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EVALUATION OF SORGHUM VARIETIES/LINES FOR SALT TOLERANCE USING PHYSIOLOGICAL INDICES AS SCREENING TOOL

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Abstract

Salinity is a major threat to irrigated agriculture in Pakistan as it is adversely affecting growth and yield of crops to various extents. So, different strategies have been adopted to overcome this problem of low productivity. Growing of salt tolerant crops is a good option to obtain economical yields from saline areas for which quick method to screen salt tolerant plants, particularly in early stages of their growth is important. For this purpose some green-house studies using some physiological parameters i.e., germination stress tolerance index (GSI), shoot length stress tolerance index (SLSI), root length stress tolerance index (RLSI) and biomass stress tolerance index (BSI) were conducted to identify the salt tolerant lines of sorghum. On the basis of results obtained using the above physiological criteria, sorghum lines JS-2002 and Sandalbar were categorized as tolerant, Hegari- sorghum and JS-263 medium tolerant while Noor as medium sensitive and FJ-115 and PSV-4 as sensitive ones. The results also indicated that the physiological parameters tried in the present study are useful to screen large quantity of sorghum germplasm for salt tolerance leading to selection of suitable lines that can be recommended for different saline areas to improve yields.

Introduction

Soil salinity is an increasing problem in the world and main obstacle to agricultural productivity especially in areas where irrigation is necessary because water contains large amount (about 30 g sodium chloride per liter) of salt (Flower, 2004). According to the United Nations reports, 20% of agricultural land and 50% of world cropland are salt affected (Yokoi *et al*., 2002). Soil salinity is one of the most serious problems in Pakistan (Khan *et al.*, 2006). Saline area in Pakistan is 6.67 million hectares out of the total 20 million hectares of agricultural land (Khan *et al.*, 2006). Salinity and water logging are continuously causing reduction in the cultivated lands every year and one acre of farmland becomes useless for crop production in every 5 minutes (Qureshi & Lennard, 1998).

Plant species differ in their salt tolerance depending on their genetic makeup ranging from high to low levels of salts in the soil. The relative growth rate of the plants in response to differential salinity level is known as their salt tolerance. Higher salinity level retards seed germination and root emergence due to osmotic effect, which is deleterious and prevents the plant in maintaining their proper nutritional requirements necessary for their healthy growth (Hamid *et al*., 2008). Salinity also causes ion toxicity, osmotic stress, mineral deficiencies which adversely affect photosynthetic, physiological and biochemical processes limiting crop yield and production to various levels across species (Krishnamurthy *et al*., 2007; Hamid *et al*., 2008). Sorghum dry matter, total shoot and root dry weights decreased at 2.1 to 5.9 dS m^{-1} (Boursier & Lauchli, 1990). The relative shoot growth, chlorophyll "a" and "b", stomatal conductance, transpiration rate, leaf blades, sheaths, leaf water potential, osmotic potential and relative water contents significantly reduced at 250 m*M* of NaCl through stomatal and non-stomatal factors (Dionisio-Sese & Tobitta, 2000; Netondo *et al.*, 2004). Sodium was retained mainly in roots as compared to shoots and Nitrate reductase activity (NRA) reduced at 100 mg L^{-1} (Khan & Ashraf, 1990). In conclusion, salinity reduces leaf growth, leaf area and photosynthesis and gas exchange processes, thereby total plant growth is affected (Hamid *et al*., 2008).

