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EFFECT OF SALINITY ON GROWTH, YIELD AND YIELD COMPONENTS IN BASMATI RICE GERMPLASM

ABID MAHMOOD[1*], TAHIR LATIF AND M. ARIF KHAN[2]

[1]Rice Research Institute, Kala Shah Kaku, Punjab, Pakistan
Barani Agricultural Research Institute, P.O. Box 35, Chakwal, Pakistan,
[2]Wheat Research Institute, Faisalabad, Pakistan.

Abstract

Salt tolerance of 4 commercial varieties and 17 breeding lines of Basmati rice (*Oryza sativa* L.) was assessed at early growth stage and at maturity in field plots artificially salinzed with NaCl and $CaCl_2$ (1:1 by weight). The average electrical conductivity (EC) of soil was 1.2, 5.2 and 10.5 dS m^{-1}. Forty-five days after sowing (20 days in saline or control conditions), shoot dry weights and sodium (Na) and potassium (K) contents of shoot were determined. At maturity, plant height, number of tillers per plant, panicle length, number of grains per panicle, 1000-grain weight, grain sterility, shoot dry weight, grain straw ratio and grain yield per plant were measured. There was significant variation between genotypes for all the characters studied. On an average, plant height, number of tillers per plant, panicle length, number of grains per panicle, shoot dry weight, grain straw ratio, grain yield per plant, K content of shoot and K/Na ratio were reduced linearly while grain sterility and Na content of shoot were increased with increasing soil salinity. With increased salinity, reduced number of grains per panicle was mainly found responsible for reduction in grain yield. Generally genotypes having ability to exclude Na from shoot were found salt tolerant in respect of grain yield and *vice versa*. Na contents of shoot and shoot dry weight 45 days after sowing (DAS) showed significant correlations with grain yield. It is suggested that selection for salinity tolerance in rice can be carried out at an early stage of growth.

Introduction

Salinity is a most serious and widespread agricultural problem. Among various strategies to overcome this problem, the possibility of selection and breeding for enhanced salinity tolerance in crop species has received considerable attention as it is an economic and efficient alternative (Toenniessen, 1984; Ashraf *et al*., 2008; Ashraf, 2009).

Existence of appropriate genetic variation is a prerequisite for the improvement of any character, through selection and breeding. Fortunately, diversity in salt tolerance at the intra specific level has been found in a considerable number of species, for example crested wheat grass (Dewey, 1962); soybean (Abel & Mackenzie, 1964, Cicek & Cakirlar, 2008); barley (Epstein & Norlyn, 1977); tall wheat grass (Shannon, 1978); triticale (Norlyn & Epstein, 1984); oats (Verma & Yadava, 1986); wheat (Ashraf & McNeilly, 1988); rice (Bari & Hamid 1988, Mishra *et al*., 2000, Zeng *et al*., 2002, Mahmood *et al*., 2004, Shaheen & Hood-Nowotny, 2005) and *Triticum tauschii* (Schachtman *et al*., 1991). Soil salinity is now recognized as an important problem in the rice growing area of Pakistan. As this part of Pakistan is one of the world best quality rice (Basmati) producing area, there is a keen interest in the development of rice varieties displaying resistance to the effects of salinity. Previous studies on salinity tolerance in Basmati rice are relatively few. To provide information about salinity tolerance, the studies were carried out in four varieties and seventeen breeding lines of Basmati rice, using saline field conditions.

*Corresponding author E-mail: abidm9@gmail.com

The objectives of these studies were to 1) determine the variability of Basmati rice in response to salinity tolerance, 2) to find out the relationship for salt tolerance at early stage of growth and at maturity and 3) the effect of salinity on grain and biomass yield.

Material and Methods

A field experiment was conducted over two cropping seasons in 2002 and 2003 at Rice Research Institute, Kala Shah Kaku, Pakistan on a clayey soil. The un-amended soil had clay: 76.2%; silt: 18.5%; sand: 5.1%; pH: 8.5% EC 1.2 dS m^{-1}; N: 0.051%; P: 8.5 mg kg^{-1}: K; 88mg kg^{-1} and Zn: 1.82mg kg^{-1}. Double polyethylene-lined, 42 x 2 x 0.5 m beds were prepared by digging out and filling in the same soil after proper lining of the bed. Three levels of soil salinity (ECe), with average of 1.2 (control), 5.2 and 10.5 dS m^{-1} (reference at 25°C), replicated three time, were established before transplanting the seedlings for each genotype by saturating the soil with artificially prepared saline water to which 0, 50 and 100 me/1 of NaCl and $CaCl_2$ were added in 1:1 ratio. Electrical conductivity of the saturated-soil extract was determined on soil samples taken fortnightly during the growing season each year. Samples were taken within the plant row in 0.10m increments to depth of 0.30m.

