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COMPARATIVE STUDY OF AGRONOMIC TRAITS OF DIFFERENT RICE VARIETIES GROWN UNDER SALINE AND NORMAL CONDITIONS.

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ABSTRACT

Salinity is a major abiotic stress limiting rice production worldwide. Identification of genotypes with better salt tolerance can promise sustained crop yields in salt affected areas. In the present research, 24 rice varieties were evaluated by conducting field trials under natural saline condition (salinity block) and normal field condition in 2010 and 2011. Pokkali, Basmati 198 and Sathra 278 were categorized as salt tolerant varieties; whereas IR36, Shaheen Basmati, Basmati 2000, Basmati 370, Basmati 6129, IR-6, KSK-133, TN-1, IRP-2 were categorized as salt susceptible varieties based on grain yield data of 2010 and 2011 field trials. Significant positive correlations of morphological traits {number of total tillers/plant, number of effective tillers/plant, panicle length, panicle weight, number of spikelets/panicle, number of grains/panicle, panicle fertility (%)} with grain yield were found under saline conditions in both years field trials. It was observed in both year field trials, under normal field conditions, days to 50% flowering and days to maturity had highly significant negative correlation with grain yield/plant, whereas under saline conditions these traits had non-significant negative correlation. During stress conditions, rice cultivars with early flowering time under normal conditions had comparative advantage under saline conditions. These cultivars had better balance between vegetative and reproductive phase, resulting in better grain yield/plant under stress conditions. Thus days to 50% flowering is an important selection criterion for salt tolerance in rice.

Key words:

INTRODUCTION

Rice is one of the most important cereals and is a major source of food for large number of the people worldwide. It is planted on about one-tenth of the earth's arable land. It is the single largest source of food energy to more than half of the world population (Ammar *et al*., 2007). It is the dominant staple food of Asia, accounting for more than 70% of caloric intake. Most of the rice in the world is grown and consumed in Asia (Khush & Brar, 2002).

Rice production is affected by many biotic and abiotic stresses throughout the world, among which abiotic stress alone contributes to about 50% of the total yield losses. Among the abiotic stresses soil/water salinity is considered one of the major and prevalent stresses limiting rice production in the world (Ren *et al*., 2010). Approximately 30% of the total irrigated land worldwide is salt-affected (Rengasamy, 2006) and that limits the total rice production in the planet. The saline area is still increasing as a consequence of irrigation or land clearing (Ammar *et al*., 2007). Furthermore, World population is increasing day by day. To combat with the increasing population it is becoming essential to utilize these saline soils either by reclamation of salinity or by growing salt tolerant plants (Saeed *et al*., 2012). Reclamation of salinity is difficult and expensive, and not the permanent solution of the problem. Introduction of salt-tolerant variety is the realistic approach to obtain better yield under saline conditions (Ashraf *et al*., 2008; Saeed *et al*., 2012).

Number of plant traits has been found associated with sustained yield under stress conditions. Some researchers have focused on the plant reproductive physiology with respect to plant yield (Mohammadi-Nejad, 2010). Flowering time is an important trait, as it marks the initiation of reproductive stage of the plants. In cereals and other crops where seed is of importance with respect to economic yield, proper and timely start of the reproductive stage and adequate period for grain filling ensures better yield. It is very crucial to select rice varieties that have a greater tolerance to salts for growing in an area where salinity is a problem. The rice varieties having salt tolerance characteristic may be chosen for cultivation in saline areas. Moreover, information about salt tolerance of different rice varieties would be useful for rice breeding programme. Limited research work was conducted on screening of different Pakistani rice varieties based on salinity tolerance and agronomic characterization of salt tolerant varieties.

The present study aimed to screen out the salt tolerant rice varieties by evaluating grain yield performance of different rice varieties grown under saline and normal condition, agronomic characterization of salt tolerant varieties, and to study genotypic differences with respect to salinity tolerance in rice.

MATERIALS AND METHODS

Plant material: Seeds of 24 rice varieties/lines were collected from Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan. List of rice varieties/lines are shown in Table 1.

Salinity Blocks: Two salinity blocks were constructed to escape the experimental error and to obtain accurate results. Salinity blocks (each of 40 feet X 20 feet X 5 feet) with glass roofs were constructed so that glass roofs would not create any hindrance in light reception and dilution of salt by rainfall could be avoided. Soil was collected from saline areas of District Sheikhupura, Punjab, Pakistan having electrical conductivity of 6-9 ds/m and used in the salinity blocks. Leaching, percolation and surface runoff of soil water were strictly controlled so that electrical conductivity remained constant.

