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RESPONSE OF WHEAT GENOTYPES TO SALINITY AT EARLY GROWTH STAGES

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Abstract

Investigations on screening of wheat genotypes under different salinity (NaCl) levels were carried out at Nuclear Institute of Agriculture (NIA) Tandojam, Pakistan during winter season of 2005-2006. The seeds of 8 different wheat genotypes viz., Sarsabz, Anmol-91, Kiran-95, Mehran-89, TJ-83, Moomal, Abadgar-94 and Marvi were sown in Petri dishes in NaCl concentrations of 50, 100, 150 and 200 mol^{-3}m in the laboratory condition. Results revealed that highly significant ($p \leq 0.01$) differences were observed among the genotypes and salinity levels for germination, shoot and root length, fresh and dry shoot weight. Studies further exhibited that wheat cv. Moomal was found leading genotype and recorded maximum seed germination (88.75%), shoot length (5.58 mm), root length (4.64 mm), fresh shoot weight (0.55 g) and dry shoot weight (0.07 g) even in the presence of NaCl concentrations of 50 to 200 mol^{-3}m as compared to other genotypes. In interaction, the genotypes Moomal and Marvi were found best performing cultivars even in salinity level of 50 mol^{-3}m and showed best performance. On average, the increased levels of salinity (NaCl) significantly reduced the seedling growth and its related parameters in all the wheat genotypes.

Introduction

Wheat is the leading crop of the temperate climates of the world and a unique world food grain because of its seed has a particular kind of protein called ‘gluten’ with varied physical and chemical properties. (Jaiswal, 2009). Salinity affects 7% of the world’s land area, which amounts to 930 million ha. The area is increasing; a global study of land use over 45 years found that 6% had become saline. In Pakistan alone, 11 million ha have become saline and has salt deposits and other land also at risk of becoming saline in the next few decades (Anon., 2006). The data indicate that in order to increase agricultural productivity, alternative technologies are needed, such as trees and shrubs to lower the water table, more effective water management to prevent water logging, and salt-tolerant and resistant strains of edible crops. Without these measures, it is likely the situation will worsen in the coming years in Pakistan (Davidson, 2000).

Plant breeders are trying and aimed to develop early maturing, biotic and abiotic stress resistant wheat cultivars. Plant response to salt stress is much common and salinity reduces the ability of plants to take up water, which quickly causes reductions in growth rate, along with metabolic changes the same as caused by water stress. (Munns, 2002). Soil salinity becoming the serious problem in the Sindh province of Pakistan (locally called Acho-Kaler of Thur) contain relatively higher concentration of soluble salt made up largely Cl- and SO_4+ of Na+ with small quantity of HCO^-_3 may occur, but soluble CO_3^- is usually absent. Hence they show higher EC values (>4dS/m).

The pH of these soils is generally less than 8.5 and ESP (exchangeable sodium percentage) is less than 15. Due to lower concentration of exchangeable complexes saline soil shows favorable structure because the colloids are highly fluctuated while crust frequently accumulates on the soil surface and streak of the salts are sometimes found within the soil (Ansari *et al.,* 2004).

Salt tolerant plants also differed from salt-sensitive ones in having a low rate of Na+ and Cl– transport to leaves, and the capability to classify these ions in vacuoles to prevent their build-up in cytoplasm or cell walls and thus avoid salt toxicity. In order to understand the processes that give rise to tolerance of salt, as distinct from tolerance of osmotic stress and to identify genes that control the transport of salt across membranes, it is important to avoid treatments that induce cell plasmolysis and to design experiments that differentiate between tolerance of salt and water stress (Munns, 2002).

Relative growth response curves of the seedlings were alike regardless of whether salt stress was imposed at planting or at the 1^{st}, 2^{nd}, or 3^{rd} leaf stage of growth (Maas & Poss, 2004). Salt stress also retarded leaf development and tillering but hastened plant maturity. Munns & James (2003) studies enunciated that measuring either biomass or leaf elongation rates revealed large decreases in growth rate due to the osmotic effect of the salt, but little genotypic differences, although there were genotypic differences in long-term experiments. Rascio *et al*., (2001) formulated that in some cases the capacity to concentrate potassium in response to NaCl stress was accompanied by a decreased growth and hence did not represent an adaptive trait to salt stress. Salt-tolerant monocotyledonous plants accumulated less sodium in their leaves than salt sensitive plants and the K/Na trait has been considered as an index of tolerance being higher in wheat tolerant genotypes. So in the present alarming situation of Pakistan, the aim of present research was also to screen out the different wheat genotypes for salt tolerance and then to include them in future breeding programme to develop salt resistant wheat genotypes.