Seed of twenty-one genotypes (listed in Table 1) of Basmati rice (*Oryza sativa* L.) were obtained from the gene pool of Rice Research Institute, Kala Shah Kaku. Among these, four were commercial varieties namely Basmati-370, Basmati-385, Basmati-198 and Basmati-Pak and other seventeen were breeding lines. The experiment was laid out as a split plot design, with salinity as main plots and genotypes as sub-plots. There were three replications, giving 189 plots in total. The size of the plot was 2m x 2m. Seedlings of all genotypes were raised in small beds as a nursery (which is a normal practice in Pakistan). Nursery was planted on June 6 in 2002 and June 9 in 2003. Sixty-four, twenty-five days old seedlings of comparable size of each genotype were transferred into level plots, keeping plant to plant distance of 25 cm on each side. Fertilizers @ 102 kg N, 67 Kg P_2O_5 and 54 kg K ha^{-1} were applied before sowing in the form of urea, single superphosphate and potassium nitrate, respectively. All plots were irrigated identically by canal water having ECe 0.27 dS m^{-1}.

The range of weekly mean maximum temperature from nursery growing to crop maturity was 21.6 to 41.1°C in 2002 and 24.8 to 43.3°C in 2003. Minimum temperatures for the same period were 7.3 to 26.6°C and 8.7 to 27.1°C. The mean maximum and minimum temperatures were 32.7 and 21.1°C in 2002 and 33.9 and 22.5°C in 2003, respectively.

Fifteen seedlings were randomly sampled from each plot 20 days following transfer to salinized or control plots (at that time seedling age was 45 days). The harvested seedlings were dried at 80°C for two days and weighed for the determination of shoot dry weights. The dried seedlings then saved, after milling, for the determination of Na and K contents. For the determination of Na and K same procedure was adopted as described previously (Mahmood & Quarrie, 1993). At maturity, the data on agronomic traits like plant height, number of tillers per plant, panicle length, number of grains per panicle, grain yield per pant, 1000-grain weight, grain sterility percentage, shoot dry weight at maturity and grain straw ratio were recorded from 20 randomly selected plants of each plot.

Results

There were no notable differences between the results in 2002 and 2003, so the data were averaged for both years. Analysis of variance showed highly significant ($p<0.01$) differences among salinity treatments and genotypes for all parameters studied. Treatment x genotype interaction was also highly significant for all characters, except grain yield per plant, 1000-grain weight and K content.

Agronomic characters: The mean shoot dry weight 45DAS, plant height, number of tillers per plant, panicle length, number of grains per panicle, grain yield per plant, 1000-grain weight, grain sterility, shoot dry weight at maturity and grain straw ratio for the twenty-one Basmati rice genotype under three treatments of salinity are given in Table 1a and 1b. At 45DAS, the average shoot dry weight of control treatment was 13.3gm while 7.1 and 5.2gm shoot dry weights were obtained at 5.2 dS m^{-1} and 10.5 dS m^{-1}, respectively. At this stage of growth, under control conditions shoot dry weight varied from 18.6g to 6.9g. Just twenty days after salt treatment, over all shoot dry weight was reduced to about half at 5.2 dS m^{-1}. Bas, 370 produced the highest shoot dry weight and PK 33892 the lowest at 10.5 dS m^{-1}.