Sorghum is grown in arid and semi arid regions of the world and is a moderately salt tolerant crop (Gates, 2009). Currently, different strategies are being adopted for alleviating the adverse effects of salinity such as screening of germplasm of different crop plants. Recently, molecular marker techniques are being utilized to find out DNA marker linked with salt tolerance and crop stability (Yokoi *et al.*, 2002). Genetic differences are basis for improvement in plants (Akber *et al*., 2009). Many genetic variations in sorghum cultivars are present in response to salinity tolerance under their genetic control (Netondo *et al*., 2004; Krishnamurthy *et al*., 2007). Accumulation of ions occur more rapidly in sensitive genotypes as compared to tolerant genotypes, which cause leaf death and ultimately death of whole plant (Munns *et al*., 2000; Akram *et al*., 2007). These genetic differences can be exploited to search varieties/cultivars for salt tolerance by rapid screening methods using different growth parameters such as relative shoot growth, leaf blades, sheaths, leaf water potential, osmotic potential, nitrate reductase activity (NRA) and relative water contents etc. Several other physiological characteristics are reliable criteria for screening. Krishnamurthy *et al.*, (2007) reported that germination and emergence stages in grain sorghum might be useful criteria to evaluate the effect of salinity. However, laboratory experiments may not be always an efficient approach under saline conditions because field salinity is present in patches (Ashraf *et al*., 2006). In contrast, Ashraf *et al.*, (2005) found a significant relationship between field and laboratory experiments. In fact, the variation of whole plant growth response is the best source to provide information to identify the salinity tolerant genotypes in sorghum (Khan & Ashraf, 1990).

In the present study the objectives were to firstly evaluate genotypic potential among different sorghum lines/varieties through effective and accelerated screening methods for salinity tolerance and also to determine the toxic effect of salinity on sorghum at various levels of NaCl and to investigate possible screening criteria which may be useful for future breeding programme.

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Materials and Methods

Experimental Conditions: Initially, experiments were conducted in Petri plates under lab conditions using 0 and 100 m*M* NaCl levels to evaluate the salt tolerance potential of 50 advance lines/varieties of sorghum for germination and early seedling growth. On the basis of their performance for germination, 7 better performing lines/varieties were selected to evaluate their salt tolerance potential for different salinity levels using some physiological indices as screening tool.

Fifty seeds of each line / variety were grown in plastic bowls (diameter, 20cm; depth, 10cm) containing washed fine river sand saturated with 0, 50,100,150 and 200 m*M* NaCl solutions. Experiments were conducted in a completely randomized block design with three replications. The experiment was repeated three times in a controlled growth chamber (Sanyo-Gallenkamp, UK) running at 28±2°C and germination was recorded when the radical was of 5 mm in length.

Physiological indices: To calculate the germination stress tolerance index (GSI), promptness index (PI) was estimated using following formula (Ashraf *et al.,* 2008):

$$PI = nd_1(1.00) + nd_2(0.75) + nd_3(0.50) + nd_4(0.25)$$

where nd_1, nd_2, nd_3 and nd_4 = Number of seeds germinated on the 1st, 2nd, 3rd and 4th day, respectively. A germination stress tolerance index (GSI) was calculated in terms of percentage as follows:

GSTI = (PI of stressed seeds / PI of control seeds) x 100

Similarly another experiment was conducted with same 7 lines/ varieties of sorghum in plastic bowls of above mentioned size under above described salinity levels in growth chamber running at 28±2 °C. Plants were allowed to grow for two weeks in growth chamber maintained at 10 h photoperiod with 80 µ*M* sec^{-1} m^{-2} light intensity. After 14 days of the experiment, shoot and root lengths and fresh weights were calculated. The plants were dried at 70°C for two days and their dry weight was also recorded. Root and shoot length stress tolerance index (RLSI, SLSI) and fresh and dry matter stress tolerance indices (FMSI, DMSI) were calculated according to the following formula:

PHSI = (Plant height of stressed plants / Plant height of control plants) x100

RLSI = (Root length of stressed plants / Root length of control plants) x100

SFSI = (Shoot fresh weights of stressed plants / Shoot fresh weights of control plants) x 100

RFSI = (Root fresh weights of stressed plants / Root fresh weights of control plants) x 100

SDSI = (Shoot dry weights of stressed plants / Shoot dry weights of control plants) x 100

RDSI = (Root dry weights of stressed plants / Root dry weights of control plants) x 100

Results

Germination stress tolerance index (GSI) was significantly reduced by the application of salinity. However, it varied in different sorghum cultivars under different levels of salinity. The maximum GSI at 50 m*M* NaCl was recorded in JS-2002, JS-263, Sandal-bar and Noor while minimum was in FJ-115 (Table 1). The highest germination (GSI) under 100 m*M* salinity level was noted for Sandalbar, which was closely followed by PSV-4 and the lowest was in FJ-115. The cultivars Sandalbar and JS-2002 were successful in maintaining the highest GSI at 150 m*M* while FJ- 115 was poorest in performance. Again at 200 m*M* NaCl level, Sandalbar and JS-2002 were at the top and JS-115 was at the bottom of list in their performance. Overall ranking on the basis of GSI indicated that Sandalbar and JS-2002 were tolerant; Hegari-sorghum and PSV-4 medium tolerant and FJ-115, and Noor sensitive ones.