Transplantation of seedling: Transplantation of seedlings in salinity block and normal field were designed as split plot design with three replications. Salinity block and normal field were taken as main plots, while genotypes were assigned to subplots. A total of seventy two (variety 24 X replication 3) experimental units were prepared in both salinity block and normal field. Each experimental unit size was 0.63 squares meter and contained 9 seedlings with spacing of 22.8 cm × 30.5 cm. Thirty days old seedlings of each variety/line grown in two large plastic pots were uprooted carefully and transplanted in both salinity block and normal field on June 25, 2010 and July 1, 2011 at a hill spacing of 22.8 cm × 30.5 cm with one seedling per hill.

Agronomic traits measurement and data analysis: Data regarding all studied agronomic traits except 50% flowering were collected at maturity stage and only days to 50% flowering trait was recorded at 50% flowering stage of each rice plant grown under saline and normal field condition. Data collected from nine plants of each rice variety for each replication was made average and thus data were collected for each rice variety for 3 replications. Agronomic traits for which data were collected were plant height, number of tillers/plant, number of effective tillers/plant, panicle weight, panicle length, number of spikelets/panicle, number of unfilled grains/panicle, number of grains/panicle, panicle fertility (%), days to 50% flowering, days to maturity, grain length, grain width, grain length-width ratio, 1000 grain weight, grain yield/plant, straw yield/plant and harvest index (%).

RESULTS

All 24 rice varieties grown in 2010 and 2011 under saline and normal conditions were assessed and categorized based on salinity tolerance performing comparative study of grain yield under normal and saline conditions using t-test: two sample assuming equal variances (Table 3). Similar results were obtained in both years field trial. All 24 rice varieties were classified into four categories- salt tolerant, moderately salt tolerant, moderately salt susceptible and salt susceptible. Pokkali, Basmati 198 and Sathra 278 were categorized as salt tolerant varieties; Super Basmati, Basmati 385, SRI-8, SRI-12, SHP were categorized as moderately salt tolerant varieties; Pak Basmati, Super Kernal, PB-95, B-515, KS-282, IRP-1, SN 4365 were categorized as moderately salt susceptible varieties, and IR36, Shaheen Basmati, Basmati 2000, Basmati 370, Basmati 6129, IR-6, KSK-133, TN-1, IRP-2 were categorized as salt susceptible varieties.

In 2010 and 2011 field trial, analysis of variance showed that considerable differences (mostly very highly significant) occurred for salt, genotypes, and salt × genotype interactions for all the traits except panicle length, days to 50% flowering, days to maturity, grain width and grain length/width ratio, for which there were non-significant differences for salt × genotype interactions treatment indicating that salt × genotype interactions affected these parameters a little (Table 4).

Number of effective tillers/plant, panicle weight, grain width, grain yield and harvest index showed very highly significant ($P > 0.001$) differences for salt treatment in 2010, whereas in 2011 number of effective tillers/plant and grain yield showed highly significant; panicle weight, grain width and harvest index showed significant differences for salt treatment (Table 4).

In 2010 field trial, number of total tillers/plant, number of effective tillers/plant, panicle length, panicle weight, number of spikelets/panicle, number of grains/panicle and panicle fertility (%) showed positive correlation with grain yield/plant under saline conditions (Table 5). Under normal field conditions, days to 50% flowering and days to maturity had significant negative correlation with grain yield/plant (r = -0.418; $P \leq 0.05$) whereas under saline conditions these traits had non-significant negative correlation (r = -0.094; $P > 0.05$) [Table 5]. Under saline conditions, number of unfilled grains/panicle had significant negative correlation with grain yield/plant (r = -0.256; $P \leq 0.05$). The trait which had significant positive correlation with grain yield/plant under normal conditions but became non-significant under saline conditions was 1000 grain weight (Table 5). Plant height had highly significant correlation with days to 50% flowering and days to maturity under saline conditions (r = 0.322 and 0.3219; $P \leq 0.01$), whereas its correlation with these traits under normal field conditions was non-significant (r = 0.2025; P > 0.05) [Table 5]. Days to 50% flowering and days to maturity had positive correlation with number of total tillers/plant, number of effective tillers/plant and number of unfilled grains/panicle under saline conditions whereas under normal field conditions, the correlation was negative. Panicle weight and panicle fertility (%) had significant negative correlation and non-significant negative correlation, respectively with days to 50% flowering and days to maturity under saline conditions, whereas under normal field conditions this correlation was significant negative and non-significant positive, respectively (Table 5). Grain yield had highly significant positive correlation (r = 0.601; P > 0.01) and significant positive correlation (r = 0.485; P > 0.05) with harvest index under normal and saline condition, respectively. Plant height had significant negative correlation (r = -0.465; P > 0.05) with harvest index under normal condition, whereas under saline condition the correlation was non-significant.

