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Original Research Article

Evaluation of Salinity Tolerance of Rice Varieties through *in vitro* Seed Germination and Seedling Growth

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Keywords

Rice, Salt stress, *In vitro*, Seed germination, Seedling growth

A B S T R A C T

Thirty selected rice varieties along with two tolerant (Pokkali and CSR-36) and two susceptible (IR-29 and IR-64) checks were screened for salinity tolerance on the basis of *in vitro* seed germination and seedling growth at different salinity levels (0, 4, 8 and 16 dS m^{-1}) created by a salt mixture of NaCl, $CaCl_2$, Na_2SO_4 in 7:2:1 ratio. The frequency of seed germination gradually decreased with increasing concentrations of salt. As observed with seed germination, seedling growth was also adversely affected with the increase of salt concentrations. The root growth was more affected than shoot growth. The salt tolerance index (STI) of the rice varieties was calculated on the basis of seed germination, seedling shoot and root dry weights at different levels of salt stresses. Varieties Pokkali, CSR-36 Mandakini, Kranthi, Jyothi, Bardhan, Pusa Sugandh-2, Duna Sankhi, Sanwal Basmati, Ratnagiri-4, Shanthi, Rajendra Dhan-102, Sahbhagi Dhan, Vaisak, Annada, Badami, Pusa-834, Govind, Sarsa and Jaytrirmayee were found to be salt tolerant whereas Khira, Pusa Sugandh-5, MTU-7029 and Saraswathi were moderately salt tolerant and varieties IR-29, IR-64, Daya, Kalinga-3, Golaka and Shatabdi were salt susceptible respectively on the basis of mean STI. Thus *in vitro* study can be used for evaluation of salinity tolerance of rice varieties.

Introduction

Rice (*Oryza sativa* L.) is one of the most important crops in the world that offers food for more than 50% of the world's population (Aggarwal *et al*., 2002; Kumari *et al*., 2016). A 100 g of rice provides 345.0 kcal, 78.2 g of carbohydrates and 6.8 g of protein (Gopalan *et al*., 2007; Ali *et al*., 2014). Compared to wheat and maize, it has the highest net protein utilization value. It also produces more calories and carbohydrates per hectare than any other cereal (Lu and Chang, 1980).

The productivity of several commercial crops is limited by major abiotic stresses including salinity, drought, water logging and heat. Damages caused by these stresses are responsible for enormous economic loss world-wide. Salinity is a major abiotic stress affecting crops adversely. It is caused by poor water management, high evaporation, heavy irrigation, previous exposure to seawater and regular use of chemical fertilizers.

Salinity is the biggest problem in rice growing areas of many countries (Senadhira, 1987). Rice is rated as a salt sensitive crop (Maas & Hoffman, 1977; Shannon *et al.*, 1998). Although, salinity affects all stages of the growth and development of rice plant and the crop responses to salinity varies with growth stages, concentration and duration of exposure to salt. Several studies indicated that rice is tolerant during germination and vegetative stage but becomes very sensitive during seedling and reproductive stage (Ali *et al*., 2014). There are other reports where grain yield is much more depressed by salt than the vegetative growth (other than that of very young seedlings). Yield is a very complex character which comprise of many components and these yield components are related to final grain yield which are also severely affected by salinity. Shoot and root length, dry and fresh weight of shoot and root, leaf size, panicle length and spikelets per panicle are significantly affected by salinity (1995; Khatun and Flowers, 1995; Munns and Testor, 2008; Hakim *et al*., 2010; Gupta and Huang, 2014; Kumari *et al*., 2016; Reddy *et al*., 2017).

To enhance salinity tolerance in rice varieties, it is very important to find sufficient variation and to devise appropriate screening techniques which are reliable and able to identify salt tolerant varieties (Kranto *et al*., 2016). Screening at field level proved to be difficult due to soil heterogeneity, climatic factors and other environmental factors which may influence the physiological processes. Hence, screening under laboratory conditions is considered to be advantageous over field screening (Ali *et al*., 2014). Thus, this study was conducted to evaluate the salinity tolerance of thirty rice varieties through *in vitro* seed germination and seedling growth at different salinity levels.

Materials and Methods

The experiment was conducted at Dr. Rajendra Prasad Central Agricultural University, Pusa (Samastipur), Bihar, India. Thirty selected rice varieties (Table 1) along with two tolerant (Pokkali and CSR-36) and two susceptible (IR-29 and IR-64) checks were screened at different salinity levels. Seeds were soaked in water overnight. Soaked seeds were treated with 70% ethyl alcohol for 30 seconds and then washed with distilled water. Thereafter seeds were treated with 0.1% mercuric chloride ($HgCl_2$) for 10-15 minutes, rinsed with sterile distilled water thrice and placed for germination on filter paper in 10 cm diameter Petri dish containing different salinity levels (0, 4, 8 and 16 dS m^{-1}) created by a salt mixture of NaCl, $CaCl_2$, Na_2SO_4 in 7:2:1 ratio. The Petri dishes were kept under laboratory conditions.

Statistical data analysis

The experiment was laid out in a factorial CRD design (Gomez and Gomez, 1984) with three replications. The data were subjected to analysis of variance and Duncan's Multiple Range Test (DMRT) for comparing population means. Mean values were compared by two-way ANOVA. The salinity tolerance index, represented as the ratio of the performance of a cultivar at a particular level of salinity to that of control, was calculated on the basis of *in vitro* germination, and seedling growth based on dry weights of shoot and root following the method of Reddy and Vaidyanath (1982).

