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MORPHO-PHYSIOLOGICAL RESPONSES OF SELECTED SORGHUM (*Sorghum bicolor* L.) GENOTYPES TO SALINITY STRESS AT EARLY VEGETATIVE STAGE

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ABSTRACT

A hydroponic experiment was conducted to study the morphological and physiological responses of selected sorghum genotypes to salinity stress at early vegetative stage with a view to screen salt tolerant genotypes. Nine sorghum genotypes *viz.* BD 687, BD 688, BD 689, BD 690, BD 691, BD 692, BD 693, BD 694 and BD 695 were grown in hydroponics with a full nutrient solution at 12 dSm^{-1} and control condition for fourteen days. Different morphological and physiological parameters *viz.* root length, shoot length, shoot dry weight, root dry weight, total dry matter, root shoot ratio, relative chlorophyll content and maximum photochemical efficiency of PSII (Fv/Fm) were recorded. Most of the parameters mentioned above showed significant variation due to salinity stress and also among the genotypes. The stress tolerance index for root and shoot lengths varied from 70-93, and 67-92, respectively. Root and shoot weights were greatly affected by the stress and the genotypes studied exhibited large variations in respect of tolerance indices that ranged from 62-78 and 62-93 for shoot and root dry weights, respectively. Leaf greenness expressed in SPAD values and Maximum photochemical efficiency of PSII (Fv/Fm) was varied due to the stress and among the genotypes. SPAD values and Fv/Fm in different genotypes ranged from 29.6-20.2, and 0.78-0.71, respectively under control and, 28.3-18.2 and 0.77-0.67, respectively under the stress. Based on the responses to the stress the genotypes BD 688, BD 690 and BD 693 appeared to be more tolerant compared to other genotypes studied.
Key words: Sorghum, salinity, genotype.

Introduction

Salinity is one of the major environmental stresses limiting crop production of marginal agricultural lands in many parts of the world. Worldwide, it is an increasing problem and main obstacle to the crop productivity especially in areas where crops should be irrigated (Ahloowalia *et al.*, 2004) because water contains high amount (about 30g NaCl/L) of salt. Salinity stress involves changes in various physiological and metabolic processes, depending on severity and duration of the stress and ultimately inhibits crop production (James *et al.*, 2011). Effect of Salinity on plant growth is a complex syndrome that involves osmotic stress, ion toxicity, mineral deficiencies, physiological and biochemical perturbations and combination of these stresses (Hasegawa *et al.*, 2000). Sorghum [*Sorghum bicolor* (L.)], a major grain and forage crop, was previously characterized as moderately tolerant to salinity, can tolerate up to 8.6 dSm^{-1}soil salinity without any reduction to its yield (Maas *et al.*, 1986). It is originated from Africa (Tari *et al.*, 2013) and is a C4 carbon cycle plant belonging to the Poaceae (or Gramineae) family with high photosynthetic efficiency and productivity. It is one of the five major cultivated species in the world because it has several economically important potential uses such as 55% as food (grain), 33% as feed (grain and biomass) and others are as fuel (ethanol production), fibre (paper), fermentation (methane production) and fertilizer (utilization of organic by-products) (Krishnamurthy *et al.*, 2007). It is the only crop from which ethanol can be produced from grain (starch), juice (sweet sorghums) and biomass (lignocellulose). It also has biological nitrification inhibition activity which reduces the loss of N from the field. Based on the tolerance to soil salinity, the crops were ranked as sorghum>sunflower>sugar beet>maize> barley> linseed>chili> sweet potato> cowpea>groundnut. In Bangladesh, it would contribute enhancing food, nutrition and energy security in the country with higher productivity during the fallow period. There is a large genotypic variation for tolerance to salinity reported in sorghum (Sun *et al.*, 2014). It is important to note that germination and early seedling growth are more sensitive to salinity than later developmental stages

(Macharia *et al.*,1994) and salt tolerance varies with the varieties (Azhar and McNeilly, 1987). In fact, the variation in whole plant biomass responses to salinity was considered to provide the best means of initial selection of salinity tolerant genotypes (Krishnamurthy *et al.*, 2007). In Bangladesh, there is a very little study on the screening of sorghum genotypes against salinity and no studies included any of the Bangladeshi local lines or genotypes. Thus, to provide more information about variation in salinity tolerance and to improve crop productivity on bare lands of the country, the relative salt tolerance of nine sorghum genotypes was determined at seedling stage based on morpho-physiological parameters in hydroponic culture. The objectives of the study were as follows: i) To determine the adverse effect of salinity on morpho-physiological characters of hydroponically grown sorghum genotypes and ii) To evaluate some potential saline tolerant sorghum genotypes based on the responses to salinity at early vegetative stage for onward selection to saline-prone areas of Bangladesh.