Increasing salinity reduced the height of plant. The average height of 103.6cm, 91.9cm and 82.7cm was recorded from control, 5.2 dS m^{-1} and 10.5 dS m^{-1}, respectively. Bas. Pak was the most affected genotype in respect of height which gave 72.4% of the control height while the least affected genotype was Bas. 198 by reducing just 8.1% height as compared to control at 10.5 dS m^{-1}. Basmati Pak produced the highest number of tillers per plant in control and 5.2 dS m^{-1} while PK 4048 produced maximum tillers at 10.5 dS m^{-1}. On an average, 13.7, 12.0 and 9.7 tillers per plant were obtained at control, 5.2 dS m^{-1} and 10.5 dS m^{-1}, respectively. On average of 21 genotypes, the panicle length was 91.2 and 85.7% of the control at 5.2 and 10.5 dS m^{-1}, respectively. Increased salinity significantly reduced the grain number per panicle. Over all mean grain number per panicle were 112.6, 61.7 and 52.0 in control, 5.2 dS m^{-1} and 10.5dS m^{-1} salinity levels, respectively. PK 49951 produced the highest number of grains per panicle while PK 33892 the lowest at all salinity levels. Bas. 370 and Bas. 385 were least affected while PK 49626 was most affected by salinity in respect of grain yield per plant. More than 75% and 50% of the control grain yield was obtained at 5.2 and 10.5 dS m^{-1}, respectively by both tolerant genotypes. On an average, 13.3g, 8.4g and 4.9g grain yield per plant was produced in control, 5.2 dS m^{-1} and 10.5 dS m^{-1}, respectively. Maximum grain yield under control conditions was produced by PK49818 while PK 1818 and Bas. 370 were top yielder at 5.2 and 10.5 dS m^{-1} salinity levels, respectively.

Grain weight was least affected by salinity. Under control conditions, 1000-grain weight was 21.3g while at 5.2 and 10.5 dS m^{-1} it was 20.4 and 19.4g, respectively. Increasing salinity significantly reduced the grain filling capacity. PK 33892 and Bas. 198 showed maximum sterility and PK 4048 the minimum at all treatments. There was a significant variation among genotypes for sterility at both saline conditions. Mean sterility of genotypes was 22.4, 39.9 and 50.5% in control, 5.2 and 10.5 dS m^{-1}, respectively. At maturity, the shoot dry weight under control condition was 28.9 gm while at 5.2 and 10.5 dS m^{-1} it was 20.7 g and 14.1 g, respectively. Grain straw ratio was also affected due to salinity. The highest grain straw ratio (0.48) was obtained under control conditions and it gradually reduced to 0.41 and 0.37 with increased salinity of 5.2 and 10.5 dS $m^{-1,}$ respectively.

Table 1a. Mean shoot dry weight 45 DAS, plant height, No. of tillers per plant, panicle length and No. of grains per panicle of 21 rice genotypes at 3 salinity levels.

