and r=-0.44, respectively). Vigor score was found to be negatively correlated with root and shoot lengths (r=-0.30 and r=-0.34, respectively) and positively correlated with Na content under saline stress.

Correlations among stress indices of morphological and physiological parameters

The simple correlation was estimated among stress indices of the morphological and physiological parameters (Table 4b). A significant positive correlation (r=0.43) was noticed between relative root length and relative shoot length. The relative root length is negatively correlated to SSI shoot length (r=-0.43) which is nevertheless positively correlated to STI shoot length (r=0.32). Likewise, the relative shoot length is negatively correlated to SSI root length (r=-0.44). Hence, both the relative lengths were positively correlated with STI indices for root and shoot lengths. STI shoot length was also found to be strongly correlated to STI root length (r=0.61). The SSI root length has a significant positive correlation with SSI of shoot length (r=0.43) and SSI vigor, whereas it is negatively correlated to STI root and shoot length. SSI shoot length is negatively correlated to STI for both, the root and shoots lengths. SSI for K^+ content has a significant negative correlation with STI for Na^+ content (r=-0.43). STI root length is positively correlated with STI shoot length (r=0.61).

Table 4—Correlation co-efficient of

(a) morphological and physiological parameters of 131 rice accessions in saline and non saline stress at seedling stage

Traits	Environments	Shoot length	Na^+ content	K^+ content	Na uptake	K uptake	Vigor score
Root length	Non saline	0.35**	0.17**	0.03 ns	-0.06 ns	-0.11 *	-0.08
	saline	0.64**	0.02	0.01 ns	0.05 ns	0.001 ns	-0.30**
Shoot length	Non saline		0.10 *	-0.01 ns	0.10 *	0.01 ns	-0.17*
	saline		0.01ns	0.01 ns	0.06	0.15 **	-0.34**
Na^+ content	Non saline			0.25**	0.108*	-0.39**	0.04 ns
	saline			0.16 **	0.471**	-0.53**	0.10*
Na^+ content	Non saline				-0.44**	0.11 *	0.06 ns
	saline				-0.51**	0.20**	0.03 ns
Na uptake	Non saline					0.37**	-0.09 ns
	saline					-0.31**	0.05 ns
K uptake	Non saline						-0.0001 ns
	saline						-0.03 ns

(b) stress indices of morphological and physiological parameters of 131 rice accessions at seedling stage

Traits	Relative		Stress Susceptibility Index (SSI)					Stress Tolerance Index (STI)			
	root length	shoot length	root length	shoot length	vigor	Na^+ content	K	root length	shoot length	vigor	Na^+ content
Relative shoot length	0.43^{**}										
SSI root length	-1.00^{**}	-0.44^{**}									
SSI shoot length	-0.43^{**}	-1.00^{**}	0.43^{**}								
SSI vigor	-0.20^{*}	-0.27^{**}	0.20^{*}	0.27^{**}							
SSI Na^+ content	0.06^{NS}	0.13^{NS}	-0.06^{NS}	-0.13^{NS}	0.03^{NS}						
SSI K^+ content	0.02^{NS}	-0.06^{NS}	-0.01^{NS}	0.06^{NS}	-0.07^{NS}	-0.08^{NS}					
STI root length	0.22^{**}	0.40^{**}	-0.22^{**}	-0.39^{**}	-0.21^{*}	0.10^{NS}	-0.03^{NS}				
STI shoot length	0.32^{**}	0.49^{**}	-0.32^{**}	-0.49^{**}	-0.18^{*}	0.22^{*}	-0.03^{NS}	0.61^{**}			
STI vigour	-0.10^{NS}	-0.21^{*}	0.10^{NS}	0.21^{*}	0.14^{NS}	0.01^{NS}	-0.02^{NS}	-0.21^{*}	-0.28^{**}		
STI Na^+ content	-0.01^{NS}	0.08^{NS}	0.01^{NS}	-0.07^{NS}	0.04^{NS}	0.14^{NS}	-0.43^{**}	0.17^{*}	0.09^{NS}	0.15^{NS}	
STI K^+ content	-0.01^{NS}	0.07^{NS}	0.01^{NS}	-0.07^{NS}	0.04^{NS}	0.21^{*}	-0.67^{**}	0.08^{NS}	0.10^{NS}	0.01^{NS}	0.72^{**}

* and ** Significant at 0.05 and 0.01 probability level, ns, not significant respectively, in *F*-tests

Discussion

Morphological and physiological behavior of rice accessions in non saline and saline stresses

Conventional breeding for salinity tolerance in rice requires consistent and speedy screening procedures which can keep with the huge number of germplasm used. Fortunately, several reports have shown that screening for salt tolerance in rice at the seedling stage could be well correlated with morphological and physiological components under saline conditions[16]. All genotypes grew robustly and showed uniform green color and height in the non stress condition. However, in the presence of salt stress, the genotypes demonstrated sizeable variation in vigor, in terms of morphological and physiological traits and their pooled effect on plant health. Overall plant health was estimated by a salt injury score ranging from 1 to 9. Seedlings grown under salt stress illustrated varied visual symptoms of salt injury. The symptoms were prominent on the leaves and were visualized by tip drying, drying of leaves, reduction in root growth, thin stem leading to complete cessation of growth and dying of seedlings. The morphological characters, the growth indicators such as root length and shoot length were severely impeded under stress as compared to the non-stress.

