Fundamental and Applied Agriculture
Vol. 4(1), pp. 735–743: 2019
doi: 10.5455/faa.18483

Crop Science
ORIGINAL ARTICLE

Screening of sorghum genotypes for salt-tolerance based on seed germination and seedling stage

Ashaduzzaman Sagar[1], Jannat E Tajkia[1], Md Eakramul Haque[2], Md Solaiman Ali Fakir[1], A K M Zakir Hossain[1*]

[1]Department of Crop Botany, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh
[2]Bangladesh Agricultural Research Institute (BARI), Rangpur, Bangladesh

ARTICLE INFORMATION

Article History
Submitted: 23 Nov 2018
Revised: 21 Dec 2018
Accepted: 30 Dec 2018
First online: 14 Jan 2019

Academic Editor
Md Alamgir Hossain

*Corresponding Author
A K M Zakir Hossain
zakir@bau.edu.bd

ABSTRACT

Soil salinity is an increasing problem in the world and main obstacle to agricultural productivity especially in areas where irrigation is necessary. Adoption of salt tolerant genotype is more important here and so screening of salt tolerant genotypes by quick method, particularly in early stages of their growth is essential. Some laboratory studies using nine sorghum genotypes were conducted to screen salt tolerant genotypes during germination and seedling growth stages. The genotypes were Hybrid sorgo, Debgiri, BD 703, BD 706, BD 707, BD 713, BD 720, BD 725 and BD 738 and salinity levels were 0 dS m^{-1} (control), 6 dS m^{-1}, 12 dS m^{-1} and 18 dS m^{-1}. There were 36 (9 $\times$ 4) treatments in a completely randomized design (CRD) with three replications. Saline treatments were imposed by sea water. To screen out the salt-tolerant genotypes - germination percentage, rate of germination, vigor index and different physiological parameters i.e. germination stress tolerance index (GSTI), root length stress tolerance index (RLSI), shoot length stress tolerance index (SLSI) and fresh weight stress tolerance index (FSTI) were studied. In this study, all the parameters were decreased with increasing salinity. Results showed that sorghum genotypes Hybrid sorgo, BD 703 and BD 707 were categorized as tolerant while Debgiri and BD 713 were as sensitive ones. Besides these, sorghum genotypes were not tolerant up to 18dS m^{-1} though some of them were tolerant at 12 dS m^{-1}. Overall, these tolerant and sensitive genotypes might be used in the further genetic improvement of the same and different crops.

Keywords: Sorghum, cereal, salinity, osmotic stress, growth mechanism, physiological indices

Cite this article: Sagar A, Tajkia JE, Haque ME, Fakir MSA, Hossain AKMZ. 2019. Screening of sorghum genotypes for salt-tolerance based on seed germination and seedling stage. Fundamental and Applied Agriculture 4(1): 735–743. doi: 10.5455/faa.18483

1 Introduction

Sorghum (*Sorghum bicolor* L. Moench) is a moderately saline tolerant grain and forage crop, (Tabatabaei and Anagholi, 2012), can tolerate up to 8.6 dS m^{-1} soil salinity (Maas et al., 1986). It is originated from Africa (Tari et al., 2012) and a C4 carbon cycle plant of the Poaceae (syn. Gramineae) family with high productivity and photosynthetic efficiency. It is one of the five major cultivated species in the world having several economically important uses such as 55% as food (grain), 33% as feed (grain and biomass) and others are as fuel (ethanol), fibre (paper), fermentation (methane) and fertilizer (organic by-products) (ICRISAT, 2009; Roy et al., 2018). It is the only crop from which ethanol can be produced from grain (starch), juice (sweet sorghums) and biomass (lignocellulose). It is also a very hard crop which can withstand to a severe water scarce condition (Khaton et al., 2016) and has biological nitrification inhibition (BNI) capacity which reduces the loss of N by denitrification (Hossain et al., 2008). Besides this, there is a large genotypic variation for tolerance to salinity in sorghum (Sun et al., 2014). Based on the salinity tolerance, the crops are ranked as sorghum> sunflower> sugarbeet> maize> barley> linseed> chili> sweet potato> cowpea> groundnut.