Materials and Methods

An experiment was conducted in the growth chamber of the Department of Crop Botany of Bangladesh Agricultural University (BAU), Mymensingh. The experimental site falls under the AEZ 9 (Old Brahmaputra Floodplain) of Bangladesh and situated at latitude 24.75° N and longitude of 90.50° E. The experiments were conducted in November 2018. Nine sorghum genotypes were used in the experiment to test their morpho-physiological attributes against salinity at osmotic phase. Seeds of 9 sorghum genotypes were collected from Bangladesh Agricultural Research Institute (BARI).

Table 1. List of genotypes used for this study

Sl.	Genotypes	Symbol	Origin
1	BD 687	V1	BARI
2	BD 688	V2	BARI
3	BD 689	V3	BARI
4	BD 690	V4	BARI
5	BD 691	V5	BARI
6	BD 692	V6	BARI
7	BD 693	V7	BARI
8	BD 694	V8	BARI
9	BD 695	V9	BARI

The experiments were set in two factors Completely Randomized Design (CRD) having three replications. The nine genotypes were randomly assigned to one tank. Therefore, 6 tanks were required for the experiment. The salinity treatments were: Control (T1): 0 dSm^{-1} and Salinity regime (T2): 12 dSm^{-1}. For salinization, crude salt was dissolved in a nutrient solution to reach the desired salinity level. The salinity level was measured through EC using Sension EC-5 meter (Hach, Loveland, Colorado, US). At the age of 21 days of sorghum seedlings, saline treatments were imposed for next 14 days. The experimental data were recorded from the screening at seedling stage in both normal and salinized condition at 14 days after salinization. The collected data were analyzed statistically following Completely Randomized Design by Statistix-10 computer package program. Data analysis was done using analysis of variance (ANOVA) and $P<0.05$ was considered as significant. The multiple comparisons of treatment means were done by Tukey HSD t-test.

Results and Discussion

In this experiment root length, shoot length, shoot dry weight, root dry weight, root shoot ratio, salt tolerance index for different parameters at seedling stage of all the sorghum genotypes declined with salinity though increased with time of incubation in all salinity regimes but never reached to the level of control. On the basis of root length, shoot length, root shoot ratio BD 688, BD 690, BD 693 performed better at 12 $dSm^{-1}$and BD 694 showed little tolerance (Table 2). Generally, the velocity of germination was greatly impeded by salinity and so there was a significantly high reduction in final root length and shoot length under high NaCl concentration. Salt stress influences vegetative growth primarily by sufficiently lowering the osmotic potential of the soil solution to retard water absorption by seeds, by causing sodium and/or chloride toxicity to the embryo or by altering protein synthesis. Hyper-osmotic stress and toxic effects of sodium and chloride ions on germinating seeds in a saline environment may delay or inhibit seedling growth (Hasegawa *et al*., 2000). The interaction between salinity levels and genotypes at osmotic phase had a significant effect on total dry matter. Results revealed that total dry matter was less affected in BD 687. The interaction between salinity levels and genotypes had also significantly difference effect on root shoot ratio. Results revealed that root shoot ratio was less affected in BD 695 (Table 2). The present study shows that salinity antagonisms to the normal growth of sorghum seedlings as indicated by shoot and root (Table 2) length stress tolerance index and their dry (Table 2) weight were observed in the experiments. Consequently, the root-shoot ratio and total dry matter decreased with increasing salinity. These results are consistent with Qu *et al*. (2012); Farooq *et al*. (2015).