Results and Discussion

Seed germination under salt stress

The seeds of thirty selected rice varieties were put to germination at different salinity

levels (0, 4, 8 and 16 dS m^{-1}). The germination of seeds was initiated within the first week. The first sign of germination was observed by the appearance of the plumule followed by radical. Only in control (0 dS m^{-1}) the seeds of all the varieties showed germination in the first week. Some seeds of varieties Pokkali and CSR-36 also germinated at 4 dS m^{-1} salinity level in the first week. The seeds of all other varieties germinated at 8, 12 and 16 salt stress levels in the second week.

The frequency of seed germination was gradually decreased with increasing concentrations of salt and are presented in Table 2 and graphically represented in Figures 1 and 2. In the effect of salt stress, at 0 dS m^{-1} salinity level all varieties showed the best seed germination with mean of (96.95%) followed by 4 (93.55%), 8 (92.31%) and 12 dS m^{-1} salinity levels (90.73%) where as the minimum germination was observed at 16 dS m^{-1} salinity level (88.96%). In case of effect of varieties, the best germination was observed in Pokkali (96.46%) followed by varieties CSR-36 (96.33%), Bardhan (96.26%), Kranthi (96.13%), Badami (95.80%), Pusa Sugandh-2 (95.60%), Sahbhagi Dhan (95.53%), Sanwal Basmati (95.46%), Jyothi (95.06%), Duna Sankhi (95.06%), Govind (94.93%), Sarsa (94.53%), Pusa Sugandh-5 (94.40%), Jyotrirmayee (94.33%), Pusa-834 (94.06%), Vaisak (94.06%), Shanthi (93.93%), MTU-7029 (93.60%), Mandakini (93.46%), Khira (93.46%), Ratnagiri-4 (93.00%), Rajendra Dhan-102 (92.93%), Annada (92.86%), Saraswathi (92.66%), IR-29 (85.60%), Shatabdi (84.53%), IR-64 (84.40%), Kalina-3 (84.40%), Daya (82.93%) and Golaka (82.93%) respectively.

Based on *in vitro* seed germination frequency at different salinity levels, variety Pokkali showed the highest mean salt tolerance index (STI) of 98.87% followed by varieties CSR-36 (98.29%), Mandakini (97.97%), Kranthi (97.61%), Jyothi (97.49%), Bardhan (97.36%), Pusa Sugandh-2 (97.35%), Duna Sankhi (97.30%), Sanwal Basmati (97.08%), Ratnagiri-4 (97.01%), Shanthi (96.88%), Rajendra Dhan-102 (96.84%), Sahbhagi Dhan (96.84%), Vaisak (96.83%), Annada (96.76%), Badami (96.70%), Pusa-834 (96.61%), Govind (96.46%), Sarsa (96.40%), Jyotrirmayee (96.14%), and can be considered as salt tolerant while Daya showed the least mean salt tolerance index (STI) of 82.53% followed by Kalinga-3 (83.38%), Shatabdi (83.95%), Golaka (84.50%), IR-64 (85.27%), IR-29 (85.68%) and can be considered as salt susceptible. The other varieties Khira, PusaSugandh-5, MTU-7029 and Saraswathi with STI of 95.86%, 95.40%, 94.02% and 93.60% respectively and can be considered as moderately tolerant (Table 3 and Figure 3).

Bhumba and Singh (1965) have shown the inhibitory effect of salt stress on seed germination, while Paliwal and Gandhi (1968) found in paddy the inhibitory effect of salt due to anions. Ali *et al*. (1996) observed in rice varieties of different groups, a concentration dependent decrease in seed germination under sodium chloride stress as found in present investigation. They also observed differences in salinity tolerance among cultivars based on germination frequency and considered it significant because decline in germination also leads to significant reduction in seedling length, early seedling vigour, speed of germination and dry matter production per plant (Reddy *et al*., 1994).

Kazemi and Eskandari (2011) observed delayed and decreased germination of rice seeds under salt stress. High concentration of salt reduces the water potential and

hinders water absorption by germinating seeds and thus reduces germination (Hakim *et al*., 2010; Vibhuti *et al*., 2015; Kumari *et al*., 2016). Salinity may affect seed germination by decreasing the ease with which the seeds take up water because the activity and events normally associated with germination get either delayed or proceed at a reduced rate (Abogadallah and Quick, 2009).

Table.1 Rice varieties used

Sl No.	Varieties	Source
1.	Pokkali	Karnatka
2.	CSR-36	CSSRI, Karnal
3.	IR-29	IRRI, Philippines
4.	IR-64	IRRI, Philippines
5.	Kranthi	Raipur
6.	Ratnagiri-4	Ratnagiri
7.	Annada	CRRI
8.	Rajendra Dhan-102	RAU, Pusa
9.	Mandakini	Bhubaneswar
10.	Sahbhagi Dhan	CURRS, Hazaribag
11.	Pusa Sugandh-2	IARI, New Delhi
12.	Daya	Bhubaneswar
13.	Kalinga-3	OUAT
14.	Sarsa	Lanrace, Bihar
15.	Jyothi	Kerala
16.	Sanwal Basmati	SKUAT, Srinagar
17.	Saraswathi	Chinsurah
18.	Golaka	Landrace, Bihar
19.	Pusa-834	IARI, New Delhi
20.	Shatabdi	CRRI, Cuttack
21.	Duna Sankhi	Landrace, Bihar
22.	Govind	Pantnagar
23.	Shanthi	
24.	Vaisak	Landrace, Bihar
25.	Khira	Landrace, Bihar
26.	Bardhan	Assam
27.	MTU-7029	ANGARU, Hydrabad
28.	Pusa Sugandh-5	IARI, New Delhi
29.	Jyotrirmayee	
30.	Badami	Bhubaneswar