Table 1. Germination stress tolerance index (GSI) of 7 lines/varieties of *Sorghum bicolor* (L.).

Sorghum lines/varieties		NaCl levels (mmol dm^{-3})				Means	Ranking
		50	100	150	200		
V1	JS-2002	100.0 a	86.5 ab	83.5 a	78.2 b	87.1 a	2
V2	JS-263	100.0 a	79.5 c	73.9 c	75.2 b	81.9 b	5
V3	Hegari-sorghum	97.2 a	88.9 ab	79.1 b	57.9 d	80.8 b	3
V4	PSV- 4	93.1 b	90.7 a	75.5 c	69.2 c	82.1 b	4
V5	Sandalbar	100.0 a	92.4 a	83.8 a	82.2 a	89.6 a	1
V6	Noor	100.0 a	85.0 ab	70.3 d	55.9 d	77.8 c	6
V7	FJ-115	89.0 c	66.0 d	52.8 e	27.4 e	58.79 d	7
	Means	**97.04 A**	**84.13 B**	**74.00 C**	**63.69 D**		

Note:- The figures bearing the same small letters in columns and same capital letters in row differed non-significantly at $p \leq 0.05$

The maximum value for plant height stress tolerance index (PHSI) at 50 m*M* was recorded in case of JS-2002 and Sandalbar followed by Hegari-sorghum and minimum PHSI was observed for JS-263 and FJ-115 (Table 2). Under 100 m*M* salt stress, the varieties/lines JS-2002 and Sandalbar proved better and JS-263 followed FJ-115 that proved sensitive. Similarly at 150 and 200 m*M* levels of NaCl, the varieties /lines JS-2002 and Sandalbar attained the maximum biomass and FJ-115 and PSV-4 remained at bottom of the list.

Table 2. Plant height stress tolerance index (PHSI) of 7 lines/varieties of *Sorghum bicolor* (L.).

Sorghum lines/varieties		NaCl levels (mmol dm^{-3})				Means	Ranking
		50	100	150	200		
V1	JS-2002	99.9 a	96.4 a	76.8 a	57.7 a	82.7 a	1
V2	JS-263	72.5 d	55. 4 c	46.8 c	33.5 c	52.0 d	5
V3	Hegari- sorghum	98.3 a	87.2 b	60.9 b	39.3 bc	71.4 b	3
V4	PSV- 4	84.7 b	58.8 c	32.9 d	30.1 d	51.7 d	5
V5	Sandalbar	99.9 a	89.2 b	74.5 a	52.6 a	79.1 a	2
V6	Noor	96.2 a	76.4 c	48.6 c	44.3 bc	66.4 c	4
V7	FJ-115	76.0 d	59.3 c	45.1 c	20.3 e	50.2 d	7
	Means	**89.62 A**	**74.66 B**	**55.07 C**	**39.66 D**		

Note:- The figures bearing the same small letters in columns and same capital letters in row differed non-significantly at $p \leq 0.05$

The data regarding root length stress tolerance index (RLSI) revealed that at all levels of NaCl, the variety JS-2002 attained maximum root length followed by Sandalbar as compared to all other varieties/lines (Table 3). However, at 50 and 100 m*M* concentrations of NaCl, the variety /line JS-263 showed decline in RLSI followed by Noor. While, at 150 m*M* level, the variety /line PSV-4 exhibited lowest value followed by FJ-115. Similarly at 200 m*M* concentration, minimum RLSI was recorded in case of PSV-4 and Noor. So keeping in view the results of RLSI, it is evident that JS-2002 and Sandalbar are salt tolerant and FJ-115, Noor and PSV-4 may be categorized as sensitive varieties.