Salinity is one of the major environmental stresses which limit crop yield of the agricultural lands in the coastal parts of the world. Due to global warming, intrusion of saline water in the coastal region is increasing day by day and salt stress has become a serious threat to crop production (Farooq et al., 2015). Crop productions become limited especially where irrigation is necessary for cultivation because water contains high amount ($\sim$ 30 g NaCl L^{-1}) of salt (Kausar et al., 2012). Osmotic stress, ion toxicity, physiological and biochemical perturbations, alteration in the internal structures and mineral deficiencies are the main consequences of salinity stress (Niu et al., 2012). Osmotic stress become active from the beginning of the application of salt and ion toxicity affects the plant growth after prolonged exposure (Munns and Tester, 2008).

Due to genetic makeup, crop plants vary in their tolerance to salinity ranging from low to high levels of salts in the soil solution. The comparative growth rate of the plant species in response to differential salt stress is known as their salt tolerance. Seed germination and radicle emergence become retarded by higher salinity (Kausar et al., 2012) and leads to poor crop establishment which prevents the crop in maintaining their nutritional necessities for their healthy growth due to osmotic stress (Farooq et al., 2015). Salinity causes osmotic stress, ion toxicity and mineral deficiencies which affect photosynthetic, physiological and biochemical processes adversely limiting crop yield and production (Hamid et al., 2008). Commonly, osmotic stress and direct toxic effects of salt stress delay the initiation, lower the rate and disperse the germination events (Farsiani and Ghobadi, 2009). Consequently, per cent germination, root and shoot dry weights, relative root and shoot growth etc. become adversely affected resulting in poor crop establishment (Tari et al., 2012).

In Bangladesh, salt stress is a major crisis and the saline area has been augmented to 1.056 million ha from 0.833 million ha in the last four decades i.e. about 63% of the agricultural lands are salinity affected and they remain fallow during dry season due to adverse effect of salinity (SRDI, 2010). As sorghum has the tremendous potentiality to grow under salinity, it would contribute in enhancing food, nutrition and energy security of the country by cultivating it in the fallow land in the dry period. In Bangladesh, there is a very little study on the screening of sorghum genotypes against salinity stress and there is a very few study for salinity tolerance including Bangladeshi local genotypes or local lines (Roy et al., 2018). Thus, to provide more information about variation in salinity tolerance, morpho-physiological parameters of nine sorghum genotypes was determined at germination and seedling stage.

2 Materials and Methods

The experiment was conducted at the growth chamber of the Department of Crop Botany in Bangladesh Agricultural University. Nine sorghum genotypes were used in the experiment for screening based on germination as affected by different levels of salinity. From the nine genotypes Hybrid sorgo and Debgiri were collected from Japan and the rest of the genotypes (BD 703, BD 706, BD 707, BD 713, BD 720, BD 725, BD 738) were collected from Bangladesh Agricultural Research Institute (BARI).

The two factorial germination test was set up in Completely Randomized Design (CRD) with three replications. Factor A was nine genotypes while factor B was four salinity treatments (0, 6, 12, 18 dS m^{-1}). The different salinity levels were obtained by dissolving sea water collected from sea shore until the treatment level reached by checking the EC meter. The control i.e. 0 was maintained using distilled water only. Therefore, 108 petri dishes were taken for the experiment. At first, seeds were sterilized with 5% sodium hypochlorite for 30 min. and washed thoroughly with distilled water. These seeds were then soaked in water and were imbibed for 24 h and then the seeds were placed in the petri dishes containing filter paper to allow them to germinate. Then ten seeds of a genotype were set up in a petri dish and were salinized with respective sea water solution and distilled water. Each treatment was performed for three times were allowed to germinate at around 25 °C. Germination percentage, germination stress tolerance index (GSTI), rate of germination, vigor index, root length and root length stress tolerance index (RLSI), shoot length and shoot length stress tolerance index (PLSI), fresh weight stress tolerance index (FSTI), were determined in all the treatments.

2.1 Per cent germination

The number of sprouted and germinated seeds was counted daily commencing from 1st day till 5th day. After 5 d, final count was done and germination percentage of final day was calculated by the following formula:

$$\%GE = \frac{S_G}{S_T} \times 100 \quad (1)$$

weher, $\%GE$ = germination percentage, S_G = total number of seeds germinated, and S_T = total number of seeds taken for germination.