Table.2 Germination (%) of seeds of rice varieties on different salinity levels

Varieties	Salinity levels (dSm^{-1})							
	0	4	8	12	16	Mean±SE	CD	CV
Pokkali	97.33^{a}±0.88	97.33^{a}±0.66	96.66^{a}±0.33	95.66^{a}±0.33	95.33^{a}±0.33	96.46±0.66	-	1.00
CSR-36	97.66^{a}±0.33	97.00^{a}±0.57	96.33^{a}±0.33	95.66^{a}±0.66	95.00^{a}±0.57	96.33±0.51	1.64	0.92
IR-29	96.66^{b}±0.88	87.66^{d}±0.33	85.66^{e}±0.66	81.66^{d}±1.66	76.33^{e}±1.85	85.60±1.22	3.92	2.48
IR-64	95.66^{b}±0.33	84.66^{e}±0.33	83.00^{f}±0.57	81.33^{d}±0.66	77.33^{e}±1.33	84.40±0.74	2.37	1.53
Kranthi	98.00^{a}±0.57	96.33^{a}±0.66	96.00^{a}±0.57	95.66^{a}±0.33	94.66^{a}±0.33	96.13±0.51	1.64	0.93
Ratnagiri-4	95.33b±0.88	94.96^{b}±0.33	93.33^{c}±0.33	92.00^{b}±0.57	89.66^{c}±0.88	93.00±0.65	2.07	1.21
Annada	95.33^{b}±0.66	94.00^{c}±0.57	93.00^{c}±0.57	91.66^{b}±0.33	90.33^{c}±0.33	92.86±0.51	1.64	0.96
Rajendra Dhan-102	95.33^{b}±0.33	94.00^{c}±0.57	92.66^{c}±0.33	92.00^{b}±0.57	90.66^{c}±0.33	92.93±0.44	1.42	0.83
Mandakini	95.00^{c}±0.57	94.66^{b}±0.33	93.66^{c}±0.33	92.66^{b}±0.33	91.33^{c}±0.33	93.46±0.39	1.25	0.73
Sahbhagi Dhan	98.00^{a}±0.57	96.66^{a}±0.33	95.33^{a}±0.33	94.33^{a}±0.33	93.33^{a}±0.33	95.53±0.39	1.25	0.71
Pusa Sugandh-2	97.66^{a}±0.33	96.33^{a}±0.66	95.66^{a}±0.33	94.66^{a}±0.33	93.66^{a}±0.33	95.60±0.42	1.34	0.76
Daya	97.33^{a}±0.88	84.00^{e}±0.57	82.00^{g}±1.00	79.33^{e}±0.66	76.00^{e}±1.00	83.73±0.84	2.69	1.74
Kalinga-3	97.33^{a}±0.33	85.33^{e}± 0.33	84.33^{e}±0.33	79.33^{e}±2.33	75.66^{e}±0.66	84.40±1.11	3.56	2.28
Sarsa	97.33^{a}±0.33	96.00^{a}±0.57	94.00^{b}±0.57	93.33^{b}±0.33	92.00^{b}±0.57	94.53±0.49	1.57	0.90
Jyothi	97.00^{a}±1.15	95.66^{b}±0.88	95.33^{a}±0.33	94.33^{a}±0.33	93.00^{b}±0.57	95.06±0.73	2.33	1.33
Sanwal Basmati	97.66^{a}±0.33	97.00^{a}±0.57	95.66^{a}±0.33	94.33^{a}±0.33	92.66^{b}±0.88	95.46±0.53	1.71	0.97
Saraswathi	97.66^{a}±0.66	93.66^{c}±0.33	92.33^{d}±0.33	90.66^{c}±0.66	89.00^{d}±0.57	92.66±0.53	1.71	1.00
Golaka	94.66^{c}±0.33	84.00^{e}±0.57	82.33^{g}±0.66	79.00^{e}±1.00	74.66^{f}±1.66	82.93±0.96	3.08	2.01
Pusa-834	97.00^{a}±0.57	95.66^{b}±0.33	94.33^{b}±0.66	92.00^{b}±0.57	91.33^{c}±0.66	94.06±0.57	1.84	1.06
Shatabdi	97.00^{a}±0.57	84.33^{e}±0.33	82.66^{g}±0.66	81.00^{d}±0.57	77.66^{e}±1.45	84.53±0.81	3.29	1.97
Duna Sankhi	96.66^{b}±0.88	96.00^{a}±0.57	95.00^{b}±0.57	94.00^{a}±0.57	93.66^{a}±0.33	95.06±0.61	2.60	1.69
Govind	97.66^{a}±0.66	96.33^{a}±0.33	95.33^{a}±0.33	93.66^{a}±0.88	91.66^{b}±0.33	94.93±0.55	1.78	1.01
Shanthi	96.33^{b}±0.33	95.33^{b}±0.33	94.00^{b}±0.57	92.66^{b}±0.33	91.33^{c}±0.66	93.93±0.47	1.50	0.86
Vaisak	96.33^{b}±0.88	95.66^{b}±0.33	94.33^{b}±0.33	93.00^{b}±0.57	91.00^{c}±0.57	94.06±0.57	1.84	1.06
Khira	96.66^{b}±1.20	95.33^{b}±0.66	93.00^{c}±0.57	91.66^{b}±0.33	90.66^{c}±0.33	93.46±0.69	2.23	1.29
Bardhan	98.33^{a}±0.33	97.33^{a}±0.33	96.33^{a}±0.33	95.33^{a}±0.33	94.00^{a}±0.57	96.26±0.39	1.25	0.71
MTU-7029	97.66^{a}±0.33	93.33^{c}±0.33	92.33^{d}±0.33	91.00^{c}±0.57	90.66^{c}±0.33	93.60±0.39	1.25	0.73
Pusa Sugandh-5	98.00^{a}±0.57	95.66^{b}±0.66	94.33^{b}±0.66	92.66^{b}±0.33	91.33^{c}±0.66	94.40±0.59	1.90	1.09
Jyotrirmayee	97.33^{a}±0.33	95.00^{b}±0.57	94.00^{b}±0.00	93.33^{b}±0.33	92.00^{b}±0.57	94.33±0.42	1.34	0.77
Badami	98.66^{a}±0.33	97.66^{a}±0.33	96.00^{a}±0.57	94.00^{a}±0.57	92.66^{b}±0.33	95.80±0.44	1.42	0.80
Mean±SE	96.95±0.63	93.55±0.50	92.31±0.49	90.73±0.73	88.96±0.77			
CD	1.81	1.43	1.40	2.07	2.20			
CV	1.14	0.93	0.92	1.39	1.51			