Table 1 List of rice varieties/lines used in this study

Sl. No.	Variety	Origin
1	IR 36	International Rice Research Institute, Philippines
2	Pokkali	Kerala Agricultural University, India
3	Shaheen Basmati	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
4	Basmati 2000	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
5	Basmati 198	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
6	Super Basmati	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
7	Pak Basmati	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
8	Basmati 370	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
9	Basmati 385	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
10	Super Kernal	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
11	PB-95	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
12	B-515	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
13	Basmati 6129	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
14	IR-6	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
15	KS-282	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
16	KSK-133	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
17	Sathra 278	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
18	TN-1	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
19	SRI-8	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
20	SRI-12	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
21	SHP	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
22	IRP-1	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
23	IRP-2	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan
24	SN 4365	Rice Research Institute, Kala Shah Kaku, Lahore, Pakistan

Table 2 Soil analysis report of salinity block and the normal field in 2010 and 2011

Parameter	2010		2011	
	Soil sample collected from salinity block	Soil sample collected from normal field	Soil sample collected from salinity block	Soil sample collected from normal field
EC (dS/m)	7.6	2.1	7.5	2.3
Available Sodium (mg/kg or ppm)	4200	460	4120	450
Available Potassiumm (mg/kg or ppm)	120	100	123	101
Available Calcium (mg/kg or ppm)	120	65	115	62
Available Phosphorus (mg/kg or ppm)	12.0	8.0	12.5	8.8
PH	8.2	7.8	8.2	8.0
Organic matter (%)	0.40	0.70	0.40	0.70
Saturation (%)	41	41	41	41
Texture	Loam	Loam	Loam	Loam

In 2010 field trial, number of total tillers/plant, number of effective tillers/plant, panicle length, panicle weight, number of spikelets/panicle, number of grains/panicle, panicle fertility (%) and harvest index showed significant positive correlation, and number of unfilled grain/panicle and grain length-width ratio showed non-significant negative correlation with grain yield/plant under both normal and saline conditions (Table 5). Under normal field conditions, days to 50% flowering and days to maturity had highly significant negative correlation with grain yield/plant (r = -0.418; $P \leq 0.01$) whereas under saline conditions these traits had non-significant negative correlation (r = 0.094; $P > 0.05$) (Table 5). Under saline condition plant height, grain length, grain width and straw yield showed non-significant positive correlation with grain yield/plant whereas under normal condition these traits had non-significant negative correlation (Table 5). The trait which had significant positive correlation with grain yield/plant (r = 0.434; $P \leq 0.05$) under normal conditions but became non-significant under saline conditions was 1000 grain weight (Table 5).

In 2011 field trial, plant height, number of total tillers/plant, number of effective tillers/plant, panicle length, panicle weight, number of spikelets/panicle, number of grains/panicle and panicle fertility (%) showed positive correlation with grain yield/plant under saline conditions (Table 6). Under normal field conditions, days to 50% flowering and days to maturity had highly significant negative correlation with grain yield/plant (r = -0.3195; $P \leq 0.01$) whereas under saline conditions these traits had non-significant negative correlation (r = 0.0752; $P > 0.05$) (Table 6). Under saline conditions, number of unfilled grains/panicle had significant negative correlation with grain yield/plant (r = -0.2428; $P \leq 0.05$). The trait which had significant positive correlation with grain yield/plant under normal conditions but became non-significant under saline conditions was 1000 grain weight (Table 6). Plant height had highly significant correlation with days to 50% flowering and days to maturity under saline conditions (r = 0.322 and 0.3219; $P \leq 0.01$), whereas its correlation with these traits under normal field conditions was non-significant (r = 0.2025; $P > 0.05$) [Table 6]. Plant height also had significant positive correlation with grain yield under saline conditions, whereas under normal field conditions it had negative correlation with grain yield. Days to 50% flowering and days to maturity had significant or highly significant positive correlation with number of total tillers/plant, number of effective tillers/plant and number of unfilled grains/panicle under saline conditions whereas under normal field conditions, the correlation was negative. Panicle weight and panicle fertility (%) had highly significant negative correlation with days to 50% flowering and days to maturity under saline conditions, whereas under normal field conditions this correlation was highly significant negative and non-significant, respectively (Table 6).

Panicle weight (r = 0.3519; $P \leq 0.01$) showed highly significant positive correlation with grain yield under normal condition in 2011, whereas it showed non-significant positive correlation in 2010 (Table 5 and Table 6). In 2011, Number of unfilled grains/panicle (r = -0.2428; $P \leq 0.05$) showed significant negative correlation with grain yield under saline condition, whereas in 2010, it showed non-significant negative correlation (Table 5 and Table 6). Plant height showed negative and positive non-significant correlation with grain yield under normal and saline condition, respectively in 2010, whereas in 2011 that trait showed negative non-significant and positive significant (r = 0.2551; $P \leq 0.05$) correlation with grain yield under normal and saline condition, respectively (Table 5 and Table 6). It indicated that correlation between plant height and grain yield was not confirmed by obtaining similar result in both years field trial under saline condition.