Genotype	Shoot dry weight 45 day after sowing (g)			Plant height (cm)			Number of tillers per plant			Panicle length (cm)			Grains per spike		
	(Control) ---dS m^{-1}---			(Control) ---dS m^{-1}---			(Control) ---dS m^{-1}---			(Control) ---dS m^{-1}---			(Control) ---dS m^{-1}---		
	1.2	5.2	10.5	1.2	5.2	10.5	1.2	5.2	10.5	1.2	5.2	10.5	1.2	5.2	10.5
PK 4048	12.70	6.30	5.60	95.30	79.00	70.00	14.10	11.80	12.10	25.70	22.70	21.40	109.60	59.80	54.90
PK 4321	15.10	4.90	4.60	89.00	76.70	68.30	15.10	13.10	11.00	21.60	20.90	18.60	107.80	42.70	38.80
PK 49732	15.30	9.90	6.30	109.60	101.30	90.70	12.90	11.30	9.40	31.20	29.00	26.80	130.70	75.90	62.30
PK 1053	13.40	7.60	6.20	105.30	102.60	94.90	12.60	11.20	10.50	29.10	28.40	26.70	131.70	70.40	57.30
PK 49916	15.90	7.10	5.70	106.50	95.00	78.60	11.20	8.80	8.50	29.00	26.80	23.80	124.70	61.30	48.70
PK 3250	14.50	6.50	5.80	106.80	102.70	92.70	11.90	10.10	9.20	29.90	27.90	25.80	144.10	73.10	51.50
PK 1053	18.60	7.50	5.50	111.70	103.00	92.10	13.90	11.80	9.20	31.60	28.40	26.90	147.30	77.50	58.30
PK 49692	13.30	5.70	4.50	107.50	102.30	86.50	13.50	9.90	9.20	28.80	27.90	24.50	130.00	79.30	54.70
PK 1818	8.50	7.50	4.70	120.40	104.60	88.60	9.90	12.50	10.70	28.60	21.10	23.60	147.30	92.20	58.10
PK 49818	18.40	8.60	5.90	108.20	99.70	86.30	13.50	11.90	9.60	28.90	27.40	24.60	144.90	70.70	53.10
PK 49730	15.10	9.10	5.40	111.20	104.30	89.90	14.80	11.20	11.00	29.70	29.20	27.50	149.50	67.10	57.30
PK 49626	12.50	5.50	3.90	103.70	85.00	78.50	14.30	11.80	8.70	25.70	22.90	20.70	115.30	51.40	31.90
PK 49931	13.60	8.50	4.80	91.90	81.60	70.60	13.50	13.60	9.50	25.60	23.50	20.70	136.70	57.10	46.70
PK 47768	13.40	9.10	5.80	105.70	96.40	88.90	13.00	11.50	9.20	29.80	26.80	26.50	132.10	64.60	55.60
PK 49951	15.00	9.40	5.60	110.40	100.80	92.90	11.40	9.60	8.30	27.80	25.50	24.90	153.90	118.10	110.30
Bas.198	8.60	6.40	4.70	81.10	70.40	74.60	14.50	13.70	11.20	23.90	20.90	21.70	54.80	24.50	33.10
PK 4048	8.60	5.90	5.30	91.90	70.30	70.20	16.10	11.80	8.80	25.20	20.70	20.10	71.90	49.10	51.00
PK 33892	6.90	3.90	2.30	67.30	54.00	61.10	17.70	16.10	10.80	21.90	19.90	20.00	19.10	17.30	28.10
Bas. Pak	10.50	6.50	3.80	122.70	105.60	88.90	19.20	16.50	10.10	26.10	21.70	20.90	54.90	32.70	42.90
Bas. 385	9.20	7.50	5.60	105.50	91.20	79.20	12.80	11.80	8.80	27.60	25.40	23.70	83.90	50.00	46.60
Bas. 370	10.70	9.00	6.90	123.80	103.00	93.10	11.00	12.50	7.40	25.30	19.50	22.20	74.90	60.60	51.80
Mean	13.30	7.10	5.20	103.60	91.90	82.70	13.70	12.00	9.70	27.30	24.90	23.40	112.60	61.70	52.00
LSD (0.05)	4.40	3.00	2.80	4.60	8.00	9.60	2.10	2.70	3.20	1.10	2.70	1.80	31.90	18.00	16.90