Table 2. Effect of salinity stress on morphological traits, fresh and dry weights of different parts in hydroponically grown plants of 9 sorghum genotypes

Genotypes	Salinity Stress	Root Length (mm)	Shoot Length (mm)	Root DW (g plant $^{-1}$)	Shoot DW (g plant $^{-1}$)	Total DM (g plant $^{-1}$)	Root-Shoot ratio
BD 687	0 dSm^{-1}	32	39.5	0.04	0.073	0.11	1.01
	12 dSm^{-1}	24.7	34	0.04	0.056	0.09	0.72
BD 688	0 dSm^{-1}	36	50	0.06	0.08	0.14	0.84
	12 dSm^{-1}	32	40	0.05	0.063	0.11	0.81
BD 689	0 dSm^{-1}	28.7	45.5	0.07	0.073	0.14	1.02
	12 dSm^{-1}	25	37.3	0.06	0.047	0.10	1.38
BD 690	0 dSm^{-1}	29.7	50.8	0.09	0.11	0.2	0.82
	12 dSm^{-1}	19.3	41.7	0.07	0.076	0.15	0.98
BD 691	0 dSm^{-1}	30	48	0.09	0.1	0.20	0.84
	12 dSm^{-1}	25.1	39	0.07	0.083	0.09	0.90
BD 692	0 dSm^{-1}	28	40.6	0.056	0.083	0.14	0.67
	12 dSm^{-1}	26	37.5	0.036	0.06	0.09	0.65
BD 693	0 dSm^{-1}	28.5	50	0.076	0.09	0.17	0.88
	12 dSm^{-1}	22.1	33.7	0.06	0.073	0.13	1.16
BD 694	0 dSm^{-1}	28.3	44	0.09	0.09	0.18	0.98
	12 dSm^{-1}	22.7	35	0.07	0.056	0.13	1.39
BD 695	0 dSm^{-1}	33.1	46	0.09	0.076	0.17	1.18
	12 dSm^{-1}	25.1	38.3	0.07	0.05	0.12	1.67
Level of Significance							
Genotype (G)		NS	NS	**	**	**	NS
Stress (S)		**	**	**	**	**	NS
Interaction (G×S)		NS	NS	NS	NS	NS	NS

** = Significant at 1% level of significance, NS = Not significant; DW = Dry Weight

The effect of salinity levels and genotypes had a significant effect on root length (Fig 1). The highest root length stress tolerance was observed in BD 692 (93.2%) followed by BD 688 (88.5%) while the minimum root length was observed in BD 695. The effect of salinity levels and genotypes had also a significant effect on shoot length (Fig 1). The highest shoot length was observed in BD 692 (91.7%) followed by while the minimum shoot length was observed in BD 693 (67.7%). The effect of salinity levels and genotypes had significantly difference effect on root dry weight stress tolerance index (Fig. 2). The highest root dry weight stress tolerance index was observed in BD 687 (93.3%) while the maximum weight loss was observed in BD 688 (74.6%). The effect of salinity levels and genotypes had also a significant effect on shoot length (Fig. 2). The highest shoot dry weight stress tolerance index was observed in BD 688 (78.9g plant^{-1}) followed by while the minimum shoot length was observed in BD 694 (61.7g plant^{-1}).

Relative chlorophyll content measured as SPAD value at the end of the experiment. In this experiment, significant differences were observed in SPAD value at osmotic stress but no differences were found in SPAD values among control and salt treatment, regardless of genotype. The Relative chlorophyll content was less affected by salt stress in BD 690 than the others and it was more affected in BD 695 (18.2). The maximum photochemical efficiency of PSII, FV/Fm value was recorded in BD 690 (0.77) in contrast minimum was in BD 695(0.67). Though there was a significant difference among the genotypes and salinity, there was no significant variation in the interaction effect (Table 3). For sorghum genotypes, the effect of salt on chlorophyll fluorescence parameters F_V/F_m was not significant over time. A similar result was found by Niu *et al.*, 2012. This may be because every time the fully expanded new leaf was measured, instead of the same leaf on different days.