Table 3. Roots lengths stress tolerance index (RLSI) of 7 lines/varieties of *Sorghum bicolor* (L.).

Sorghum lines/varieties		NaCl levels (mmol dm^{-3})				Means	Ranking
		50	100	150	200		
V1	JS-2002	93.9 a	86.1 a	55.7 a	42.5 a	69.5 a	1
V2	JS-263	48.4 d	36.0 e	34.3 d	31.4 b	37.5 d	6
V3	Hegari- sorghum	78.8 b	59.7 c	35.3 d	25.7 c	49.9 c	4
V4	PSV- 4	84.1 b	61.8 c	27.0 e	22.9 c	48.9 c	5
V5	Sandalbar	92.0 a	86.3 a	47.7 b	33.5 b	64.9 a	2
V6	Noor	63.1 c	45.1 d	29.9 e	15.5 d	38.4 d	7
V7	FJ-115	83. 3 b	82.8 b	41.7 c	31.5 b	59.8 b	3
	Means	**77.65 A**	**65.40 B**	**38.81 C**	**28.98 D**		

Note:- The figures bearing the same small letters in columns and same capital letters in row differed non-significantly at $p \leq 0.05$

Salinity significantly reduced the shoot fresh weight stress tolerance index (SFSI) of all varieties/ lines of sorghum at all levels. The reduction was increased in all lines/varieties with increasing level of salinity. Under 50 m*M* of NaCl, the maximum reduction was observed in case of FJ-115 followed by Noor and minimum reduction was recorded for JS-2002 followed by PSV-4. Similarly at salinity level of 100 m*M*, the minimum reduction in SFSI was recorded in JS-2002 and Sandalbar while it was maximum in FJ-115, which was followed by Noor (Table 4). Overall, on the basis of SFSI, the varieties Sandalbar and JS-2002 showed better results as compared to others. However, FJ-115 followed by Noor exhibited poor performance against salinity.

Table 4. Shoots fresh weights stress tolerance index (SFSI) of 7 lines/varieties of *Sorghum bicolor* (L.).

Sorghum lines/varieties		NaCl levels (m mol dm^{-3})				Means	Ranking
		50	100	150	200		
V1	JS-2002	83.5 a	71.7 a	62.7 a	50.0 a	**67.0 a**	1
V2	JS-263	74.6 b	56.8 cd	38.3 c	35.8 b	**51.4 b**	4
V3	Hegari- sorghum	70.1 b	65.3 b	50.9 b	33.8 b	**55.1 b**	3
V4	PSV- 4	82.7 a	64.1 b	36.9 c	33.6 b	**54.3 b**	6
V5	Sandalbar	79.9 a	71.3 a	51.9 b	45.2 a	**62.1 a**	2
V6	Noor	60.5 c	51.9 cd	37.4 c	29.6 c	**44.9 c**	5
V7	FJ-115	56.0 d	48.0 e	24.0 d	20.0 d	**37.0 d**	7
	Means	**63.42 A**	**53.63 B**	**37.77 C**	**31.00 D**		

Note:- The figures bearing the same small letters in columns and same capital letters in row differed non-significantly at $p \leq 0.05$

On the basis of root fresh weights stress tolerance index (RFSI), the varieties /lines JS-2002 and JS-263 showed better results and Sandabar and Noor showed poor performance at 50 m*M* of NaCl. In the same way at 100 m*M* of salinity, the varieties/lines JS-2002 and PSV-4 attained maximum weights while Noor, Sandalbar and FJ-115 showed minimum values (Table 5). Same trend was shown by all these varieties/lines at 150 and 200 m*M* levels. Shoot dry weight stress tolerance index (SDSI) was inversely related to increasing salinity levels (Table 6). At all levels of NaCl, the SDSI were recorded maximum in JS-2002 and Sandalbar, while minimum in case of FJ-115 and JS-263 at 50 m*M* salinity. At 100 m*M* level, JS-263 followed by FJ-115 showed poor results. Similarly, at 150 and 200 m*M* levels, PSV-4 and FJ-115 showed poor performance against salinity.