Materials and Methods

Studies on screening of wheat genotypes under different salinity levels were carried at the Nuclear Institute of Agriculture (NIA) Tandojam, Pakistan during the winter season of 2005-2006. Homogeneous and viable seeds of eight wheat genotypes namely Sarsabz, Anmol-91, Kiran-95, Mehran-89, TJ-83, Moomal, Abadgar-94 and Marvi were placed in Petri dishes (water culture) containing NaCl concentrations of 50, 100, 150 and 200 $mol^{-3}m$. All the concentrations were made in ¼ strength Hoagland nutrients. The study was conducted for two weeks in a randomized complete block (RCB) design with three replications with factorial arrangement under controlled conditions. The data were recorded on germination %, shoot and root length, fresh and dry shoot weight. Data were subjected to the statistical analysis according to Steel *et al.,* (1997) and comparison of mean was calculated after Gomez & Gomez (1984) using Duncun's Multiple Range (DMR) test at 5%.

Results and Discussion

The seed germination percentage varied significantly ($p \leq 0.01$) between salinity levels and genotypes, while the differences in their interactions were non-significant (Table 1). Seed germination was maximum and statistically at par in case of genotypes

Marvi and Moomal (88.75%), followed by Kiran-95 and Abadgar-94 (86.25%) and Sarsabz (83.00%), while low seed germination was observed in Mehran-89, TJ-83 and Anmol-91 ranged from 76.75 to 78.50% (Table 2). The NaCl was applied at 50 and 100 mol^{-3}ms showed increased and at par seed germination for cultivars (93.25 & 91.75%). The germination decreased gradually at high salinity levels of 150 and 200 mol^{-3}m i.e. 78.88 and 68.63%, respectively. In interactions, numerically the cv. Moomal and Marvi showed 100 and 98.00% seed germination with 50 mol^{-3}m, respectively. Large decreases were observed in growth rate due to osmotic effect of the salt (Munns & James, 2003). Ahmed *et al*., (1998) reported that emergence, seedling height, shoot dry weight, root length and weight decreased with increasing salinity level in wheat. Wheat germination decreased significantly at different salinity levels as compared to non-saline treatments (Phogat *et al*., 2001). Wheat species were less salt tolerant at germination than they were after the three-leaf stage of growth.

Shoot length varied significantly ($p \leq 0.01$) among genotypes and NaCl levels, with significant interactions (Table 1). The cultivars Moomal, Kiran-91 and Marvi showed highest shoot lengths that ranged from 5.34 to 5.58 mm (Table 3) and were found statistically at par with Abadgar-94 (5.16 mm). However, Mehran-89 and Anmol-91 produced lowest shoot length (4.24 and 4.53 mm). The other three wheat genotypes showed medium shoot length (4.63 to 4.77 mm). Results further indicated that salinity level (50 mol^{-3}m) showed maximum shoot length (5.53 mm) followed by 100 mol^{-3}m (5.13 mm) and 150 mol^{-3}m (4.80 mm). However, the highest salinity level (200 mol^{-3}m) significantly reduced the shoot length (4.31 mm). In interactions, cultivars Moomal and Marvi showed highest shoot length of 6.20 and 6.10 mm at 50 mol^{-3}m NaCl. Munns (2002) also mentioned that if excessive amounts of salt enter the plant and will eventually rise to toxic levels in the older leaves which reduce the photosynthetic leaf area of the plant to a level that cannot sustain growth. Rajper & Sial (2002) reported that seedling emergence and shoot length were decreased by salinity. Ahmed *et al*., (1998) reported that emergence, seedling height and root weight decreased with increasing the salinity in wheat. However, Maas & Poss (2004) explained that relative growth response of the seedlings were alike regardless of whether salt stress was imposed at planting or at the 1st, 2nd, or 3rd leaf stage of growth, however the salt stress retarded leaf development and tillering but hastened plant maturity.

The mean squares of root length revealed that cultivars and NaCl levels differed significantly ($p \leq 0.01$), while their interactions were non-significant (Table 1). Cultivar Moomal produced longer roots (4.64 mm) and it was found at par with three cultivars Kiran-95, Marvi and Abadgar-94 ranged from (4.18 to 4.24 mm). However, Mehran-89 displayed minimum roots length (3.64 mm) and was found at par with three cultivars (Table 4). Low salinity levels (50mol^{-3}m & 100 mol^{-3}m) enunciated greater and equal root length (4.63 mm & 4.25 mm), respectively. The salinity levels 150 mol^{-3}m (3.84 mm) and 200 mol^{-3}m (3.27 mm) provided lowest root length. In case of interactions, the cultivars Moomal and Marvi displayed maximum root length of 5.32 and 5.15 mm under 50mol^{-3}m NaCl, respectively. Seedling emergence and root length were decreased by increased salinity levels (Rajper & Sial, 2002; Ahmad *et al*., 1998). Inan *et al.,* (2001) also noticed that wheat root growth inhibition was more pronounced at higher NaCl rates. Munns & James (2003) observed large decreases in growth rate due to osmotic effect of the salt.