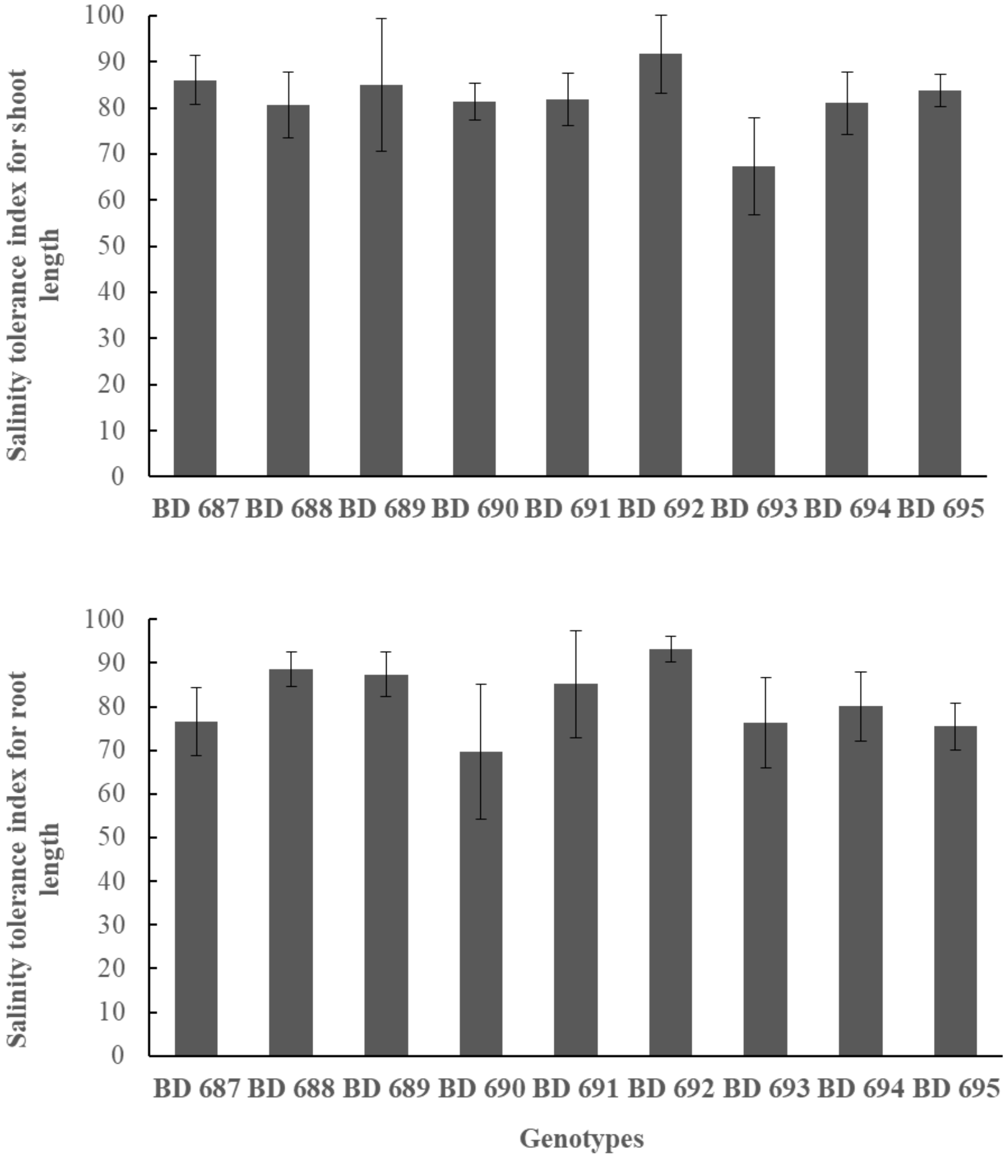
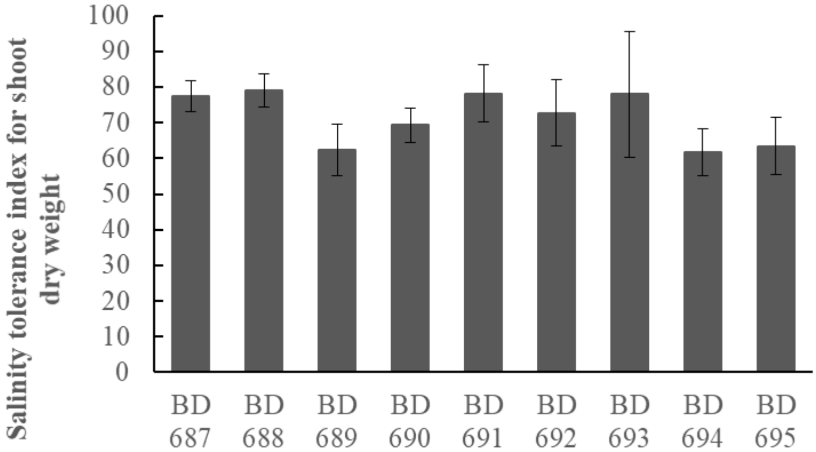