Table 3 Mean values for grain yield of rice varieties grown in 2010 and 2011 under normal and saline condition

Name of the variety	2010				2011			
	Grain yield (g/plant)			Status of salt tolerance	Grain yield (g/plant)			Status of salt tolerance
	Normal	Saline	Mean difference		Normal	Saline	Mean difference	
IR 36	38.48	19.85	18.63***	Salt susceptible	39.68	20.55	19.13***	Salt susceptible
Pokkali	29.77	28.68	1.08^{NS}	Salt tolerant	30.97	29.38	1.58^{NS}	Salt tolerant
Shaheen Basmati	37.99	18.15	19.84***	Salt susceptible	39.19	18.85	20.34***	Salt susceptible
Basmati 2000	47.71	13.43	34.28***	Salt susceptible	48.91	14.13	34.78***	Salt susceptible
Basmati 198	33.60	31.35	2.24^{NS}	Salt tolerant	34.80	32.05	2.74^{NS}	Salt tolerant
Super Basmati	42.41	34.16	8.24*	Moderately salt tolerant	43.61	34.86	8.74*	Moderately salt tolerant
Pak Basmati	30.11	19.99	10.12**	Moderately salt susceptible	31.31	20.69	10.62**	Moderately salt susceptible
Basmati 370	21.91	8.45	13.45***	Salt susceptible	23.11	9.15	13.95***	Salt susceptible
Basmati 385	43.10	33.19	9.91*	Moderately salt	44.40	33.99	10.41*	Moderately salt

				tolerant				tolerant
Super Kernal	25.11	12.46	12.65**	Moderately salt susceptible	26.41	13.26	13.15**	Moderately salt susceptible
PB-95	29.19	11.74	17.45**	Moderately salt susceptible	30.49	12.54	17.95**	Moderately salt susceptible
B-515	59.56	47.60	11.97**	Moderately salt susceptible	60.86	48.40	12.47**	Moderately salt susceptible
Basmati 6129	38.19	18.49	19.70***	Salt susceptible	39.49	19.29	20.20***	Salt susceptible
IR-6	56.77	17.58	39.19***	Salt susceptible	58.07	18.38	39.69***	Salt susceptible
KS-282	59.60	21.12	38.49**	Moderately salt susceptible	60.90	21.92	38.99**	Moderately salt susceptible
KSK-133	64.00	20.97	43.02***	Salt susceptible	65.30	21.77	43.52***	Salt susceptible
Sathra 278	14.29	12.43	1.87^{NS}	Salt tolerant	15.54	13.18	2.37^{NS}	Salt tolerant
TN-1	13.91	4.34	9.56***	Salt susceptible	15.16	5.09	10.06***	Salt susceptible
SRI-8	28.22	21.74	6.48*	Moderately salt tolerant	29.47	22.49	6.98*	Moderately salt tolerant
SRI-12	28.78	20.94	7.84*	Moderately salt tolerant	30.03	21.69	8.34*	Moderately salt tolerant
SHP	37.95	29.17	8.78*	Moderately salt tolerant	39.20	29.92	9.28*	Moderately salt tolerant
IRP-1	22.96	17.62	5.34**	Moderately salt susceptible	24.21	18.37	5.84**	Moderately salt susceptible
IRP-2	35.33	9.46	25.87***	Salt susceptible	36.58	10.21	26.37***	Salt susceptible
SN 4365	6.83	3.74	3.09**	Moderately salt susceptible	8.08	4.49	3.59**	Moderately salt susceptible

NS = non-significant; * = significant ($P \leq 0.05$); ** = highly significant ($P \leq 0.01$);
*** = very highly significant ($P \leq 0.001$)

Table 4 Analysis of variance estimates for morphological and yield traits of 24 rice varieties grown in 2010 and 2011 under normal versus saline conditions

	2010			2011		
Source of variation/Trait	**Genotype**	**Salt**	**Genotype X Salt**	**Genotype**	**Salt**	**Genotype X Salt**
Plant height (cm)	3267.959***	13670.48***	482.6712***	3269.5359***	13244.174***	484.3330***
No. of total tillers /plant	43.93448***	302.1803***	35.2896***	43.9345***	291.8403**	35.2896***
No. of effective tillers /plant	41.61564***	256.5336***	22.97796***	41.6156***	212.6736**	24.0649***
Panicle length (cm)	115.8603***	172.4844***	3.187198NS	115.5060***	117.3611***	5.2742NS
Panicle weight (g)	4.756948***	0.81***	0.026438***	4.7641***	0.7526*	0.0266***
Number of spikelets/ panicle	6202.792***	12731.36***	367.2162***	6139.1582***	12506.694***	376.9843***
Number of unfilled grains/panicle	621.7669***	3481***	389.4638***	621.7669***	2809***	389.4638***
Number of grains/panicle	6065.293***	29526.69***	660.5785***	5995.8261***	27170.028***	672.6944***
Panicle fertility (%)	487.5082***	5118.736***	296.7244***	450.7969***	4012.7798***	269.8470***
Days to 50% flowering	384.8068***	1024***	1.347826NS	384.8068***	196***	1.3478NS
Days to maturity	384.8068***	1024***	1.347826NS	384.8068***	196***	1.3478NS
Grain Length (mm)	7.482382***	6.084444***	0.021271*	7.4824***	5.5068***	0.0212*
Grain Width (mm)	0.640941***	1.120069***	0.003019NS	0.6409***	0.9967*	0.0030NS
Grain Length-Width ratio	4.307817***	0.968397***	0.024478NS	4.0139***	0.7178***	0.0216NS
1000 Grain Weight (g)	37.89383***	54.80934***	0.267314***	37.8938***	59.3413***	0.2673***
Grain Yield (g/plant)	750.4129***	8514.436***	231.0049***	762.7072***	8238.4102**	252.3910***
Straw Yield (g/plant)	66762.85***	148456.3***	17909.83***	67339.588***	126849.25***	19244.479***
Harvest index (%)	3948.52***	338.8097***	10.6454NS	3619.8146***	306.8930*	7.8321NS