2.2 Physiological indices

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

$$PI = (nd_1 \times 1.0) + (nd_2 \times 0.75) + (nd_3 \times 0.50) + (nd_4 \times 0.25) \quad (2)$$

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 (GSTI) was calculated in terms of percentage as follows:

$$GSTI = \frac{PI_S}{PI_C} \times 100 \quad (3)$$

where, PI_S and PI_C designate PI of stressed and control seeds, respectively.

Similarly, root and shoot length stress tolerance index (RLSI, SLSI) and fresh weight stress tolerance indices (FSTI) were calculated according to the following formula:

$$RLSI = \frac{RL_S}{RL_C} \times 100 \quad (4)$$

$$SLSI = \frac{SL_S}{SL_C} \times 100 \quad (5)$$

$$FSTI = \frac{FW_S}{FW_C} \times 100 \quad (6)$$

where, RL, SL, FW designate root length (cm), shoot length (cm), fresh weight (g), respectively and subscript S and C associated with each equation designate stressed and control seedlings, respectively.

2.3 Rate of germination

Rate of germination (RG) was calculated as described in the following formula (Khodarahmpour, 2011; Sagar, 2017):

$$RG = \sum \frac{G_{c_1}}{d_{c_1}} + \frac{G_{c_2} - G_{c_1}}{d_{c_2}} + \ldots + \frac{G_{c_n} - G_{c_{(n-1)}}}{d_{c_n}} \quad (7)$$

where, G_{c_1}, G_{c_2} and G_{c_n} designate the cumulative seed germination 1st, 2nd and nth counts, respectively, and d_{c_1}, d_{c_2} and d_{c_n} designate days to 1st, 2nd and nth counts, respectively from the date to seed set for germination.

2.4 Vigor index

Vigor index was calculated as described in the following Formula:

$$VI = \frac{S_L}{GE} \quad (8)$$

where, S_L and GE designate seedling length (cm) and percent germination, respectively.

2.5 Shoot and root length

Shoot and root length of all sproutings from each replication were measured daily from 1st to 5th days. Shoot length was measured from shoot base to the tip of the longest leaf and root length was measured from root base to the root tip.

2.6 Root and shoot fresh weight

Roots and shoots were separated from the seedlings immediately after harvest and fresh weight were recorded.

2.7 Statistical analysis

The collected data were analyzed statistically following Completely Randomized Design by Statistix-10 computer package programme. Data analysis was done using analysis of variance (ANOVA) and p<0.05 was considered as significance. The multiple comparisons of treatment means were done by Tukey's HSD *posthoc* test.

3 Results

3.1 Per cent germination

Salinity stress significantly ($p \leq 0.001$) reduced the germination percentage of the sorghum genotypes. Generally, in control condition, the percentage of germination was the highest and it decreased gradually with increasing salinity. Result revealed that the decrement of germination due to salinity was lesser in hybrid sorgo, BD 703 and BD 738 than the other six genotypes. In control, the highest germination was observed in BD 703 (100%) and BD 738 (100%) while the lowest was in Debgiri (86.7%; Fig. 1a). The maximum germination under 6 dS m^{-1} salinity level was noted for BD 703 and the minimum was in Debgiri. The genotypes hybrid sorgo and BD 703 were unbeaten in maintaining the highest germination at 12 dS m^{-1} while BD 706, BD 720 and BD 725 were the poorest in performance. Again at 18 dS m^{-1} salinity, hybrid sorgo was at the top and BD 713 and BD 720 were at the bottom of the list in their performance. Overall ranking on the basis of per cent germination indicated that hybrid sorgo, BD 703 and BD 738 were tolerant, BD 707, BD 713 and BD 725 were as medium tolerant and Debgiri sensitive ones.