In the same way, root dry weight significantly indicated a decrease with progressive increase in salinity level. Root dry weight stress tolerance index (RDSI) was with the highest value at 50 m*M* in variety/line JS-2002 followed by JS-263, Noor, Sandalbar and PSV-4, while it was noted minimum in FJ-115 followed by Hegari-sorghum (Table 7). However, at 100 m*M* level of NaCl, the JS-2002, JS-263 and Noor showed maximum RDSI followed by Sandalbar and FJ-115 remained lower in the list. At 150 m*M* concentration of NaCl, the variety/line JS-2002 attained maximum RDSI followed by Sandalbar and Noor while FJ-115 remained at the bottom. Similarly at 200 m*M* levels of salinity, JS-2002 and Sandalbar showed maximum RDSI which was minimum in FJ-115 and Noor. So in view of the above results, it may be concluded that two lines/varieties viz. JS-2002 and Sandalbar are tolerant while FJ-115 and Noor are sensitive to salinity.

Table 5. Roots fresh weights stress tolerance index (RFSI) of 7 lines/varieties of *Sorghum bicolor* (L.).

Sorghum lines/varieties		NaCl levels (m mol dm^{-3})				Means	Ranking
		50	100	150	200		
V1	JS-2002	99.5 a	88.9 a	88.4 a	84.9 a	90.4 a	1
V2	JS-263	89.3 b	70.7 c	68.8 c	66.9 c	73.9 c	3
V3	Hegari- sorghum	71.8 c	68.8 c	67.5 c	64.93 c	68.3 c	4
V4	PSV- 4	85.1 b	77.5 b	74.6 b	74.0 b	77.8 b	2
V5	Sandalbar	58.4 e	48.5 e	47.2 de	45.7 d	49.9d	6
V6	Noor	58.2 e	47.2 e	44.0 de	43.4 de	48.2 d	7
V7	FJ-115	63.2 d	59.8 d	54.7d	39.3 de	54.3 d	5
	Means	**75.1 A**	**65.9 B**	**63.6 BC**	**59.9 BC**		

Note:- The figures bearing the same small letters in columns and same capital letters in row differed non-significantly at $p \leq 0.05$

Table 6. Shoots dry weights stress tolerance index (SDSI) of 7 lines/varieties of *Sorghum bicolor* (L.).

Sorghum lines/varieties		NaCl levels (m mol dm^{-3})				Means	Ranking
		50	100	150	200		
V1	JS-2002	93.5 a	73.1 b	63.1 b	54.6 a	**71.1 a**	2
V2	JS-263	52.0 d	46.0 e	46.0 d	30.0 cd	**43.5 e**	5
V3	Hegari- sorghum	61.4 c	61.4 d	42.9 de	28.6 cde	**48.6 d**	6
V4	PSV- 4	78.9 b	69.7 bc	39.5 de	34.2 c	**55.6 c**	4
V5	Sandalbar	90.6 a	90.1 a	70.4 a	54.7 a	**76.5 a**	1
V6	Noor	78.4 b	68.2 bc	56.4 c	48.4 b	**62.8 b**	3
V7	FJ-115	59.0 c	56.4 d	28.2 f	25.6 cde	**42.3 e**	7
	Means	**73.4 A**	**66.4 B**	**49.5 C**	**39.5 D**		

Note:- The figures bearing the same small letters in columns and same capital letters in row differed non-significantly at $p \leq 0.05$

Table 7. Roots dry weights stress tolerance index (RDSI) of7 lines/varieties of *Sorghum bicolor* (L.).

Sorghum lines/varieties		NaCl levels (m mol dm^{-3})				Means	Ranking
		50	100	150	200		
V1	JS-2002	100.0 a	100.0 a	100.0 a	99.0 a	100.3 a	1
V2	JS-263	100.0 a	100.0 a	82.5 b	68.8 c	87.8 b	2
V3	Hegari- sorghum	66.0 b	66.0 c	66.0 c	52.8 d	62.7 d	5
V4	PSV- 4	100.0 a	95.0 a	70.0 c	16.3 e	70.3 c	4
V5	Sandalbar	100.0 a	86.2 b	86.2 b	79.3 b	87.9 b	2
V6	Noor	100.0 a	100.0 a	86.5 b	51.4 d	84.5 b	3
V7	FJ-115	60.0 b	60.0 c	40.0 d	20.0 e	45.0 e	6
	Means	**89.7 A**	**86.7 A**	**75.9 B**	**55.4 C**		

Note:- The figures bearing the same small letters in columns and same capital letters in row differed non-significantly at $p \leq 0.05$

Discussion

The main purpose of the study was to identify salt tolerant genotypes in sorghum germplasm in relation to biomass production at early vegetative growth stages under different levels of salinity.