Table 1b. Mean grain yield per plant, 1000 grain weight, grain sterility, shoot dry weight at maturity and grains straw ratio of 21 rice genotypes at 3 salinity levels.

Genotype	Grain yield per plant (g)			1000 Grain weight (g)			Sterility % age			Shoot dry weight at maturity (g)			Grains straw ratio		
	(Control) ---dS m^{-1}---			(Control) ---dS m^{-1}---			(Control) ---dS m^{-1}---			(Control) ---dS m^{-1}---			(Control) ---dS m^{-1}---		
	1.2	5.2	10.5	1.2	5.2	10.5	1.2	5.2	10.5	1.2	5.2	10.5	1.2	5.2	10.5
PK 4048	14.40	8.30	5.30	21.90	20.30	18.40	15.40	19.40	21.20	21.20	13.80	7.70	0.71	0.60	0.31
PK 4321	11.90	7.40	3.90	21.60	20.50	18.10	18.40	70.80	57.50	25.10	22.40	12.10	0.46	0.34	0.33
PK 49732	16.30	9.70	5.40	22.00	23.80	19.60	19.50	43.80	34.40	27.10	23.00	14.40	0.64	0.42	0.37
PK 1053	15.30	9.50	6.90	21.60	18.80	21.30	20.30	39.20	49.60	27.90	24.80	16.60	0.63	0.38	0.44
PK 49916	11.90	6.90	3.90	20.90	19.20	18.90	20.80	46.10	61.10	29.90	19.90	13.00	0.39	0.33	0.28
PK 3250	12.90	9.50	5.10	21.50	20.70	19.90	22.10	28.20	43.70	27.80	19.80	12.20	0.54	0.50	0.42
PK 1053	15.40	11.40	6.10	21.20	20.80	19.90	21.50	33.60	49.30	30.70	25.60	15.20	0.49	0.46	0.41
PK 49692	14.70	8.80	6.30	21.80	21.60	22.30	23.30	24.90	36.70	29.80	20.70	10.20	0.48	0.44	0.62
PK 1818	15.70	11.50	4.90	24.20	21.40	19.60	17.70	26.10	47.60	27.90	24.20	16.40	0.54	0.47	0.37
PK 49818	15.90	9.40	4.90	20.80	20.20	19.30	22.40	32.00	44.20	24.50	20.90	11.20	0.69	0.45	0.44
PK 49730	15.30	10.10	6.40	21.70	20.90	19.80	27.10	40.20	53.50	39.10	20.90	15.10	0.37	0.49	0.43
PK 49626	13.40	6.10	2.90	20.90	18.50	17.10	27.30	47.60	87.90	36.70	22.90	11.80	0.33	0.27	0.25
PK 49931	11.40	8.00	3.60	21.60	19.50	20.60	16.50	26.00	48.60	26.80	22.20	15.00	0.48	0.36	0.24
PK 47768	15.80	8.40	5.40	21.30	19.90	19.80	20.30	48.10	43.00	22.90	24.10	13.30	0.65	0.36	0.29
PK 49951	13.60	8.70	4.90	19.60	20.30	18.30	27.90	29.60	38.20	29.60	21.90	15.50	0.61	0.57	0.49
Bas.198	5.70	3.20	2.80	20.80	19.80	19.60	32.70	89.90	95.40	32.80	20.90	22.50	0.16	0.15	0.13
PK 4048	12.80	8.10	4.90	21.00	20.30	19.00	18.30	22.60	25.20	22.90	11.20	9.10	0.58	0.62	0.55
PK 33892	8.40	4.60	2.60	17.20	16.80	17.20	36.50	81.50	97.30	28.80	18.10	15.00	0.29	0.20	0.17
Bas. Pak	11.90	7.30	5.60	24.40	23.30	20.50	16.60	30.30	35.50	41.20	21.10	14.80	0.30	0.35	0.38
Bas. 385	11.70	8.90	5.90	21.00	20.80	19.50	22.90	37.10	55.70	27.50	17.00	12.90	0.44	0.55	0.48
Bas. 370	14.00	11.2	7.40	19.60	20.50	17.90	22.30	20.50	32.90	26.30	19.40	11.40	0.39	0.38	0.43
Mean	13.30	8.40	4.90	21.30	20.40	19.40	22.40	39.90	50.40	28.90	20.70	14.10	0.48	0.41	0.37
LSD (0.05)	3.40	3.10	2.20	1.60	3.30	2.40	9.40	17.00	24.20	8.60	6.40	7.80	0.22	0.16	0.15

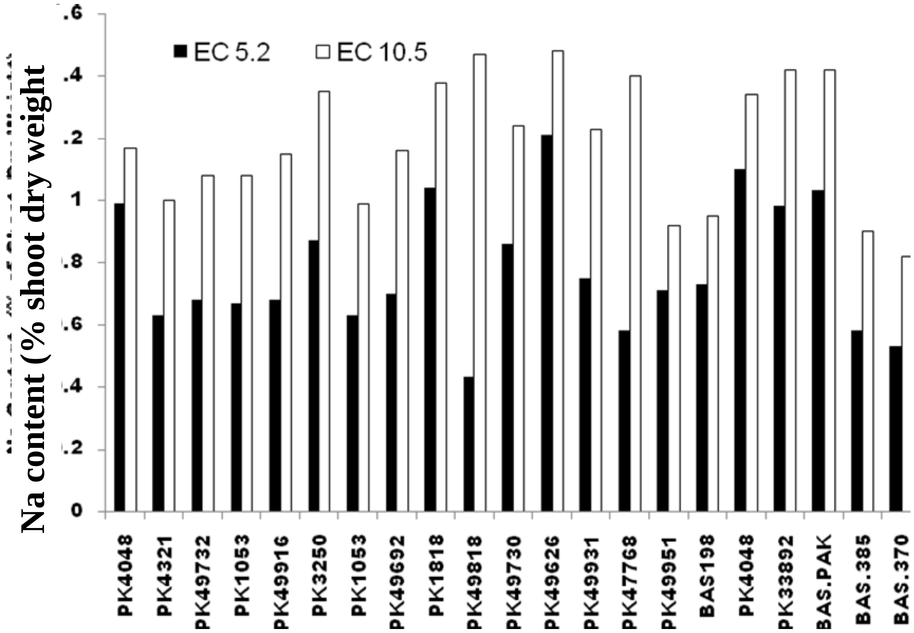

Fig. 1a. Na content of 21 genotypes at 5.2 and 10.5 dS m^{-1} salinity.