Values followed by the same letter in columns are not significantly different using Duncan's Multiple Range Test (DMRT) at 5%

Table.3 Salinity tolerance index (STI) of rice varieties based on germination frequency under salt stress

Varieties	Germination frequency on different salinity levels (dSm^{-1})					STI on different salinity levels (dSm^{-1})					Mean STI
	0	4	8	12	16	0	4	8	12	16	
Pokkali	97.33	97.33	96.66	95.66	95.33		100	99.27	98.28	97.94	98.87
CSR-36	97.66	97.00	96.33	95.66	95.00		99.32	98.63	97.95	97.27	98.29
IR-29	96.66	87.66	85.66	81.66	76.33		90.68	88.61	84.48	78.96	85.68
IR-64	95.66	84.66	83.00	81.33	77.33		88.50	86.76	85.01	80.83	85.27
Kranthi	98.00	96.33	96.00	95.66	94.66		98.29	97.95	97.61	96.59	97.61
Ratnagiri-4	95.33	94.96	93.33	92.00	89.66		99.61	97.90	96.50	94.05	97.01
Annada	95.33	94.00	93.00	91.66	90.33		98.60	97.55	96.15	94.75	96.76
Rajendra Dhan-102	95.33	94.00	92.66	92.00	90.66		98.60	97.19	96.50	95.10	96.84
Mandakini	95.00	94.66	93.66	92.66	91.33		99.64	98.58	97.53	96.13	97.97
Sahbhagi Dhan	98.00	96.66	95.33	94.33	93.33		98.63	97.27	96.25	95.23	96.84
Pusa Sugandh-2	97.66	96.33	95.66	94.66	93.66		98.63	97.95	96.92	95.90	97.35
Daya	97.33	84.00	82.00	79.33	76.00		86.30	84.24	81.50	78.08	82.53
Kalinga-3	97.33	85.33	84.33	79.33	75.66		87.67	86.64	81.50	77.73	83.38
Sarsa	97.33	96.00	94.00	93.33	92.00		98.63	96.57	95.89	94.52	96.40
Jyothi	97.00	95.66	95.33	94.33	93.00		98.61	98.27	97.24	95.87	97.49
Sanwal Basmati	97.66	97.00	95.66	94.33	92.66		99.32	97.55	96.59	94.88	97.08
Saraswathi	97.66	93.66	92.33	90.66	89.00		95.90	94.54	92.83	91.13	93.60
Golaka	94.66	84.00	82.33	79.00	74.66		88.73	86.96	83.45	78.87	84.50
Pusa-834	97.00	95.66	94.33	92.00	91.33		98.61	97.24	94.84	94.15	96.21
Shatabdi	97.00	84.33	82.66	81.00	77.66		86.93	85.21	83.50	80.16	83.95
Duna Sankhi	96.66	96.00	95.00	94.00	93.66		99.31	98.28	97.24	96.89	97.30
Govind	97.66	96.33	95.33	93.66	91.66		98.63	97.61	95.90	93.85	96.46
Shanthi	96.33	95.33	94.00	92.66	91.33		98.96	97.58	96.19	94.80	96.88
Vaisak	96.33	95.66	94.33	93.00	91.00		99.30	97.92	95.65	94.46	96.83
Khira	96.66	95.33	93.00	91.66	90.66		98.62	96.21	94.82	93.79	95.86
Bardhan	98.33	97.33	96.33	95.33	94.00		98.98	97.96	96.94	95.59	97.36
MTU-7029	97.66	93.33	92.33	91.00	90.66		95.56	94.54	93.18	92.83	94.02
Pusa Sugandh-5	98.00	95.66	94.33	92.66	91.33		97.61	96.25	94.55	93.19	95.40
Jyotrirmayee	97.33	95.00	94.00	93.33	92.00		97.60	96.57	95.89	94.52	96.14
Badami	98.66	97.66	96.00	94.00	92.66		98.98	98.66	95.27	93.91	96.70