On the basis of germination stress tolerance index, for the soils having 50 m*M* of salinity, the varieties/lines, JS-2002, JS-263, Sandalbar, and Noor can be recommended while for soil with salinity level close to 100 m*M* or 10 dS m^{-1} the varieties Sandalbar, JS-2002 and PSV-4 can prove suitable (Table 1). Similarly, at 150 to 200 m*M* level of salinity, Sandalbar and JS-2002 could be grown to have maximum germination. It is well-documented fact that if crop stand is good then the yield will be higher than that crop with poor stand. There are many reports which indicate that the genotypes which maintained higher germination under saline conditions produced higher biomass and yield (Ashraf *et al.,* 2006; Krishnamurthy *et al*., 2007), however, in contrast, the salt tolerant cultivars can be identified on the basis of germination stress tolerance index because during germination, seed vigor and seed storage conditions also affect. However, in the present study, healthy seeds having similar size and good viability were used. So in this case the reduction in germination stress tolerance index may have been due to the effect of salinity. Results of Hamid *et al*., (2008) also confirmed the present findings. Higher salinity level retard seed germination and root emergence due to osmotic effect which is deleterious and prevent the plants from maintaining their proper nutritional requirements necessary for their healthy growth (Krishnamurthy *et al*., 2007).

The data regarding plant height stress tolerance index indicated that the varieties/lines JS-2002 and Sandalbar are salt tolerant and FJ-115 proved salt sensitive at all concentrations of NaCl (Table 2). The variety JS-263, at lower salinity levels (50 and 100 m*M*) while PSV-4 at higher levels (150 and 200 m*M*) of salinity showed sensitive behavior towards salinity. These differences might be due to the genetic variation among lines/varieties (Krishnamurthy *et al*., 2007). Overall, PHSI of all varieties/lines exhibited decline with all increasing level of salinity. Reduction in plant growth due to the adverse effect of salinity has been also reported in many other crops (Ashraf & O' leary, 1997; Hasegawa *et al*., 2000; Krishmamurthy *et al*., 2007).

In the present experiment, root length stress tolerance index showed that JS-2002 and Sandalbar could be grown as salt tolerant varieties up to 20 dS m^{-1} of salinity (Table 3) because they produced the maximum biomass and it is well known fact that tolerant lines/ varieties produce more yield and biomass under saline environment than sensitive lines (Ashraf *et al*., 2008). However at lower levels of salinity (5 dS m^{-1} and 10 dS m^{-1}), JS-263, FJ-115 and Noor exhibited maximum decrease in root growth (Table 3). Plants vary in their tolerance to salinity that depends on their efficiency of root system with regards to nutrient absorption and K, Na uptake discrimination (Khan *et al*., 1995) or mainly the translocation of sodium and chloride ions. In sorghum sodium mainly remained in roots as compared to shoots (Khan & Ashraf, 1990) that might be due to the mechanism of retention more of Na^+ in roots (Khan *et al.,* 1995) as compared to other plant parts.

According to shoot fresh weight stress tolerance index at lower levels of salinity, the varieties JS-2002, Sandalbar and PSV-4 showed better results as compared to others lines/varieties, while FJ-115 followed by Noor that remained at the lowest level (Table 4). However, at higher levels of salinity, JS-2002 and Sandalbar proved as the most salt tolerant and FJ-115 and Noor were noted as sensitive ones. It is well known that salinity reduces the productivity of most crops (Krishnamurthy *et al*., 2007; Hamid *et al*., 2008).