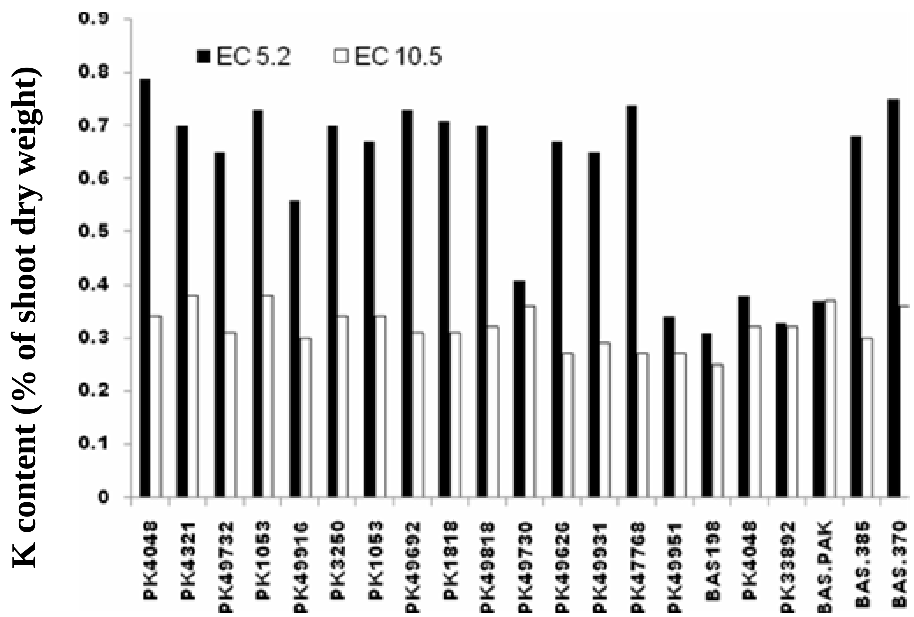

Fig. 1b. K content of 21 genotypes at 5.2 and 10.5 dS m^{-1} salinity.

Na and K contents: The Na and K contents of shoot of salt stressed genotypes are shown in Fig. 1a and b. With increased salinity the Na content of shoot was increased while K content was decreased. In general, genotypic differences in grain yield reflected variation to the extent of Na accumulation in the shoot. Thus Bas. 370 had both the lowest reduction in grain yield under salt conditions and the lowest shoot Na content, and the PK 49626 had the highest Na under saline conditions which were associated with the highest reduction in grain yield due to salinity. At 5.2 dS m^{-1}, highest K was accumulated by the shoot of PK 4048 and the lowest by Bas. 198. Bas. Pak and PK 1053 had the maximum K content and Bas. 198 had the minimum at the highest salinity level. The mean K/Na ratios of shoot of salt treatments are shown in Fig. 1c. The genotypes differed significantly for K/Na ratio. At both salinity levels Bas. 370 had the highest K/Na ratio while PK 4048 and PK 49626 had the lowest K/Na ratio at 5.2 and 10.5dS m^{-1}, respectively.