Table 1. Mean squares for various growth traits of wheat genotypes under different salinity levels.

Source of variation	df	Mean squares				
		Germination %	Shoot length	Root length	Fresh shoot weight	Dry shoot weight
Replications	2	16.125$^{N.S}$	1.024$^{N.S}$	0.471$^{N.S}$	0.032$^{N.S}$	0.000012$^{N.S}$
NaCl levels (L)	3	348.938**	10.004**	14.357**	1.017**	0.05134**
Genotypes (G)	7	118.313**	15.442**	7.777**	2.792**	0.00368**
L × G	21	7.688$^{N.S}$	0.247$^{N.S}$	0.913$^{N.S}$	0.037$^{N.S}$	0.000611$^{N.S}$
Error	**62**	**9.375**	**0.726**	**0.982**	**0.027**	**0.000043**

** = Significant at p≤0.01, NS = Non-significant

Table 2. Mean performance of wheat genotypes under different salinity levels for germination %.

Genotypes	NaCl mol^{-3}m				Mean
	50	100	150	200	
Sarsabz	92	90	80	70	83.00 c*
Anmol-91	89	88	72	65	78.50 d
Kiran-95	98	97	82	68	86.25 b
Mehran-89	86	85	76	60	76.75 d
TJ-83	88	87	70	62	76.75 d
Moomal	100	98	85	72	88.75 a
Abadgar-94	95	93	82	75	86.25 b
Marvi	98	96	84	77	88.75 a
Mean	**93.25 a**	**91.75 a**	**78.88 b**	**68.63 c**	

*Values followed by similar letters do not differ significantly at p≤0.05

Table 3. Mean performance of wheat genotypes under different salinity levels for shoot length %.

Genotypes	NaCl mol^{-3}m				Mean
	50	100	150	200	
Sarsabz	5.20	5.00	4.88	4.00	4.77 bc*
Anmol-91	5.00	4.80	4.50	3.80	4.53 d
Kiran-95	6.00	5.75	5.00	4.60	5.34 a
Mehran-89	4.80	4.35	4.00	3.82	4.24 d
TJ-83	5.15	5.00	4.35	4.00	4.63 cd
Moomal	6.20	6.00	5.20	4.90	5.58 a
Abadgar-94	5.80	5.15	5.00	4.70	5.16 ab
Marvi	6.10	5.80	5.50	4.65	5.51 a
Mean	**5.33 a**	**5.13 ab**	**4.8 bc**	**4.31 c**	

*Values followed by similar letters do not differ significantly at p≤0.05

Table 4. Mean performance of wheat genotypes under different salinity levels for root length.

Genotypes	NaCl mol^{-3}m				Mean
	50	100	150	200	
Sarsabz	4.30	4.15	3.90	3.22	3.89 b*
Anmol-91	4.00	3.90	3.50	3.00	3.60 b
Kiran-95	5.10	4.35	4.00	3.50	4.24 ab
Mehran-89	4.00	3.88	3.45	2.95	3.57 b
TJ-83	4.15	3.90	3.51	3.00	3.64 b
Moomal	5.32	5.00	4.25	3.98	4.64 a
Abadgar-94	5.00	4.50	4.00	3.20	4.18 ab
Marvi	5.15	4.33	4.10	3.30	4.22 ab
Mean	**4.63 a**	**4.25 a**	**3.84 b**	**3.27 b**	

