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Salt Tolerance in Bread Wheat: Genetic Variation and Heritability for Growth and Ion Relation

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Abstract: The response of ten different wheat genotypes to three NaCl levels i.e., control, 7.5 and 15 dS m^{-1} were compared. Increase in salinity level caused significant reduction in plant height, fresh shoot weight, and dry shoot weight. On the basis of relative salt tolerance, genotypes 243/1 and Tob.66 were found to be more tolerant to salinity and KLR-3-4,SARC-I, NIAB-20, NIAB-30, 5039 and 6529-11 were moderately tolerant and the genotypes 4072 and 6142 were least tolerant to salinity. The estimates of broad-sense heritability for these characters ranged 0.09 to 0.68. The data suggested that improvement in NaCl tolerance in bread wheat is possible by exploiting variability through conventional breeding methods.

Key words: Wheat, salinity, genetic variation, heritability, salt tolerance in wheat

Introduction

Salinity has created an alarming situation in Pakistan. Saline and sodic soil conditions reduce the value and productivity of crops. The poor crop growth in saline soils is thought to be due to such causes as imbalance in mineral nutrition, reduction in water uptake and direct toxicity of salts to plants. Depending upon a number of soil and climatic factors, the salt accumulation in soils vary which in turn affects plant growth to different degrees (Bernstein, 1975). The problem of soil salinity is of frequent occurrence in irrigated areas of the world (Shannon, 1984). In Pakistan, about 6.3 x 10^6 hectares of arable land is affected adversely by salinization problem (Malik and Shah, 1996). Development of salt tolerant genotypes is a possible alternative to the expensive engineering approach to utilize the waste lands (Shannon, 1984).

In recent years there has been of much interest in the development of salt tolerant crop varieties (Tal, 1985; Wyn Jones and Gorham, 1986; Epstein and Rains, 1987; Salim, 1991). Physiological parameters such as Na^+, K^+, and K^+/Na^+ ratio are responsible for salt tolerance in various plant species (Ashraf and O'Leary, 1996; Raced *et al.*, 1999; Salam *et al.*, 1999).

Wheat is a staple food of the people of Pakistan. It is also a staple crop in arid and semi-arid regions of the world. In many of these regions, salinity problem range from incipient to extensive. Therefore, development of salinity tolerance within the species would be of great value. This crop has been ranked as moderately salt tolerant (Anonymous, 1947). In the tribe Triticeae, the best-documented system controlling ion uptake in salt-treated plants is the enhanced K^+/Na^+ discrimination trait controlled by the gene Knal (Salam *et al.*, 1999).

The availability of genetic variation in salinity tolerance is necessary for the development of salt tolerant genotypes. The study examines the variability for salt tolerance in ten genotypes of bread wheat and the magnitude of heritability for the morpho-physiological characters.

Materials and Methods

In study, ten genotypes namely 4072, 5039, 6142, 6529-11, SARC-1, NIAB-20, NIAB-30, KLR-3-4, Tob.66, and 243/1 were used. The experiment involved three NaCl concentrations, control, 7.5 and 15 dSm^{-1}. Seeds of all the genotypes were grown in pots filled with approximately 6 kg of sand and clay mixed in the ratio of 2:1, respectively. The salinity levels were achieved by adding NaCl salt and mixing with sand and clay at the time of sowing. Sixty pots were arranged in a Completely Randomized Design in a greenhouse. The seeds of each genotype were dibbled in soil under proper moisture condition. At four leaf-stage, the plants were harvested and data on plant height, fresh shoot weight, dry shoot weight, Na^+, K^+ and K^+/Na^+ ratio were recorded.

Data were subjected to analysis of variance technique and the response of ten genotypes were compared in relative terms as suggested by Maas (1986).

The indices of salt tolerance were computed:

$$\text{Relative salt tolerance} = \frac{\text{Mean performance in stress}}{\text{Mean performance in control}} \times 100$$

Estimates of broad-sense heritability (h^2_{BS}) of six plant characters assessed under each NaCl treatment level were made following the formula given by Falconer (1981) based on the variance due to between-accessions and within-accessions:

$$h^2_{BS} = \frac{\text{Variance between-accessions}}{\text{Variance between-accessions} + \text{Variance within-accessions}}$$

Results and Discussion

The availability of genetically controlled variation in salinity tolerance is essential for the development of salt tolerant lines of wheat, by using conventional breeding methods. In order to gain such information about variation, ten genotypes of different pedigrees were evaluated. Mean squares for plant height, fresh shoot weight, dry shoot weight, Na^+, K^+ and K^+/Na^+ ratio showed significant differences measured between varieties and NaCl treatments except K^+/Na^+ ratio, which is non-significant (Table 1).