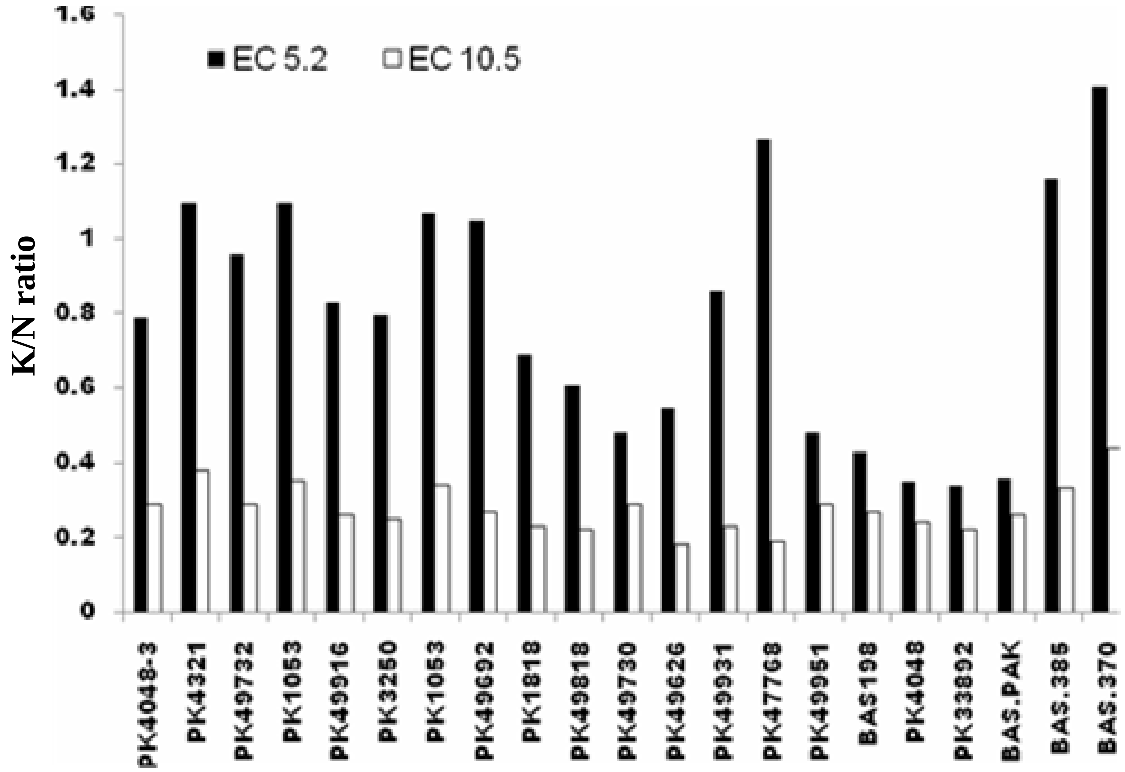

Fig. 1c. K/Na ratio of 21 genotypes at 5.2 and 10.5 dS m^{-1} salinity.

Correlation: Correlation coefficients of 9 agronomic characters with Na content of shoot and shoot dry weight 45DAS, were calculated taking overall data of all treatments and separately at 5.2 and 10.5 dS m^{-1}, are presented in Table 2 when correlation coefficients were calculated on overall data basis, Na contents of shoot showed highly significant ($p< 0.01$) negative correlation with all agronomic traits i.e., plant height, number of tillers, panicle length, number of grains per panicle, 10000 grain weight, shoot dry weight at maturity, grain straw ratio and grain yield and significant positive correlation with grain sterility. However correlation coefficients were higher ($r<-0.05$) for panicle length, grain number per panicle, shoot dry weight at maturity and grain yield. Similarly correlation coefficients were highly significant between shoot dry weight 45DAS and all agronomic traits.

When only data for plants grown at 5.2 dS m^{-1} were analyzed, highly significant negative correlations of Na content of shoot was observed with panicle length, grain number per panicle and grain yield while merely significant ($p<0.05$) negative with tiller number and shoot dry weight at maturity. At this salinity level shoot dry weight 45DAS also showed highly significant positive correlation with panicle length, grain number per spike and grain yield. Sodium content of shoot was highly significantly negatively correlated with tiller number per plant, panicle length, grain number per panicle, shoot dry weight at maturity and grain yield at 10.5 dS m^{-1} salinity level. The relationship of plant height, panicle length, grain number per spike and grain yield with shoot dry weight 45DAS was also highly positively significant at this salinity level.

Grain yield had a significant positive correlation with 1000-grain weight, grains per panicle, tiller number and panicle length and significant negative with grain sterility at each treatment and on over all data basis (data not shown).

Table 2. Correlation of Na content and shoot dry weight 45 DAS with agronomic characters on overall data basis and at EC 5.2 dS m^{-1} and EC 10.5 dS m^{-1} salinity.

Characters	Overall		5.2 dS m^{-1}		10.5 dS m^{-1}	
	Na content of shoot	Shoot dry weight 45 day after sowing	Na content of shoot	Shoot dry weight 45 day after sowing	Na content of shoot	Shoot dry weight 45 day after sowing
Plant height	-0.48**	0.59 **	-0.14	0.24	-0.19	0.37**
No. of tillers/plant	-0.30 **	0.35 **	-0.30 **	-0.06	-0.39**	0.22
Panicle length	-0.52**	0.60**	-0.44**	0.46**	-0.54**	0.39**
No. of grains per panicle	-0.67**	0.79**	-0.38**	0.33**	-0.43**	0.45**
1000-grain weight	-0.30**	0.37**	0.03	0.03	0.12	0.17
Grain sterility	0.45**	-0.50**	0.11	0.09	0.10	-0.43**
Shoot dry weight at maturity	-0.58**	0.60**	-0.26**	0.23	0.32**	0.13
Grain straw ratio	-0.34**	0.38**	-0.16	0.19	0.21	0.31*
Grain yield per plant	-0.73**	0.79**	-0.34**	-0.39**	0.51**	0.65**

*, ** Significant at 5.0 and 1.0 % levels, respectively.