3.2 Germination stress tolerance index

Germination stress tolerance index (GSTI) was significantly affected in different sorghum genotypes by the application of salinity. In each case, GSTI was 100 in control condition. But the maximum GSTI value at 6 dS m^{-1} was recorded in BD 713 (112.3) followed by BD 720 (103.2). Both of them scored higher than control which indicates slightly saline condition increases the germination and the minimum GSTI at 6 dS m^{-1} was in hybrid sorgo followed by Debgiri (Fig. 1b). Under 12 dS m^{-1} salt stress, BD 713 and hybrid sorgo proved better and Debgiri followed by BD 706 that proved sensitive. Similarly at 18 dS m^{-1} salinity BD 738, BD 703 and hybrid sorgo were at the top and BD 720, BD 713 and BD 706 were at the bottom of the list. On the basis of the consistency of GSTI observed for BD 713, BD 738 and Hybrid sorgo were as tolerant and Debgiri were as sensitive ones.

3.3 Vigor index

Salinity stress drastically decreased the seedling vigor of the sorghum genotypes. The interaction between salinity levels and genotypes at germination stage showed a significant effect on vigor index (Fig. 1c). Results revealed that seedling vigor was maximum in BD 707 (348.0) in contrast Debgiri was minimum in all the genotypes at controlled condition. Under 6 dS m^{-1}, vigor index was less affected in BD 707 followed by BD 713 and Hybrid sorgo on the other hand vigor index was drastically affected in Debgiri and BD 706. Again at 12 dS m^{-1}, BD 703 showed the highest Vigor index while BD 713 showed the lowest one. Again at 18 dS m^{-1} no genotypes showed better vigor index. So keeping in view the results of vigor index it is evident that BD 707, BD 703 and Hybrid sorgo were tolerant and BD 738 and Debgiri classified as sensitive genotypes.

3.4 Rate of germination

The interaction between salinity levels and genotypes had a significant effect on germination rate (Fig. 1d). The highest rate was observed in BD 703 and BD 707 (4.9 and 4.8 number in a day respectively) and the lowest rate was observed in BD 720 in control condition. In slight salinity like 6 dS m^{-1} BD 713 and BD 703 were less affected while Debgiri was more affected. A little increase in rate of germination was found in BD 713 at 6 dS m^{-1} (4.7) salinity than control (4.2). Again BD 703 and hybrid sorgo showed the maximum rate while BD 706 and Debgiri showed the minimum rate at both 12 and 18 dS m^{-1}. So overall BD 703, BD 738 and Hybrid sorgo were tolerant genotypes and BD 720 and Debgiri were susceptible in view of rate of germination.

3.5 Root length

The interaction between salinity levels and genotypes had a significant effect on root length (Table 1). Results revealed that root length was maximum in BD 707 (30.1 mm) followed by BD 703 (24.0 mm) at the controlled condition and minimum was in BD 713 and Debgiri. Similarly, BD 707, Hybrid sorgo, BD 725 and BD 738 showed the highest root length at 6 dS m^{-1} and BD 720 attained the minimum root length. At 12 dS m^{-1}, BD 703 and BD 707 had the highest root length while BD 713 had the lowest one. And in 18 dS m^{-1}, root length was drastically affected in all the genotypes.

3.6 Root length stress tolerance index

Like root length, RLSI was adversely affected by different levels of salinity. In each case, RLSI was 100% in control condition. After that the maximum RLSI value was recorded in BD 738 at 6 dS m^{-1} (81.3) while minimum was in BD 703. At 12 dS m^{-1}, Debgiri had the highest RLSI while BD 713 had the lowest value. Like root length, RLSI was also drastically affected in all the genotypes at 18 dS m^{-1} (Table 1).

3.7 Shoot length

Salinity stress significantly reduced the shoot length of all the genotypes at 1% level of significance. The longest shoot in control condition was observed in BD 725 (7.0 mm) followed by Hybrid sorgo and the shortest shoot was for BD 713 and BD 738. Under 6 dS m^{-1} BD 707 and Hybrid sorgo were at the top and BD 738 followed by BD 725 were at the bottom of the list. Again at 12dS m^{-1} Debgiri and BD 703 showed longest shoot while BD 738 showed the shortest. In contrast, the shoot length was affected severely in all the genotypes at 18 dS m^{-1} salinity.