NS = non-significant; * = significant ($P < 0.05$); ** = highly significant ($P < 0.01$);
*** = very highly significant ($P < 0.001$)

Table 5 Correlation coefficients for morphological and yield traits of rice varieties grown in 2010 under normal versus saline conditions

	TTP	*ETP*	*PaL*	*PaW*	*SpPa*	*UfGPa*	*GPa*	*PaF*	*DFF*	*DM*	*GL*	*GW*	*GL-W R*	*1000 GW*	*GY*	*SY*	*HI*
	-0.169^{NS}	-0.355^{NS}	0.307^{NS}	0.202^{NS}	0.164^{NS}	0.380^{NS}	0.104^{NS}	-0.267^{NS}	0.217^{NS}	0.217^{NS}	-0.247^{NS}	0.314^{NS}	-0.369^{NS}	0.257^{NS}	-0.097^{NS}	0.383^{NS}	-0.465*
PH	0.361^{NS}	0.147^{NS}	0.636***	0.324^{NS}	0.441*	0.423*	0.227^{NS}	-0.220^{NS}	0.297^{NS}	0.297^{NS}	-0.217^{NS}	0.326^{NS}	-0.423*	0.148^{NS}	0.245^{NS}	0.760***	-0.354^{NS}
		0.941***	0.213^{NS}	0.125^{NS}	0.405*	-0.251^{NS}	0.461*	0.476*	-0.338^{NS}	-0.338^{NS}	-0.128^{NS}	-0.239^{NS}	0.033^{NS}	0.203^{NS}	0.909***	-0.116^{NS}	0.574**
TTP	1	0.823***	0.315^{NS}	0.144^{NS}	0.434*	0.157^{NS}	0.345^{NS}	0.023^{NS}	0.201^{NS}	0.201^{NS}	-0.171^{NS}	-0.086^{NS}	-0.061^{NS}	-0.344^{NS}	0.514**	0.500*	-0.087^{NS}
			0.105^{NS}	0.019^{NS}	0.243^{NS}	-0.239^{NS}	0.292^{NS}	0.411*	-0.349^{NS}	-0.349^{NS}	-0.106^{NS}	-0.207^{NS}	0.020^{NS}	0.189^{NS}	0.834***	-0.128^{NS}	0.580**
ETP		1	0.106^{NS}	-0.096^{NS}	0.198^{NS}	0.159^{NS}	0.116^{NS}	-0.053^{NS}	0.280^{NS}	0.280^{NS}	0.105^{NS}	-0.075^{NS}	0.125^{NS}	-0.214^{NS}	0.446*	0.242^{NS}	0.175^{NS}
				0.533**	0.741***	0.198^{NS}	0.731***	0.236^{NS}	0.040^{NS}	0.040^{NS}	0.076^{NS}	-0.013^{NS}	-0.003^{NS}	0.326^{NS}	0.453*	0.240^{NS}	0.138^{NS}
PaL			1	0.588**	0.753***	0.198^{NS}	0.631***	0.100^{NS}	0.002^{NS}	0.002^{NS}	0.002^{NS}	0.080^{NS}	-0.114^{NS}	0.327^{NS}	0.622***	0.338^{NS}	0.112^{NS}
					0.611**	0.535**	0.539**	-0.197^{NS}	-0.434*	-0.434*	-0.185^{NS}	0.430*	-0.460*	0.352^{NS}	0.341^{NS}	-0.115^{NS}	0.245^{NS}
PaW				1	0.741***	-0.082^{NS}	0.751***	0.369^{NS}	-0.420*	-0.420*	-0.194^{NS}	0.417*	-0.458*	0.387^{NS}	0.663***	0.165^{NS}	0.238^{NS}