Table.4 Seedling growth of rice varieties under different salinity levels

Varieties	Salinity levels	Seedling growth							
		Shoot			Root			Salinity tolerance index (STI)	
		Fresh wt (mg)	Dry wt (mg)	STI	Fresh wt (mg)	Dry wt (mg)	STI	Average STI	**Mean STI**
Pokkali	0	67.32	9.96		51.36	9.00			84.21
	4	64.34	9.76	97.99	46.00	8.46	94.00	95.99	
	8	55.36	8.56	85.94	41.00	8.26	91.77	88.85	
	12	50.00	8.00	80.32	35.56	7.42	82.44	81.38	
	16	42.88	7.43	74.59	25.98	6.00	66.66	70.62	
CSR-36	0	65.84	11.00		56.28	10.00			84.11
	4	62.10	10.99	99.90	52.36	9.00	90.00	94.95	
	8	55.81	10.20	92.72	44.92	8.10	81.00	86.86	
	12	53.21	8.92	81.09	36.81	7.99	79.90	80.49	
	16	44.00	8.00	72.72	33.33	7.56	75.60	74.16	
IR-29	0	12.04	3.19		11.22	1.99			38.74
	4	9.23	2.01	63.00	8.34	1.26	63.31	63.15	
	8	7.64	1.33	41.69	4.98	0.87	43.71	42.70	
	12	5.81	1.00	31.34	3.00	0.65	32.66	32.00	
	16	2.02	0.62	19.43	1.02	0.30	15.07	17.11	
IR-64	0	12.01	2.98		11.02	1.92			35.66
	4	8.11	1.99	66.77	8.00	1.22	63.54	65.15	
	8	6.43	1.00	33.44	4.82	0.88	45.83	39.63	
	12	4.52	0.84	28.18	2.21	0.56	29.16	28.67	
	16	1.22	0.27	9.06	0.84	0.18	9.37	9.21	
Kranthi	0	66.00	11.22		57.00	10.10			83.14
	4	64.42	11.00	98.03	53.00	9.10	90.09	94.06	
	8	56.00	10.01	89.21	45.10	8.88	87.92	88.56	
	12	51.33	8.02	71.48	37.20	8.12	80.39	75.93	
	16	42.88	7.73	68.89	34.28	8.00	79.20	74.04	
Ratnagiri-4	0	65.01	11.80		56.11	10.00			80.41
	4	64.21	10.92	92.54	53.99	9.00	90.00	91.27	
	8	61.99	9.81	83.13	45.00	8.22	82.20	82.66	
	12	52.00	8.99	76.18	36.99	8.00	80.00	78.09	
	16	46.63	7.21	61.10	29.82	7.82	78.20	69.65	
Annada	0	63.40	10.02		51.22	9.80			79.13
	4	61.68	9.00	89.82	48.00	8.70	88.77	89.29	
	8	52.00	8.88	88.62	39.30	7.99	81.53	85.07	
	12	49.42	8.00	79.84	34.11	7.10	72.44	76.14	
	16	41.00	7.10	70.85	26.43	6.00	61.22	66.03	
Rajendra Dhan-102	0	68.00	11.98		58.88	10.92			79.56
	4	65.66	11.00	91.81	53.81	10.00	91.57	91.69	
	8	57.00	10.00	83.47	47.10	9.00	82.41	82.94	
	12	52.11	9.00	75.12	39.11	8.88	81.31	78.21	
	16	43.01	8.00	66.77	31.00	7.00	64.10	65.43	
Mandakini	0	68.00	10.00		52.22	9.97			83.42
	4	65.10	9.99	99.90	47.48	8.81	88.36	94.13	
	8	56.00	8.99	89.99	41.00	8.00	80.24	85.11	
	12	51.20	8.67	86.70	36.00	7.87	78.93	82.81	
	16	43.10	7.98	79.80	26.00	6.33	63.49	71.64	
Sahbhagi Dhan	0	70.00	12.48		61.38	11.00			79.49
	4	68.38	11.97	95.91	56.20	10.00	90.90	93.40	
	8	61.10	10.88	87.17	48.36	9.10	82.72	84.94	
	12	54.00	8.28	66.34	39.11	8.87	80.63	73.48	
	16	42.10	7.21	57.77	32.14	8.20	74.54	66.15	
Pusa Sugandh-2	0	64.22	11.00		55.41	9.98			81.42
	4	63.00	10.12	92.00	52.00	9.00	90.18	91.09	
	8	58.99	9.23	83.90	45.21	8.44	84.56	84.23	
	12	51.00	8.70	79.09	35.00	7.97	79.85	79.47	
	16	45.11	7.00	63.63	28.01	7.80	78.15	70.89	
Daya	0	10.69	2.00		9.98	1.99			27.12
	4	6.66	1.03	54.00	6.50	0.99	49.74	51.87	
	8	4.31	0.77	38.50	4.10	0.79	36.18	37.34	
	12	2.64	0.34	17.00	2.00	0.28	14.07	15.53	
	16	0.68	0.09	4.50	0.52	0.06	3.01	3.75	
Kalinga-3	0	11.20	2.88		10.99	2.00			27.17
	4	7.22	1.64	56.94	7.10	1.10	55.00	55.97	
	8	5.34	0.88	30.55	3.20	0.69	34.50	32.50	
	12	3.61	0.64	22.22	1.11	0.16	8.00	15.11	
	16	0.99	0.18	6.25	0.61	0.08	4.00	5.12	