The significant interactions (Varieties x NaCl treatments) for fresh shoot weight, dry shoot weight, Na^+ and K^+ indicated that four characters of different varieties responded differently to different NaCl treatments, while that for plant height and K^+/Na^+ ratio was non-significant and different varieties for these characters responded similarly to different salinity concentrations.

The adverse effect of increasing salinity on all the traits of all genotypes and also indicated differences in responses between varieties (Table 2).

Indices of salt tolerance based upon plant height provided estimates of the salinity tolerance of genotypes. Plant height at both the salinity levels seemed to be similar but genotypic variation is evident from the data. The genotypes KLR-3-4 and SARC-1 gave mean index of 77.96 and 77.02 of the control treatment at 7.5 dS m^{-1} in contrast to 64.74 and 50.46 of genotypes 6142 and 4072. At 15 dS m^{-1}, the genotypes 243/1 and Tob.66 gave tolerant index 75.13 and 75.38, respectively in comparison with 61.40 and 55.86 of SARC-1 and 4072. However, from over all assessment, the genotypes KLR-3-4 and 243/1 with tolerant index of 72.52 and 72.31, respectively appeared to be more tolerant where as 6142 and 4072 with mean values of 64.32 and 53.16, respectively seemed to be less tolerant genotypes.

Based upon fresh shoot weight, comparison of indices of salt tolerance reveals that some of the genotypes are more tolerant than the others. The genotype 243/1 gave 45.38 fresh shoot weight of the control treatment and in contrast the genotype

Table 1: Mean squares of 10 wheat genotypes in 3 NaCl levels

Source of Variation	df	Plant Height	Fresh Shoot Weight	Dry Shoot Weight	Na^+	K^+	K^+/Na^+
Varieties(V)	9	104.17**	1.380**	0.0449**	554.57**	5307.38**	0.2482NS
Treatments(T)	2	1373.79**	57.480**	1.3405**	1739.02**	6110.22**	1.9561**
V x T	18	11.56^{NS}	0.879**	0.0212**	136.43**	1163.47**	0.1149NS
Error	60	9.62	0.215	0.0076	26.87	389.95	0.1356

* = Significant   ** = Highly significant   NS = Non-significant

Table 2: Relative salt tolerance of 10 genotypes of bread wheat against 3 NaCl levels

	Plant Height			Fresh Shoot Weight			Dry Shoot Weight		
	NaCl levels dS m^{-1}			NaCl levels dS m^{-1}			NaCl levels dS m^{-1}		
Genotypes	7.5	15	Mean	7.5	15	Mean	7.5	15	Mean
4072	50.46	55.86	53.16	13.99	20.99	17.49	14.81	17.26	16.04
5039	70.44	70.98	70.71	30.56	20.83	25.70	41.36	40.76	41.06
6142	64.74	63.90	64.32	19.69	17.21	18.45	21.52	19.02	20.27
6529-11	69.10	69.67	69.39	32.49	26.18	29.34	27.97	22.81	25.39
SARC-1	77.02	61.40	69.21	36.49	16.38	26.44	45.38	24.60	34.99
NIAB-20	72.87	66.42	69.65	31.20	29.74	30.47	39.11	37.62	38.37
NIAB-30	71.84	68.41	70.13	33.77	23.84	28.81	30.66	20.44	25.55
KLR-3-4	77.96	67.07	72.52	37.03	22.97	30.00	41.62	27.80	34.71
Tob.66	64.78	75.38	70.08	42.25	40.14	41.20	39.44	37.75	38.60
243/1	69.48	75.13	72.31	45.38	40.76	43.07	62.31	56.41	59.36

Table 2: Continue

	Na^+			K^+			K^+/Na^+		
	NaCl levels dS m^{-1}			NaCl levels dS m^{-1}			NaCl levels dS m^{-1}		
Genotypes	7.5	15	Mean	7.5	15	Mean	7.5	15	Mean
4072	56.15	104.60	80.38	51.67	80.98	66.33	91.50	76.19	83.85
5039	66.82	102.85	84.84	65.11	94.41	79.76	97.54	92.28	94.91
6142	59.20	99.61	79.41	63.06	82.31	72.69	107.31	82.39	94.85
6529-11	50.36	96.60	73.48	45.25	85.33	65.29	89.85	88.33	88.85
SARC-1	83.33	85.87	84.60	91.56	70.33	80.95	109.29	81.79	95.54
NIAB-20	112.77	113.67	113.22	109.42	92.46	100.94	96.44	81.23	88.84
NIAB-30	84.91	115.72	100.32	89.46	98.68	94.07	105.59	85.86	95.73
KLR-3-4	103.68	123.42	113.55	111.85	115.26	113.56	107.79	93.51	100.65
Tob.66	92.61	130.29	111.45	81.27	114.63	97.95	88.72	88.43	88.58
243/1	102.97	166.83	134.90	95.57	118.85	107.21	92.74	71.29	82.02