						0.267^{NS}	0.986***	0.328^{NS}	0.050^{NS}	0.050^{NS}	-0.195^{NS}	0.084^{NS}	-0.230^{NS}	0.095^{NS}	0.619**	0.128^{NS}	0.288^{NS}
SpPa					1	0.162^{NS}	0.887***	0.223^{NS}	-0.021^{NS}	-0.021^{NS}	-0.177^{NS}	0.196^{NS}	-0.295^{NS}	0.044^{NS}	0.806***	0.344^{NS}	0.248^{NS}
							0.105^{NS}	-0.780***	-0.091^{NS}	-0.091^{NS}	-0.512**	0.583**	-0.736***	0.013^{NS}	-0.170^{NS}	0.246^{NS}	-0.300^{NS}
UfGPa						1	-0.313^{NS}	-0.890***	0.366^{NS}	0.366^{NS}	-0.298^{NS}	0.179^{NS}	-0.379^{NS}	-0.131^{NS}	-0.256^{NS}	0.637***	-0.350^{NS}
								0.472*	0.067^{NS}	0.067^{NS}	-0.113^{NS}	-0.013^{NS}	-0.112^{NS}	0.096^{NS}	0.668***	0.090^{NS}	0.349^{NS}
GPa							1	0.631***	-0.191^{NS}	-0.191^{NS}	-0.031^{NS}	0.105^{NS}	-0.107^{NS}	0.103^{NS}	0.896***	0.033^{NS}	0.403*
									0.167^{NS}	0.167^{NS}	0.311^{NS}	-0.490*	0.524**	0.110^{NS}	0.542**	-0.125^{NS}	0.426*
PaF								1	-0.365^{NS}	-0.365^{NS}	0.213^{NS}	-0.079^{NS}	0.245^{NS}	0.243^{NS}	0.551**	-0.460*	0.435*
										1***	0.272^{NS}	0.016^{NS}	0.191^{NS}	-0.255^{NS}	-0.418*	0.442*	-0.343^{NS}
DFF									1	1***	0.299^{NS}	0.065^{NS}	0.183^{NS}	-0.182^{NS}	-0.094^{NS}	0.452*	-0.361^{NS}
											0.272^{NS}	0.016^{NS}	0.191^{NS}	-0.255^{NS}	-0.418*	0.442*	-0.343^{NS}
DM										1	0.299^{NS}	0.065^{NS}	0.183^{NS}	-0.182^{NS}	-0.094^{NS}	0.452*	-0.361^{NS}
												-0.058^{NS}	0.726***	0.182^{NS}	-0.092^{NS}	-0.302^{NS}	0.304^{NS}
GL											1	0.014^{NS}	0.723***	0.202^{NS}	0.123^{NS}	-0.393^{NS}	0.314^{NS}
													-0.708***	0.371^{NS}	-0.082^{NS}	0.098^{NS}	-0.071^{NS}
GW												1	-0.659***	0.379^{NS}	0.170^{NS}	0.220^{NS}	-0.050^{NS}
														-0.137^{NS}	-0.067^{NS}	-0.308^{NS}	0.223^{NS}
GL-W R													1	-0.113^{NS}	-0.039^{NS}	-0.449*	0.228^{NS}
															0.434*	-0.027^{NS}	0.168^{NS}
1000 GW														1	0.213^{NS}	-0.128^{NS}	0.221^{NS}
																-0.070^{NS}	0.601**
GY															1	0.040^{NS}	0.485*
																	-0.513**
SY																1	-0.660***