3.8 Shoot length stress tolerance index

Like RLSI, SLSI was 100% in control condition. After that at 6 dS m^{-1}, the maximum SLSI value was recorded in BD 713 (50.4) which was statistically similar with Hybrid sorgo and BD 707 and the minimum SLSI was BD 725. At 12 dS m^{-1} Debgiri and BD 703 showed better performance while BD 738 affected mostly. And like shoot length no value for the SLSI was found in all the genotypes at 18 dS m^{-1} (Table 1).

3.9 Seedling length

Seedling length of the genotypes was drastically affected by high levels of salinity. The interaction be-

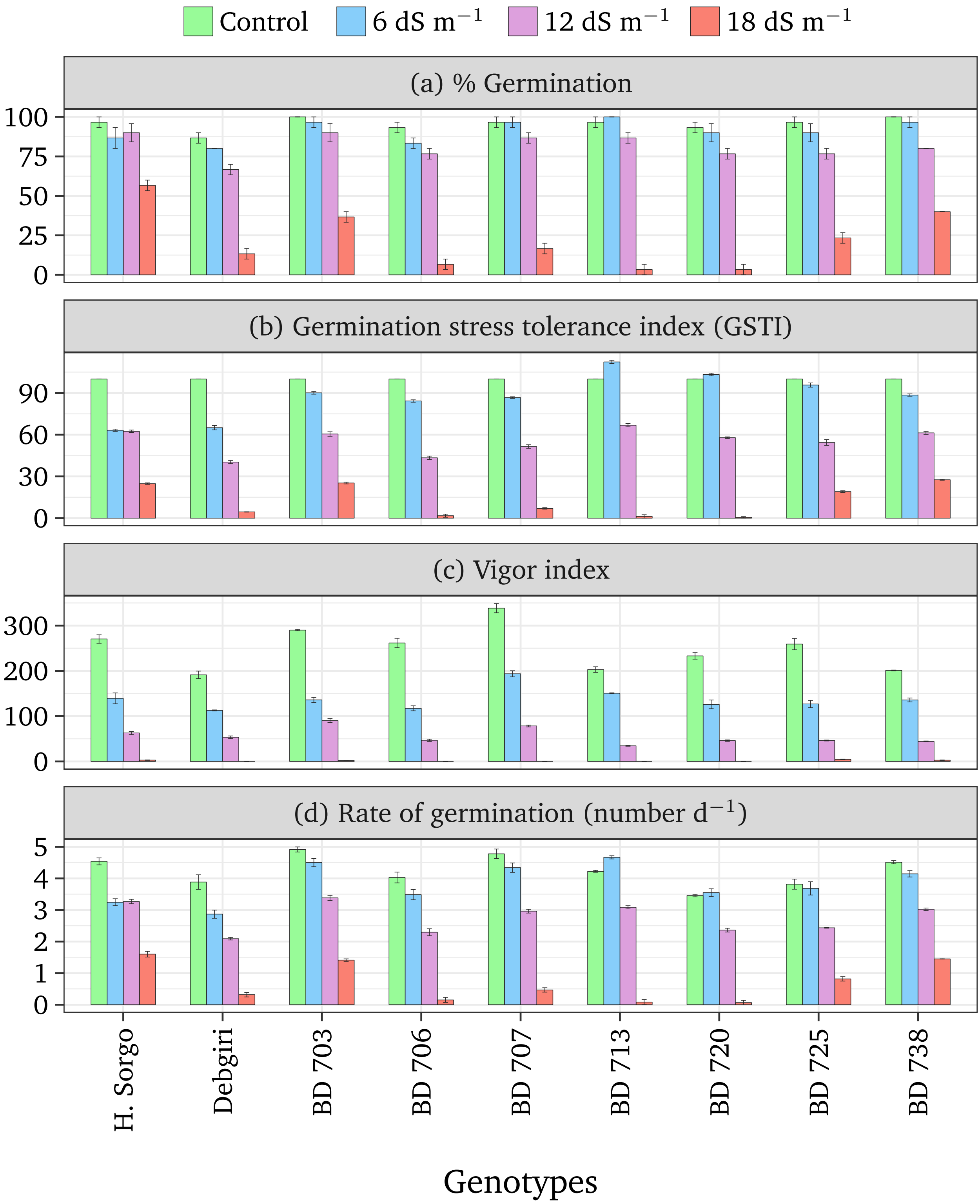

Figure 1. Effect of salinity on (a) per cent germination, (b) germination stress tolerance index (GSTI), (c) vigor index, and (c) rate of germination of different genotypes of sorghum. Vertical bars are SEM (n=3). H. Sorgo denotes Hybrid Sorgo