Sarsa	0	67.00	12.00		58.12	10.99			77.72
	4	65.44	11.12	92.66	53.46	9.98	90.80	91.73	
	8	57.00	10.00	83.33	46.00	8.86	80.61	81.97	
	12	50.02	8.00	66.66	37.01	8.44	76.79	71.72	
	16	41.91	7.00	58.33	30.00	7.98	72.61	65.47	
Jyothi	0	64.72	10.91		55.31	9.99			82.16
	4	63.11	10.00	91.57	53.00	9.01	90.19	90.88	
	8	60.56	9.12	83.51	44.81	8.00	80.08	81.79	
	12	56.00	9.00	82.41	35.00	7.99	79.97	81.19	
	16	48.81	7.80	71.42	29.01	7.81	78.17	74.79	

Table.4 Continued

Varieties	**Salinity levels**	**Seedling growth**							
		Shoot			**Root**			Salinity tolerance index (STI)	
		Fresh wt (mg)	Dry wt (mg)	STI	Fresh wt (mg)	Dry wt (mg)	STI	Average STI	**Mean STI**
Sanwal Basmati	0	68.10	10.60		52.00	9.90			80.80
	4	65.66	9.88	93.20	47.88	8.80	88.88	91.04	
	8	56.02	9.00	84.90	40.00	8.20	82.82	83.86	
	12	51.00	8.66	81.69	35.10	7.12	79.91	80.80	
	16	43.00	7.20	67.92	26.89	6.01	60.70	64.31	
Saraswathi	0		9.82		42.00	8.70			65.24
	4	51.21	8.66	88.18	35.22	7.00	80.45	84.31	
	8	43.02	7.92	80.65	31.00	6.01	69.08	74.86	
	12	37.86	6.99	71.18	25.82	4.98	57.24	64.21	
	16	26.01	4.00	40.73	19.81	3.00	34.48	37.60	
Golaka	0	9.88	2.11		7.23	1.30			35.48
	4	7.61	1.32	62.55	5.44	0.88	67.69	65.12	
	8	5.36	0.98	46.44	3.26	0.47	36.15	41.29	
	12	3.69	0.72	34.12	2.57	0.22	16.92	25.52	
	16	1.09	0.26	12.32	0.88	0.10	7.69	10.00	
Pusa-834	0	66.00	11.99		57.00	10.22			78.27
	4	65.01	11.00	91.74	54.01	9.44	92.36	92.05	
	8	62.81	9.92	82.73	45.74	8.88	86.88	84.80	
	12	51.00	8.11	67.63	36.00	7.98	78.08	72.85	
	16	44.21	7.00	58.38	27.29	6.99	68.39	63.38	
Shatabdi	0	10.82	2.44		8.66	1.78			34.47
	4	8.36	1.18	48.36	6.48	0.99	55.61	51.98	
	8	6.21	1.01	41.39	4.27	0.92	51.68	46.53	
	12	4.02	0.77	31.55	2.09	0.56	31.46	31.50	
	16	2.72	0.45	18.44	0.97	0.13	7.30	7.87	
Duna Sankhi	0	65.02	11.81		56.00	10.00			81.20
	4	64.00	10.90	92.29	53.42	9.00	90.00	91.14	
	8	61.00	9.76	82.64	45.88	8.88	88.80	85.72	
	12	52.10	8.98	76.03	36.01	7.99	79.90	77.96	
	16	46.33	7.20	60.96	30.47	7.90	79.00	69.98	
Govind	0	68.22	12.01		59.01	11.00			78.27
	4	64.00	11.00	91.59	54.42	10.00	90.90	91.24	
	8	57.22	10.21	85.01	47.00	8.98	81.63	83.32	
	12	51.00	8.98	74.77	38.02	8.00	72.72	73.74	
	16	42.11	7.81	65.02	32.00	7.10	64.54	64.78	
Shanthi	0	62.00	9.80		50.06	9.00			80.11
	4	60.01	8.99	91.73	47.03	8.00	88.88	90.30	
	8	51.00	8.00	81.63	38.09	7.31	81.22	81.42	
	12	46.04	7.78	79.38	33.00	7.22	80.22	79.80	
	16	37.00	6.98	71.22	25.01	6.00	66.66	68.94	
Vaisak	0	62.06	9.82		51.00	9.22			79.42
	4	60.90	8.99	91.54	46.03	8.01	86.87	89.20	
	8	51.00	8.08	82.28	38.00	7.00	75.92	79.10	
	12	45.00	7.58	77.18	32.22	6.99	75.81	76.49	
	16	37.10	6.99	71.18	25.26	6.88	74.62	72.90	
Khira	0	36.91	6.53		25.25	4.75			71.84
	4	34.00	6.40	98.00	24.60	4.70	98.94	98.47	
	8	33.57	5.85	89.58	20.00	3.42	72.00	80.79	
	12	26.25	4.00	61.25	18.50	3.20	67.36	64.60	
	16	22.50	2.00	30.62	16.00	2.68	56.42	43.52	
Bardhan	0	64.00	10.92		55.00	9.99			82.04
	4	63.00	10.80	98.90	54.90	9.90	99.09	98.99	
	8	60.22	9.00	82.41	46.00	8.84	88.48	85.44	