Plant roots are the first tissue to become exposed to salinity and root growth is particularly sensitive and rapidly reduced by salinity due to direct contact with the growth media[17]. In this study, a significant and positive correlation was found between root and shoot lengths of all the accessions, regardless of the treatment, though the values of correlation coefficient differed in presence and absence of saline stress differed. The effect of the increased Na^+ concentration in the medium is detrimental to morphological traits as evident by 52% reduction in root length and a concomitant 50% reduction in shoot length. The per cent increment in Na uptake increased significantly in most of the accessions which substantiates the fact that due to higher availability of Na, the uptake also increased invariably in those accessions. Selection within accessions with low Na^+ transport has been made in rice[18]. The Na^+/K^+ ratio shows relative decrease in K^+ content compared to Na^+ content in the genotypes along the salinity gradient[19]. Generally, the salt tolerant varieties maintain homeostasis with low Na^+ content in their foliage in comparison to the salt susceptible varieties during exposure to stress[20]. Thus, Na^+/K^+ ratio in the leaves of plants can be used as a central marker of salinity tolerance and breeding for low ion buildup could be a simple way to improve tolerance to saline stress. The concentration of Na^+ in the samples increased contrary to K^+ concentration which showed a reverse trend, leading to increased Na^+/K^+ ratios as the levels of salt tolerance decreased in the plants[21]. Preference for K^+ over Na^+ in the non-stress plants where the K^+ concentration was greater than Na^+ concentration while a reverse trend was observed during the saline treatment[22]. There was a significant correlation between root and shoot lengths during saline stress treatment and was further validated by concomitant 50 and 52% reductions in shoot and root length, respectively under stress. The longest root and shoot length in non stress were 32 and 62 cm, respectively, however, in saline stress the longest root and shoot lengths were reduced to 19 and 41 cm, respectively. The results reported in this study showed a progressive decline in the observed growth indices of rice plant in saline stress. These results are also consistent with the reports that rice seedling were very sensitive to salinity[23,24]. Also, the salinity stress hampered the expression of growth parameters and this reduction was elevated in stress. Saline stress may reduce plant growth by water deficit, ion toxicity, ion imbalance or combination of these factors[25]. With increasing salinity, reduction of root and shoot lengths, and dry wt. of root and shoot was observed[26], as the vigor score increased (sensitive), the root length and the length of the shoot reduced significantly. A significant correlation between root length and shoot length in salinity (r=0.64) and their concurrent decrease in stress substantiates[27].

Ion uptake is one character of meticulous concern. Several reports have indicated that plant growth is inversely proportional to Na^+ concentration, as the levels of stress increases[27]. Salinity in rice was associated with Na^+ exclusion and increased absorption of K^+ to maintain a good Na^+/K^+ balance in the shoot under saline condition. It is considered that injury of foliage was mainly ascribed to the buildup of Na^+ from the root to the shoot in higher concentrations[28]. The K content reduced in saline stress and advocates either efflux or lower uptake as illustrated by a negative correlation between Na uptake and K content per gram dry weight. Screening 130 rice accessions for salinity tolerance at the seedling stage in this study has shown that the visual salt injury scoring (ST scores) correlated well with the Na^+/K^+ content and their ratio. Ability of plants to reduce Na^+ uptake, exclude Na^+ and decrease K^+ efflux induced by NaCl has been accepted as the essential mechanisms for salinity tolerance[29,30]. For rice, at seedling and reproductive stages, Na^+ and K^+ content has been widely used as a standard reliable criterion together with the visual score for evaluating salinity tolerance in rice[31,32]. The genetic architecture of the rice accession in relation to morphological and physiological traits helps to identifying the rice genotypes for salinity tolerance at seedling stage[33].

Two types of stress indices viz. stress tolerance index (STI) and stress susceptibility index (SSI) were employed as indices for determining the relative tolerance to salinity[31,32]. The STI was projected as a selection criterion which identifies genotypes with stress tolerance potentials[32]. Stress susceptibility index relies on identifying only those genotypes which show minimum reduction under stress compared to non-stress[8]. Lower values of SSI indicate genotypes performing well under stress and having sufficient plasticity to respond to the potential environment. Similarly, genetic diversity also good method to identify the genotypes for seedling stage salinity tolerance. Researchers have reported that many markers in Saltol region could be used to identify the genotypes through cluster analysis[33]. The value of correlation coefficient between SSI root length and SSI shoot length was 0.438. Three accessions, namely IC 545004, IC 545486 and IC 545215 appeared among the bottom 10 accessions for SSI for root length, shoot length and Na content.

The higher values of STI indicate the superiority of genotypes due to both high yield potential and stress tolerance[32]. The value of correlation coefficient between STI root length and STI shoot length was 0.61. Among the top 10 accessions for STI, the same three corresponded and appeared as common in top ten candidates of STI for the same morphological characters mentioned earlier.

On the overall basis, STI was found to be correlated with more attributes than SSI, revealing the higher importance of former index in germplasm selection and breeding. In the perspective of correlations of SSI and STI with morphological and biochemical traits, it was found that STI could develop significant correlation with many traits in saline stress than SSI thus revealing the higher utility of STI in indirect selection. Therefore, STI can serve as an effective selection criterion to improve the salinity tolerance via breeding. Several genotypes of common beans were superior for heat tolerance based on the stress indices and on the consistency of their reactions across environments[34].

Conclusion

In the present study three accessions namely, IC 545004, IC 545486 and IC 545215 were adjudged as the best performers on the basis of the morphological, physiological criteria and stress indices. These three accessions performed better in saline stress and can be used in genotypic studies and as donor parents in future breeding programs . It may be concluded that screening at the seedling stage along with other morphological, physiological parameters and stress indices do provide useful clues about the salt tolerance potential of rice genotypes.

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