Fig1. Salinity tolerance index for shoot and root lengths in 9 sorghum genotypes. Vertical bars represent standard errors of means, SE (r=3)



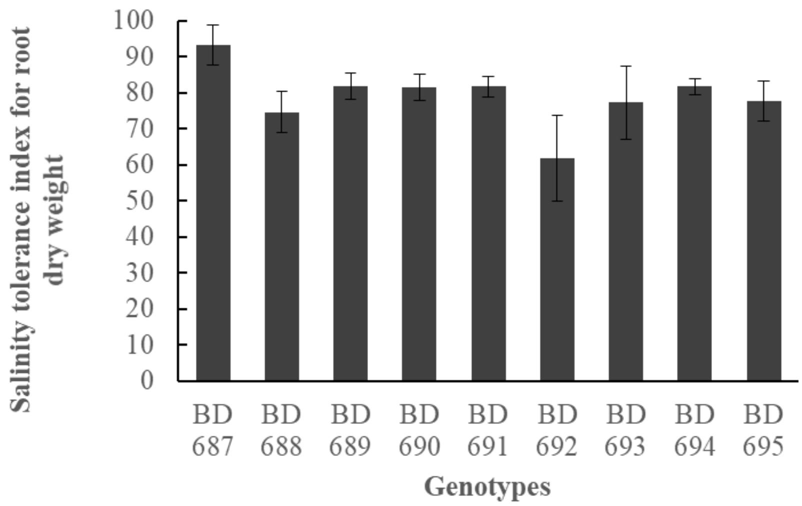


Fig. 2. Salinity tolerance index for shoot and root dry weights in 9 sorghum genotypes. Vertical bars represent standard errors of means, SE (r=3)

Table 3. Effect of salinity on Leaf greenness (SPAD reading) and Maximum photochemical efficiency of PSII (F_v/F_m)in hydroponically grown plants of 9 sorghum genotypes.

Genotypes	Salinity Stress	Leaf greenness (SPAD reading)	Maximum photochemical efficiency of PSII (Fv/Fm)
BD 687	0 dSm^{-1}	28.7	0.76
	12 dSm^{-1}	26.2	0.75
BD 688	0 dSm^{-1}	25.7	0.77
	12 dSm^{-1}	22.4	0.75
BD 689	0 dSm^{-1}	28.2	0.75
	12 dSm^{-1}	24.5	0.71
BD 690	0 dSm^{-1}	29.5	0.78
	12 dSm^{-1}	28.3	0.77

Genotypes	Salinity Stress	Leaf greenness (SPAD reading)	Maximum photochemical efficiency of PSII (Fv/Fm)
BD 691	0 dSm^{-1}	29.6	0.78
	12 dSm^{-1}	25.5	0.75
BD 692	0 dSm^{-1}	21.7	0.75
	12 dSm^{-1}	28.1	0.73
BD 693	0 dSm^{-1}	28.8	0.76
	12 dSm^{-1}	27.1	0.74
BD 694	0 dSm^{-1}	28.1	0.76
	12 dSm^{-1}	24.4	0.74
BD 695	0 dSm^{-1}	20.3	0.71
	12 dSm^{-1}	18.2	0.67
Level of Significance			
Genotype (G)		**	**
Stress (S)		**	**
Interaction (G×S)		NS	NS

** = indicates significant at 0.1% level of significance, NS = indicates not significant

Conclusion

1. At vegetative stage under salt stress, tolerant genotypes exhibited a minimum relative reduction of morpho-physiological properties.
2. BD 688, BD 690 and BD 693 genotypes were found salt tolerant while BD 694 appeared salt sensitive based on physiological characteristics at salinity stress.

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