	12	52.10	8.00	73.26	36.10	8.00	80.08	76.67	
	16	46.00	7.00	64.10	29.00	7.00	70.07	67.08	
MTU-7029	0	51.86	9.00		40.88	8.00			66.72
	4	49.00	8.02	89.11	34.01	6.99	87.37	88.24	
	8	42.06	7.00	77.77	30.98	6.00	75.00	76.38	
	12	34.64	6.03	67.00	23.81	4.01	50.12	58.56	
	16	27.00	4.20	46.66	20.00	3.26	40.75	43.70	
Pusa Sugandh-5	0	52.10	9.20		39.64	8.20			69.12
	4	50.00	8.33	90.54	38.00	7.10	86.58	88.56	
	8	41.43	7.00	76.08	33.67	6.67	81.34	78.71	
	12	32.31	6.44	70.00	26.00	5.00	60.97	65.48	
	16	26.00	4.34	47.17	20.52	3.31	4036	43.76	
Jyotrirmayee	0	66.00	11.88		57.00	10.83			76.30
	4	64.88	11.00	92.59	52.76	9.41	86.88	89.73	
	8	56.81	10.00	84.17	45.57	8.02	74.05	79.11	
	12	50.06	8.02	67.50	36.21	8.00	73.86	70.68	
	16	40.28	7.00	58.92	29.00	7.80	72.02	65.80	
Badami	0	69.33	12.00		60.20	10.92			78.90
	4	67.21	11.00	91.66	55.33	10.00	91.57	91.61	
	8	60.00	10.00	83.33	47.21	9.00	82.41	82.87	
	12	55.38	8.30	69.16	38.00	8.00	73.26	71.21	
	16	43.00	7.88	65.66	32.00	8.10	74.17	69.91	

Fig.4 Effect of rice varieties on seedling growth under salinity stress

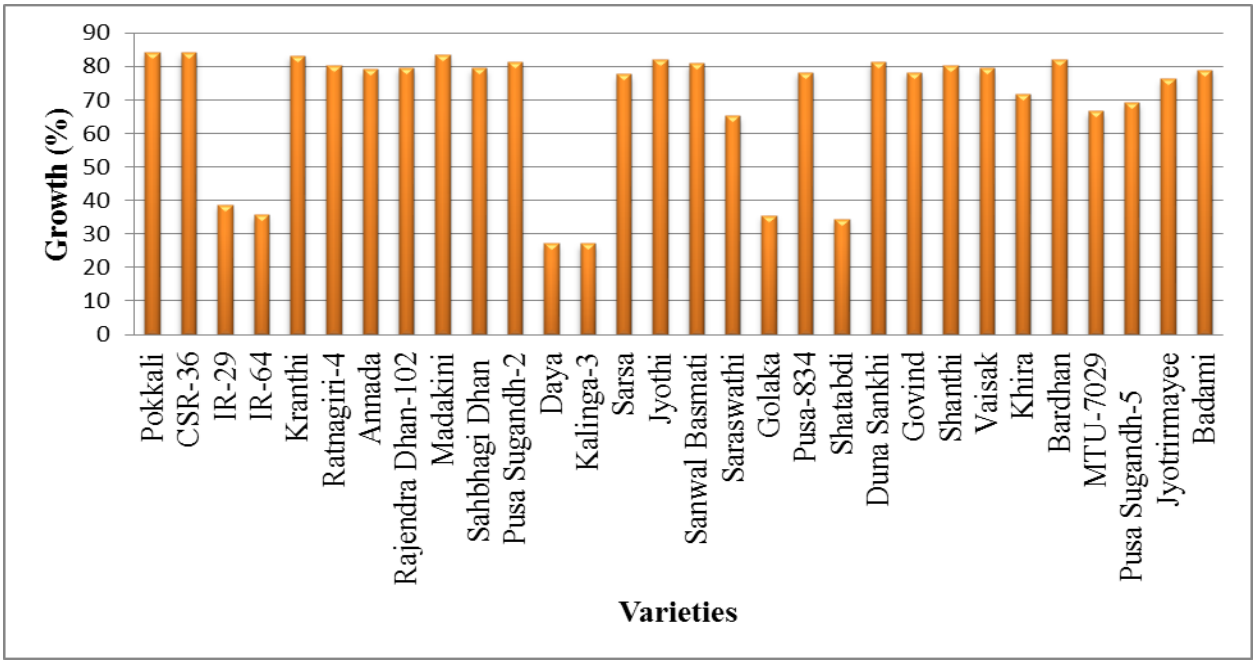
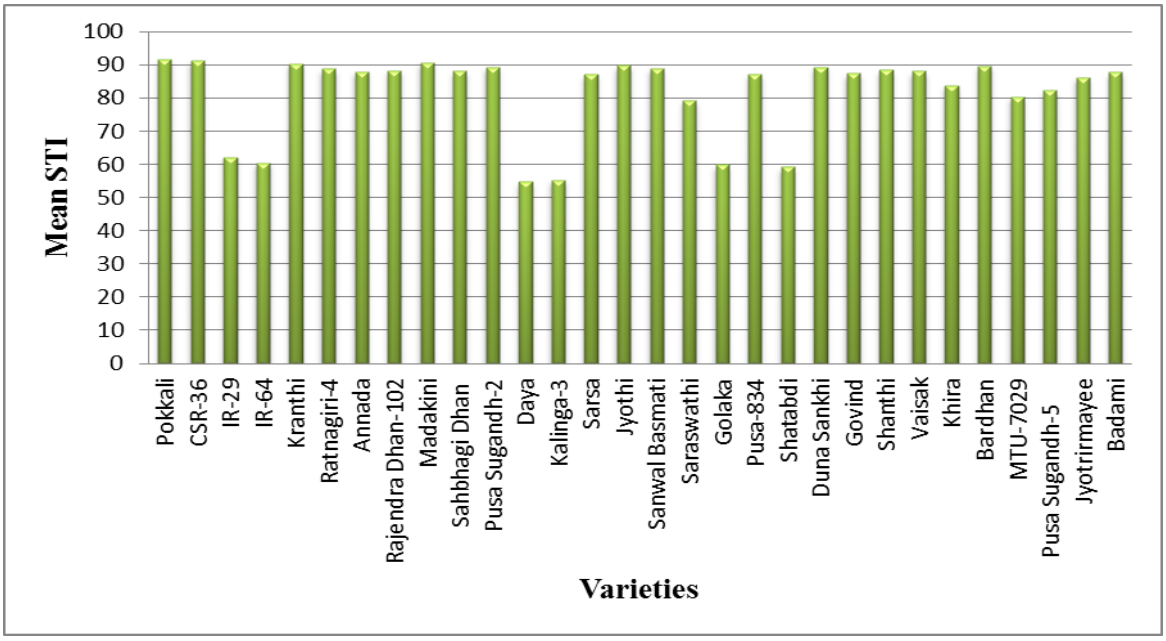