Discussion

Data of Table 1a and 1b revealed that a considerable amount of variability is present between genotypes for all agronomic characters. Some genotypes like Bas. 370 and Bas. 385 had even more than 50% of the control grain yield at the highest salinity level whilst the other genotypes such as PK 49626 and PK 49818 were more sensitive to salinity with just 21.6 and 30.8% of control grain yield at same salinity level. Even after twenty days in 10.5 dS m^{-1} salinity the reduction in shoot dry weights of PK 49626 and PK 49818 was double than those of Bas. 370, Bas. 385 and PK 4048. Variation in the response of genotypes to increasing salinity is also evident from the data of other agronomic characters. These results indicate that some genotypes were more salt tolerant than the others. Similar type of variability in rice for growth characters was observed by Akbar *et al.*, (1972), Venkateswarl *et al.*, (1972), Yeo & Flowers (1986) and Bari & Hamid (1988).

Similar to growth characters Fig. 1 also shows that there were significant differences among genotypes at both stress levels for the accumulation of Na in the shoot. Bas. 370 and Bas. 385 have much more efficient exclusion of Na from the shoot than exhibited by the other genotypes. A negative correlation between Na accumulation and growth has been frequently reported (Shannon, 1978; Munns & Termaat, 1986; Mahmood & Quarrie, 1993; Ashraf, 2004; Mahmood, 2009) and our results confirm previous reports of more efficient exclusion of Na by Bas. 370 and Bas. 385 than the other salt susceptible genotypes in respect of grain yield. The uptake of K is frequently reduced by addition of Na salt to the medium (Storey & Wyn Jones, 1978, Erdei & Kuiper, 1979; Ahmad *et al.*, 2007), similar trend was observed in our experiment where K contents were reduced by the increase of salinity and on average at 10.5 dS m^{-1} it was one third of the control treatment. In general, with the addition of salt in the medium, Na content of shoot increased and K content decreased. Consequently, the K/Na ratio was higher in relatively salt tolerant genotypes. This observation is in line with the report of Gorham *et al*., 1980, Goudarzi & Pakniyat, 2008). In rice, the K/Na ratio has been correlated with the plant survival rate under salt stress (Zhu *et al*., 2001, Gao *et al*., 2007).

The salt tolerance ability in respect of both grain yield and Na exclusion of relatively old commercial varieties (Basmati-370 and Basmati-385) was more than the newly developed breeding lines and commercial varieties. One reason of this difference may be that Basmati-370 and Basmati-385 are being cultivated in this area since long (Basmati-370 was approved for general cultivation in 1937 and Basmati-385 in 1985). As most of the rice growing area in Pakistan is saline, therefore, these varieties may have adopted themselves in moderate saline conditions (Ahmad *et al*., 2009).

These studies have shown that there are strong correlations between genotypic performance measured at 45DAS and at maturity stage. Sodium content of shoot and shoot dry weight 45DAS had significant correlation with grain yield and yield components (Table 2). This relationship indicates that selection for salinity tolerance on the basis of Na exclusion ability and shoot dry weights at early stage of growth could be effective (Naz *et al*., 2009). However, correlation coefficients between the shoot dry weight 45DAS and grain yield were much higher than the correlation coefficients between Na content of shoot and grain yield which indicate that selection based on shoot dry weights will be more effective and reliable than of Na contents. Moradi & Ismail (2007) also observed a relationship for salinity tolerance in rice at seedling and reproductive stage.

Correlation studies also show that all the three components of yield i.e., tiller number, grain number per panicle and grain weight were responsible for reduction in the grain yield. These results are in line with Subhashini & Reddy (1989) and Zeng (2004). The strong negative correlation between grain yield and grain sterility indicate that grain number per panicle contributed the most variation as correlation coefficients between grain yield and grain number per panicle were more than those of other two variables.

From these studies it can be concluded that I) significant variability is present for salt tolerance in Basmati rice, 2) selection for salinity tolerance can be carried out at early stages of growth, 3) there is a relationship between Na exclusion and salt tolerance in respect of grain yield and 4) reduced grain yield under saline conditions is mainly due to reduction in grain number per panicle.

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