*Values followed by similar letters do not differ significantly at p≤0.05

In case of fresh shoot weight, wheat genotypes and salinity levels manifested highly significant differences ($p \leq 0.01$), while their interactions were non-significant (Table 1). In genotypes, the cultivars Moomal, Kiran-95, Marvi, Abadgar and Sarsabz showed maximum and at par fresh weight of 0.55, 0.55, 0.53, 0.51 and 0.50 g, respectively (Table 5). However, cultivar Mehran-89 revealed lowest fresh shoot weight (0.32 g) and other cultivars showed medium fresh shoot weight. Among the salinity levels, low NaCl (50 mol^{-3}m) showed maximum fresh shoot weight (0.60 g) and was found at par with 100 mol^{-3}m (0.51 g). The increased NaCl level (200 mol^{-3}m) displayed lesser fresh shoot weight (0.35 g). In interactions, the cultivars Moomal and Marvi displayed maximum fresh shoot weight (0.71 & 0.68 g) at lowest salinity level of 50 mol^{-3}m. Salinity levels had a significant affect on shoot and root length/weight. Increasing levels of salinity has a detrimental affect on all the parameters studied (Maas & Poss, 2004; Shafi *et al.*, 2006). Vegetative growth of wheat was decreased more by soil salinity and species were less salt tolerant at germination than they were after the three-leaf stage of growth. Ahmed *et al.*, (1998) reported that emergence, dry shoot weight, root length and weight decreased with increasing salinity level in wheat.

According to shoot biomass, the differences in genotypes and salinity levels were highly significant ($p \leq 0.01$), while their interaction was non-significant (Table 1). Genotype Moomal produced maximum dry shoot weight of 0.07 g (Table 6), and was found at par with two cultivars Kiran-95 and Abadgar-95 (0.06 g), while Mehran-89 and TJ-83 displayed low dry shoot weight (0.03 g). Other genotypes showed medium dry shoot weight. The lowest salinity level (50 mol^{-3}m) resulted greater dry shoot weight (0.08 g) followed by 100 mol^{-3}m (0.05 g) and 150 mol^{-3}m (0.03 g), while greater salinity level (200 mol^{-3}m) recorded lowest dry shoot weight (0.02 g). In interactions, numerically the cultivars Moomal and Marvi displayed maximum dry shoot weight (0.11 & 0.10 g) at lowest level of NaCl, respectively. Results demonstrated that cultivars Moomal and Marvi were genetically different from the rest of the genotypes and that's why showed remarkable response for the all the traits even under salt stress conditions. Increased salinity reduced fresh and dry shoot/root weight and relative growth of shoot of wheat (Mansour & Salama, 1996). Drihem & Pilbeam (2002) also reported that plant growth was stimulated by low concentration of NaCl and was depressed by high concentration of NaCl. Excessive amounts of salt will eventually rise to toxic levels in plants and reduce the photosynthetic activities and eventually growth also (Munns, 2002).

Conclusion

On the basis of present investigations, it is concluded that salinity reduced germination %, root and shoot growth and fresh and dry shoot weight in all the wheat genotypes. However, the genotypes Moomal and Marvi were found best performing wheat cultivars even in salinity conditions and provided maximum germination, shoot and root length, and fresh and dry shoot weight as compared to other six genotypes. Therefore, the said two promising genotypes can be used in future breeding programme to develop salt resistant wheat genotypes.

Table 5. Mean performance of wheat genotypes under different salinity levels for fresh shoot weight.

Genotypes	NaCl mol^{-3}m				Mean
	50	100	150	200	
Sarsabz	0.60	0.55	0.48	0.35	0.50 a*
Anmol-91	0.50	0.49	0.37	0.28	0.41 ab
Kiran-95	0.67	0.58	0.50	0.45	0.55 a
Mehran-89	0.48	0.35	0.23	0.20	0.32 b
TJ-83	0.52	0.50	0.44	0.30	0.44 ab
Moomal	0.71	0.58	0.50	0.42	0.55 a
Abadgar-94	0.66	0.52	0.48	0.37	0.51 a
Marvi	0.68	0.55	0.50	0.40	0.53 a
Mean	0.60 a	0.51 ab	0.44 bc	0.35 c	

*Values followed by similar letters do not differ significantly at p≤0.05

Table 6. Mean performance of wheat genotypes under different salinity levels for fresh dry shoot weight.

Genotypes	NaCl mol^{-3}m				Mean
	50	100	150	200	
Sarsabz	0.60	0.55	0.48	0.35	0.50 a*
Anmol-91	0.50	0.49	0.37	0.28	0.41 ab
Kiran-95	0.67	0.58	0.50	0.45	0.55 a
Mehran-89	0.48	0.35	0.23	0.20	0.32 b
TJ-83	0.52	0.50	0.44	0.30	0.44 ab
Moomal	0.71	0.58	0.50	0.42	0.55 a
Abadgar-94	0.66	0.52	0.48	0.37	0.51 a
Marvi	0.68	0.55	0.50	0.40	0.53 a
Mean	0.60 a	0.51 ab	0.44 bc	0.35 c	

*Values followed by similar letters do not differ significantly at p≤0.05

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