PH = plant height; *TTP* = No. of total tillers/plant; *ETP* = No. of effective tillers/plant; *PaL* = panicle length; *PaW* =panicle weight; *SpPa* = No. of spikelets/panicle; *UfGPa* = No. of unfilled grains/panicle; *GPa* = No. of grains/panicle;*PaF* = panicle fertility (%); *DFF* = days to 50% flowering; *DM* = days to maturity; *GL* = grain length; *GW* = grain width; *GL-W R* = grain length- width ratio; *1000 GW* = 1000 grain weight; *GY* = grain yield; *SY* = Straw yield; *HI* = harvest index (%); NS = non-significant; * = significant ($P < 0.05$); ** = highly significant ($P < 0.01$); Normal-sized font values = normal field; bold-sized font values = salinity block

Table 6 Correlation coefficients for morphological and yield traits of rice varieties grown in 2011 under normal versus saline conditions

	PH	*TTP*	*ETP*	*PaL*	*PaW*	*SpPa*	*UfGPa*	*GPa*	*PaF*	*DFF*	*DM*	*GL*	*GW*	*GL-W R*	*1000 GW*	*GY*
	-0.1541^{NS}															
TTP	0.3591**	1														
	-0.3429**	0.9408**														
ETP	0.1735^{NS}	0.8343**	1													
	0.2524*	0.2942*	0.1744^{NS}													
PaL	0.6683**	0.3241**	0.1542^{NS}	1												
	0.1979^{NS}	0.1339^{NS}	0.0165^{NS}	0.5052**												
PaW	0.3229**	0.1421^{NS}	0.0625^{NS}	0.5863**	1											
	0.1579^{NS}	0.4096**	0.2389*	0.7386**	0.6067**											
SpPa	0.4399**	0.4243**	0.2137^{NS}	0.7258**	0.7470**	1										
UfGP	0.3784**	-0.2001^{NS}	-0.2074^{NS}	0.2022^{NS}	0.5353**	0.2699*										
a	0.4249**	0.1600^{NS}	0.1709^{NS}	0.2301^{NS}	-0.0800^{NS}	0.1651^{NS}	1									
	0.0966^{NS}	0.4583**	0.2832*	0.7275**	0.5327**	0.9856**	0.1031^{NS}									
GPa	0.2238^{NS}	0.3335**	0.1254^{NS}	0.5909**	0.7573**	0.8857**	-0.3118**	1								
	-0.2495*	0.4475**	0.3880**	0.2758*	-0.1565^{NS}	0.3812**	-0.7412**	0.5241**								
PaF	-0.2325*	0.0104^{NS}	-0.0716^{NS}	0.0461^{NS}	0.3694**	0.2156^{NS}	-0.8953**	0.6292**	1							
	0.2025^{NS}	-0.3448**	-0.3172**	0.0585^{NS}	-0.4201**	0.0066^{NS}	-0.0480^{NS}	0.0152^{NS}	0.0997^{NS} -							
DFF	0.3220**	0.2374*	0.2701*	0.0248^{NS}	-0.4176**	0.0090^{NS}	0.3520**	-0.1570^{NS}	0.3452**	1						
	0.2025^{NS}	-0.3448**	-0.3172**	0.0585^{NS}	-0.4201**	0.0066^{NS}	-0.0480^{NS}	0.0152^{NS}	0.0997^{NS} -	1***						
DM	0.3219**	0.2374*	0.2701*	0.0248^{NS}	-0.4176**	0.0090^{NS}	0.3520**	-0.1570^{NS}	0.3452**	1***	1					
	-0.2426*	-0.1074^{NS}	-0.0681^{NS}	0.1239^{NS}	-0.1786^{NS}	-0.1876^{NS}	-0.4840**	-0.1088^{NS}	0.2659*	0.2929*	0.2929*					
GL	- 0.2136^{NS}	-0.1528^{NS}	0.0896^{NS}	-0.0128^{NS}	- 0.1915^{NS}	-0.1769^{NS}	-0.2939*	-0.0320^{NS}	0.2112^{NS}	0.2928*	0.2928*	1				
	0.3130**	-0.1808^{NS}	-0.1425^{NS}	0.0511^{NS}	0.4347**	0.0967^{NS}	0.5950**	-0.0047^{NS}	-0.4731** -	0.0532^{NS}	0.0532^{NS}	-0.0392^{NS}				
GW	0.3289**	-0.0593^{NS}	-0.0526^{NS}	0.1076^{NS}	0.4154**	0.2021^{NS}	0.1819^{NS}	0.1091^{NS}	0.0825^{NS}	0.0651^{NS}	0.0651^{NS}	0.0249^{NS}	1			
GL-	-0.3681**	0.0008^{NS}	-0.0028^{NS}	-0.0217^{NS}	-0.4622**	-0.2360*	-0.7329**	-0.1150^{NS}	0.4867**	0.1712^{NS}	0.1712^{NS}	0.7045**	-0.7140**			
W R	-0.4224**	-0.0695^{NS}	0.0925^{NS}	-0.1460^{NS}	-0.4561**	-0.3009*	-0.3785**	-0.1117^{NS}	0.2463*	0.1786^{NS}	0.1786^{NS}	0.7178**	-0.6569**	1		
1000	0.2573*	0.2146^{NS}	0.2041^{NS}	0.3372**	0.3586**	0.1040^{NS}	0.0295^{NS}	0.1023^{NS}	0.1091^{NS}	-0.2118^{NS}	-0.2118^{NS}	0.1872^{NS}	0.3791**	-0.1451^{NS}		
GW	0.1516^{NS}	-0.3236**	-0.2032^{NS}	0.3238**	0.3887**	0.0503^{NS}	-0.1275^{NS}	0.1084^{NS}	0.2351*	-0.2064^{NS}	-0.2064^{NS}	0.2066^{NS}	0.3837**	-0.1141^{NS}	1	
	-0.1355^{NS}	0.9103**	0.8485**	0.5066**	0.35186**	0.6171**	-0.1181^{NS}	0.6583**	0.5165**	-0.3195**	-0.3195** -	-0.0504^{NS}	-0.0182^{NS}	-0.0859^{NS}	0.4440**	
GY	0.2551*	0.5278**	0.4701**	0.6069**	0.6695**	0.8048**	-0.2428*	0.8896**	0.5340**	-0.0752^{NS}	0.0752^{NS}	0.1138^{NS}	0.1741^{NS}	-0.0517^{NS}	0.2088^{NS}	1
	-0.4694**	0.5830**	0.5927**	0.1909^{NS}	0.2591*	0.2985*	-0.2705*	0.3559**	0.4082**	-0.3578**	-0.3578**	0.3078**	-0.0451^{NS}	0.2034^{NS}	0.1791^{NS}	0.6272**
HI	-0.3605**	-0.0880^{NS}	0.1620^{NS}	0.0877^{NS}	0.2390*	0.2482*	-0.3540**	0.4058**	0.4360**	-0.3419**	-0.3419**	0.3207**	-0.0447^{NS}	0.2312^{NS}	0.2266^{NS}	0.4778**