tween salinity levels and genotypes at germination stage showed a significant effect on seedling length (Table 1). Results revealed that in control maximum seedling height was obtained by BD 707 while minimum in BD 738. At 6 dS m^{-1} seedling length was less affected in BD 707 followed by Hybrid sorgo in contrast BD 720 were more affected. At 12 dS m^{-1}, BD 703 and BD 707 showed maximum height while BD 713 showed minimum. Again limited height of the seedling was found in all the genotypes at 18 dS m^{-1}. So, keeping in view the results of the plant height, it is evident that BD 707, BD 703 and Hybrid sorgo were tolerant while Debgiri, BD 738 and BD 713 were sensitive to salinity. Besides this, 18 dS m^{-1} salinity was intolerable to sorghum genotypes as their shorter growth.

3.10 Fresh weight stress tolerance index

Fresh weight stress tolerance index (FSTI) was significantly reduced by the application of salinity. In control condition FSTI was 100% in all the genotypes. After that, the maximum FSTI value was recorded in BD 720 at 6 dS m^{-1}, which was statistically similar with BD 703 while minimum FSTI was recorded in BD 720 at 18 dS m^{-1} (Table 1).

4 Discussion

Salinity is a global problem and in Bangladesh, a large area is affected by salinity and remains fallow during winter or boro season. Therefore the main purpose of the study was to screen salt tolerant genotypes in sorghum in relation to germination and early seedling growth stages under different levels of salinity.

It is a recognized truth that tolerance at mature stage is expressed by the tolerance at early stage of the plant. This matter has been proved in maize (Khan et al., 2003), sorghum (Kausar et al., 2012), wheat (Rahnama et al., 2010), rice (Islam and Karim, 2011). So, the experiment was taken in germination stage. In this experiment, germination percentage, GSTI, the rate of germination and vigor index of all the sorghum genotypes declined with salinity though it was increased with time of incubation in all salinity regimes but never reached to the level of control. On the basis of germination, Hybrid sorgo and BD 703 performed better at different levels of salinity and Debgiri showed little tolerance. It is well established fact that genotypes which showed better performance under salinity produced higher biomass and yield later (Krishnamurthy et al., 2007).

Final germination percentage was reduced due to the reduced velocity of the process and this happened because salt stress primarily lower the water potential of the solution to hinder the water and nutrient absorption by seeds, and also cause sodium and chloride toxicity to the embryo or alter the protein synthesis (Kazemi, 2011). A differing result was found in the study that slight salinity increased the rate of the germination process in BD 713 and BD 720 at 6 dS m^{-1} salinity. Similar result was found by (Panuccio et al., 2014) and it might be due to sensitive genotypes react first and fast at salinity stress or due to osmopriming. Again poor sprout emergence caused by hypocotyls death associated with the salts accumulation at the root surface (Sun et al., 2014) because in sorghum, sodium stored more in roots as compared to shoot (Khan et al., 1990). Therefore, salinity reduced the root and shoot growth and ultimately reduced the biomass of the sorghum genotypes. As root is the first developing organ, reduced growth occurred here at first due to the limited O_2 under salinity which deprived the plants of energy source and gathering of higher ethylene that inhibit root growth (Akram et al., 2010). Reduced shoot development occurred due to the inhibition of leaf opening and spreading out as well as internode growth and by accelerating leaf abscission (Qu et al., 2012).