Fig.5 Mean STI of rice varieties based on *in vitro* seed germination and seedling growth (shoot and root dry weight) under salt stress



Seedling growth under salt stress

Seedling of all thirty selected varieties was grown at different salinity levels (0, 4, 8 and 16 dS m^{-1}). The seedling growth was inversely proportional to the salt concentrations. The root growth was more affected than the shoot growth. The fresh and dry weights of seedling were measured to evaluate the seedling growth under different salt stress. Salinity tolerance index (STI) was calculated based on shoot and root dry weights at different levels of salt stresses of all selected thirty varieties. STI based on shoot growth was higher than that of root growth at all concentrations of salt indicating the former being less affected than the later under salt stress (Table 4 and 5). Variety Pokkali showed the highest mean salt tolerance index (STI) of 84.21% followed by varieties CSR-36 (84.11%), Mandakini (83.42%), Kranthi (83.14%), Jyothi (82.16%), Bardhan (82.04%), Pusa Sugandh-2 (81.42%), Duna Sankhi (81.20%), Sanwal Basmati (80.80%), Ratnagiri-4 (80.41%), Shanthi (80.11%), Rajendra Dhan-102 (79.56%), Sahbhagi Dhan (79.49%), Vaisak (79.42%), Annada (79.13%), Badami (78.90%), Pusa-834 (78.27%), Govind (78.27%), Sarsa (77.72%), Jyotrirmayee (76.30%), Khira (71.84%), Pusa Sugandh-5 (69.12%), MTU-7029 (66.72%), Saraswathi (65.24%), IR-29 (38.74%), IR-64 (35.66%), Golaka (35.48%), Shatabdi (34.47%), Kalinga-3 (27.17%) and Daya (27.12%) respectively (Figure 4 and Table 4 and 5). Finally, the thirty selected rice varietiess were ranked for their salt tolerance level on their mean salinity tolerance index (STI) based on *in vitro* seed germination and seedling growth (shoot and root dry weight) under salt stress. Variety Pokkali showed the highest mean salt tolerance index (STI) of 91.54% followed by varieties CSR-36 (91.20%), Mandakini (90.69%), Kranthi (90.37%), Jyothi (89.82%), Bardhan (89.70%), Pusa Sugandh-2 (89.38%), Duna Sankhi (89.25%), Sanwal Basmati (88.94%), Ratnagiri-4 (88.71%), Shanthi (88.49%), Rajendra Dhan-102 (88.20%), Sahbhagi Dhan (88.16%), Vaisak (88.12%), Annada (87.94%), Badami (87.80%), Govind (87.36%), Pusa-834 (87.24%), Sarsa (87.07%), Jyotrirmayee (86.22%) and can be considered as salt tolerant while Daya

showed the least mean salt tolerance index (STI) of 54.82% followed by Kalinga-3 (55.27%), Golaka (59.99%), Shatabdi (59.21%), IR-64 (60.46%), IR-29 (62.21%) and can be considered as salt susceptible.

The other varieties Khira, Pusa Sugandh-5, MTU-7029 and Saraswathi with mean STI of 83.85%, 82.26%, 80.37% and 79.42% respectively and can be considered as moderately tolerant (Figure 5).

Seedling survival and growth were also important indicator of the salt tolerance of a cultivar (Garg *et al*., 1996). As observed with seed germination, seedling growth was also adversely affected with the increase of salt concentration. The root growth was more affected than shoot growth. A similar observation on adverse effect on seedling growth due to salt stress and root growth being more affected than shoot growth was observed in rice (Welfare *et al*., 1996; Vibhuti *et al*., 2015; Kumari *et al*., 2016). Adverse effect of salinity on seedling growth of rice has also been reported by Djanaguiraman *et al*. (2003) and Hakim *et al*. (2010). The adverse effect of salt stress is reflected in the dry matter accumulation of the seedling. Thus the dry matter accumulation of seedling shoot and root indicated by their dry weight can be used as an index to measure the salinity tolerance of the cultivar.

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