Table 3: Components of variances and broad-sense heritabilities of salt tolerance in 10 *Triticum aestivum* L. genotypes in 3 NaCl levels

Components of variance	Characters NaCl levels (dS m^{-1})	Plant height	Fresh shoot weight	Dry shoot weight	Na^+	K^+	K^+/Na^+
Phenotypic	Control	19.516	1.278	0.032	96.077	857.266	0.0647
	7.5	23.9801	0.1203	0.0073	130.781	1371.675	0.1033
	15	18.152	0.077	0.005	102.685	1095.725	0.242
Genotypic	Control	13.210	0.784	0.016	70.739	568.446	0.0137
	7.5	15.9302	0.0493	0.0043	112.070	1091.466	0.0143
	15	3.684	0.007	0.001	66.136	494.909	0.006
Heritability	Control	0.684	0.6140	0.501	0.7363	0.6631	0.2117
	7.5	0.6643	0.4098	0.5890	0.8569	0.7957	0.1384
	15	0.203	0.0910	0.200	0.6441	0.4517	0.0248

4072 gave 14.00 at 7.5 dS m^{-1}. With increasing the salinity level fresh shoot weight of all the genotypes was affected but to varying degrees. At 15 dS m^{-1}, differences among the responses of genotypes became more apparent. The genotypes, SARC-1, 6142 and 5039 gave only 16.38, 17.21 and 20.83 respectively relative values in comparison with 40.76 and 40.14 of Tob. 66 and 243/1 respectively. However from overall assessment of the genotypes, 243/1 and Tob.66 appeared to be the most tolerant to salinity.

Salt tolerance indices based upon dry shoot weight provide further estimates of the salinity tolerance of genotypes. Although dry shoot weight decreased markedly at 15 dS m^{-1} but the differences between genotypes are still evident. The genotypes SARC-1 and KLR-3-4, which were tolerant at 7.5 dS m^{-1}, appeared to be less tolerant at high salinity concentrations i.e., at 15 dS m^{-1}. However from overall assessment of genotypic responses, the genotypes 243/1, 5039 and Tob.66 with mean values of about 59.36, 41.06 and 38.60, respectively seemed to be more tolerant whereas 4072 and 6142 with mean values 16.04 and 20.27, respectively appeared to be less tolerant genotypes.

All treatments reduced the above mentioned traits to varying degrees (Table 2) and this reduction became more pronounced with the increase in salinity. Such similar observations have been made by other workers Azhar and McNeilly (1987), Chang *et al.*

(1994), Seraj *et al*. (1998), Shereen *et al*. (2001).

Indices of salt tolerance based upon Na^+ provide estimates of the salinity tolerance of genotypes. With increase in salinity level, Na^+ uptake was increased by all the genotypes where as K^+ uptake was also increased. The genotypes with higher K^+/Na^+ ratio are considered tolerant (Lacan and Durand, 1996). The genotype KLR-3-4 showed the highest mean value i.e., 100.65 followed by NIAB-30 (95.73) and are more tolerant as compared to others.

Although size of the sample of genotypes tested is small, yet the data reveal considerable variation in the responses of the germplasm assessed here.

The estimates of broad-sense heritability (h^2_{BS}) of plant height, fresh shoot weight and dry shoot weight under two NaCl levels and control are given in Table 3. The estimate was maximum (0.68) in control for plant height and decreased as the salinity level increased i.e., 0.66 and 0.20 at 7.5 dS m^{-1} and at 15 dS m^{-1} respectively. The heritability estimates based upon fresh shoot weight were 0.61, 0.41 and 0.09 under control, 7.5 dS m^{-1} and 15 dS m^{-1} NaCl level, respectively. The estimates of heritability based upon dry shoot weight data were 0.50, 0.59 and 0.20 under control, 7.5 and 15 dS m^{-1} NaCl level, respectively. The heritability estimates based upon Na^+ were 0.7363, 0.8569 and 0.6441, for K^+ were 0.6631, 0.7957 and 0.4517 and that for K^+/Na^+ ratio were 0.2117, 0.1384 and 0.0248 under control, 7.5 dS m^{-1} and 15 dS m^{-1} NaCl levels, respectively.

These estimates showed that salinity tolerance was a heritable character as observed by other workers like, Noble *et al*. (1984) and Allen *et al*. (1985). According to Falconer (1981) the heritability estimates are subject to considerable environmental conditions, and therefore, must be interpreted and used with great care in plant improvement exercise. The estimates of broad-sense heritability suggested that prospects of improving salinity tolerance in bread wheat through selection and breeding are present, provided that the genetic system controlling the variation in the character is predominantly affected by additive genetic effects.

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