So, JS-2002 and Sandalbar can be recommended for an area having salinity up to 200 m*M* or 20 dS m^{-1}. The results clearly indicated that according to the root fresh weight stress tolerance index in the lines/varieties, JS-2002 attained maximum biomass at all levels of applied salinity and proved that it can be grown as the most tolerant variety in salt-affected areas and varieties /lines Sandalbar and PSV-4 as moderately tolerant and the varieties/lines FJ-115 and Noor may be categorized as salt sensitive (Table 5). These results confirmed the findings of Hasegawa *et al*., (2000); Krishmamurthy *et al*., (2007). Similarly Akram *et al*., (2007) and Hamid *et al*., (2008), noted that root fresh weights, root dry weights, shoot lengths showed decline with increasing levels of salinity with NaCl in all hybrids of maize (Z*ea mays* L.), sugarcane and wheat respectively.

Shoot dry weight stress tolerance index of the lines/varieties JS-2002 and Sandalbar showed maximum biomass production, so they can be considered for cultivation as tolerant varieties at all levels of salinity tried and FJ-115, JS-263, PSV-4 and Hegari-sorghum are sensitive because they produced minimum biomass (Table 6). However, salinity reduced the shoot biomass production at all levels. These results are in accordance with Yurtseven *et al.*, 2005. It is well established fact now that the highest levels of NaCl in the given medium caused stunted growth of plants (Takemura *et al*., 2000). Salinity reduced dry mass of both roots and shoots of sorghum and damaged the leaves which may be due to accumulation of Na^+ in leaves (Khan *et al.*, 1995). However, tolerant varieties have lower uptake of Na^+ than sensitive ones (Ashraf *et al*., 2008). Roots, the first developing organ is sensitive to increasing levels of salinity (Akram *et al*., 2007). In fact, lower availability of O_2 under saline conditions deprives the plants from energy source and accumulation of high level of ethylene inhibits root growth (Akram *et al*., 2007). On the basis of root dry weights stress tolerance index (Table 7), it was clear that salinity decreased growth of roots at all concentrations. However, JS-2002 followed by Sandalbar produced maximum root biomass as compared to all others and FJ-115 remained the lowest in value and showed sensitive behavior towards salinity. These findings are in agreement with those of Ashraf *et al*., (2008).

Keeping in view the above results it is clear that salinity reduced all growth parameters at all levels. Reduction in growth may be due to lower transport rate of essential ions like NO_3^- that reduced the N compounds and increased Na^+ in plant under high salinity (Hamid *et al*., 2008). Biomass production at 50 and 100 m*M* NaCl levels was reduced by 48 and 59 % in beans and by 14 % in cotton (Gouia *et al*., 1994). Toxic ions like Na^+, SO_4^{2-} and Cl^- severely inhibit the uptake of NO_3^- (Chien *et al*., 2009).

Yurtseven *et al*., (2005) reported that biomass decreased with increasing salinity levels in plants. The relative shoot lengths of seedlings are related with the biomass production and plant tolerance is directly related to more absorption of K^+ and lower shoot Na^+ concentrations which may positively relate to K^+/Na^+ and Ca^{2+} /Na^+ ratios of plants (Krishnamurthy *et al*., 2007). The results of present study regarding biomass reducing due to salinity are similar to that of previous investigations (Igartua *et al*., 1995; Netondo *et al*., 2004; Krishnamurthy *et al*., 2007).

It is concluded that salinity reduces growth parameters like leaf surface expansion, fresh dry weights of leaves, stem and roots which are inversely related to increasing levels of NaCl (Ashraf & O, leary, 1997; Chartzoulakis & Kalapaki, 2000), which has also been reported by many other researchers (Takemura *et al*., 2000; Ashraf *et al*., 2003; Krishnamurthy *et al*., 2007). Several workers have proved that tolerance of plants in their rooting medium is under genetic control (Munns *et al*., 2000). Genetic variabilities are basis for improvement in plants (Akber *et al*., 2009). Crops have shown genetic variability for salinity stress and sorghum has great potential of variability (Netondo *et al*., 2004). These genetic differences presents a good basis to provide information about lines/ varieties of sorghum that could be grown in salt-affected areas to chance crop productivity, and also for determining degree of salt tolerance in different plant species to further utilize them in breeding programme.

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