PH = plant height; *TTP* = No. of total tillers/plant; *ETP* = No. of effective tillers/plant; *PaL* = panicle length; *PaW* =panicle weight; *SpPa* = No. of spikelets/panicle; *UfGPa* = No. of unfilled grains/panicle; *GPa* = No. of grains/panicle;*PaF* = panicle fertility (%); *DFF* = days to 50% flowering; *DM* = days to maturity; *GL* = grain length; *GW* = grain width; *GL-W R* = grain length- width ratio; *1000 GW* = 1000 grain weight; *GY* = grain yield; *HI* = harvest index (%); NS = non-significant; * = significant ($P < 0.05$); ** = highly significant ($P < 0.01$); Normal-sized font values = normal field; bold-sized font values = salinity block

DISCUSSION

Grain yield is a highly complex trait that can be divided into component characters, like number of tillers, number of effective tillers, panicle length, panicle weight, number of grains per panicle and thousand grain weight. Proper partitioning between vegetative and reproductive phases is also conducive for plant yield potential. A strong positive correlation was found between number of tillers per plant, panicle weight, and shoot biomass with plant yield (Shereen, *et al*., 2005; Chanyalew *et al*., 2006; Chanyalew *et al*., 2009). Moreover, plant yield is influenced directly or indirectly by a number of other agronomic characters, such as plant height, leaf area, dry-matter yield, heading date, lodging resistance, and proneness to shattering (Heidari *et al*., 2011; Saeed *et al*., 2011).

Zhou *et al*. (2010) reported that effective number of panicles per plant, plumped number of grains per panicle, total number of grains per panicle, 1000-grain weight and grain weight per plant were greatly affected by salt stress condition. Salinity stress caused a decrease in vegetative growth, yield and yield components of rice (Afifi *et al*., 2010). Similar work was conducted by Cha-um (2010). Grain yield of rice was reduced due to salinity stress (Clermont-Dauphin *et al*., 2010; Fitzgeralda *et al*., 2010). Salt tolerant varieties provided similar number of spikelet/panicle, number of unfilled grain/panicle, number of grain/panicle, panicle fertility, grain length, grain yield and straw yield compared to normal condition. Sterility or unfilled grain formation was less in salt tolerant varieties compared to other categories of rice varieties under saline condition and that was a cause to minimize grain yield reduction under salinity stress. It was reported by Bhowmik (2009) that plant height and total dry matter were reduced in salt susceptible varieties. Motamed (2008) reported that salinity adversely affected grain yield, number of tillers, filled and unfilled spikes, panicle fertility and 100 grain weight, but increased number of unfilled grain.

Proper partitioning between vegetative and reproductive phases is crucial in grain yield under stress conditions. Proper time for grain filling is ensured by the duration of grain filling period (Lobell *et al*., 2012). Flowering time adjustment is an important trait which plants incorporate in abiotic stress adaptation and tolerance by permitting enough time for grain filling. In some studies, effort was made to evaluate genotypic variation with respect to plants reproductive physiology and development and it was suggested that this variation might be used in attempts to enhance the resistance of rice to salinity (Mohammadi-Nejad, 2010). In cereals, reproductive stage is most important in yield determination. Flowering time adjustment gives plant appropriate time for grain filling stage. Cultivars which can adjust flowering time can tolerate abiotic stress conditions resulting in sustained yield. In the present study, the non-significant negative correlation of days to 50% flowering and days to maturity to grain yield/plant was found under salt treatment, whereas under normal field conditions highly significant negative correlation of these traits with grain yield/plant was observed in both 2010 and 2011 years field trials. It showed that under salinity stress the cultivars with early flowering time are at comparative advantage and their yield is not affected considerably under saline conditions. These cultivars have proper balance between the vegetative and reproductive phases which results in enough time for proper grain filling. Thus, days to 50% flowering is an important selection criterion in cereals with respect to salt stress tolerance. This trait can be employed in the development of elite salt tolerant rice cultivars. In future, efforts should be concentrated to explore the molecular mechanism underlying flowering time in cereals.

Pokkali, Basmati 198 and Sathra 278 were found as salt tolerant varieties and may be used to grow in saline areas. These varieties are also important sources to explore the molecular basis of salt tolerance in rice. Information regarding salt tolerance of different rice varieties will be helpful for rice breeding program.

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