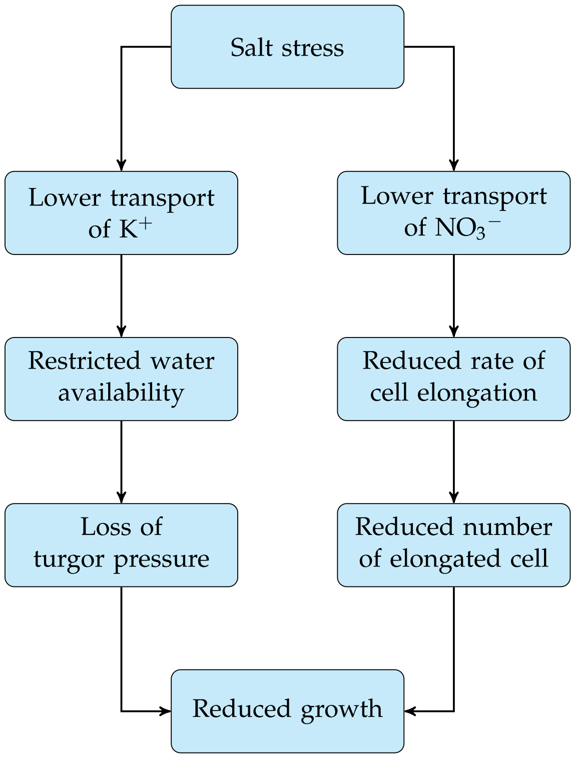

Figure 2. Mehcanism of plant growth reduction under salinity stress

The present study showed that salinity opposite to the regular growth of sorghum seedlings, as indicated by shoot and root (Table 1) length stress tolerance index. Consequently, the root-shoot ratio (Table 1) and total dry matter (Table 1) decreased with increasing salinity. These results are consistent with Qu et al. (2012). They found NaCl salinity led to be short of growth characters and the shoot was more affected than the root, while leaf indices was declined signifi-

Table 1. Combined effect of genotypes and salinity level on seedling characteristics of sorghum based on germination

Geno. × Salinity†	Root length (mm)	RLSI	Shoot length (mm)	SLSI	Seedling length (cm)	FSTI
H. Sorgo × 0	22.0 c	100 a	6.0 b	100 a	2.8 c	100 a
H. Sorgo × 6	13.1 g	59.5 f	3.0 e	49.8 b	1.6 i	51.5 g-j
H. Sorgo × 12	6.0 k	27.3 k	1.0 g	16.5 g	0.7 o	50.8 h-k
H. Sorgo × 18	0.5 o	2.4 r	0.0 h	0.0 i	0.1 t	47.0 j-m
Debgiri × 0	17.1 e	100 a	5.0 c	100 a	2.2 f	100 a
Debgiri × 6	12.1 h	70.9 d	2.0 f	39.9 c	1.4 k	52.5 f-i
Debgiri × 12	6.0 k	35.3 i	2.0 f	40.1 c	0.8 n	50.3 h-k
Debgiri × 18	0.0 p	0.0 s	0.0 h	0.0 i	0.0 u	44.6 l-n
BD 703 × 0	24.0 b	100 a	5.0 c	100 a	2.9 b	100 a
BD 703 × 6	12.1 h	50.2 h	2.0 f	40.3 c	1.4 k	62.1 bc
BD 703 × 12	8.0 i	33.5 i	2.0 f	40.2 c	1.0 l	59.8 cd
BD 703 × 18	0.5 o	2.2 r	0.0 h	0.0 i	0.1 t	56.4 d-g
BD 706 × 0	22.0 c	100 a	6.0 b	100 a	2.8 c	100 a
BD 706 × 6	12.1 h	54.8 g	2.0 f	33.4 d	1.4 k	60.1 cd
BD 706 × 12	5.1 l	23.0 n	1.0 g	17.0 h	0.6 p	58.7 c-e
BD 706 × 18	0.0 p	0.0 s	0.0 h	0.0 i	0.0 u	52.7 f-i
BD 707 × 0	30.1 a	100 a	5.0 c	100 a	3.6 a	100 a
BD 707 × 6	17.0 e	56.7 g	3.0 e	49.8 b	2.0 h	46.2 k-n
BD 707 × 12	7.0 j	23.4 mn	2.0 f	34.8 d	0.9 m	44.3 l-n
BD 707 × 18	0.0 p	0.0 s	0.0 h	0.0 i	0.0 u	43.0 mn
BD 713 × 0	17.0 e	100 a	4.0 d	100 a	2.1 g	100 a
BD 713 × 6	13.0 g	76.8 c	2.0 f	50.4 b	1.5 j	57.7 c-f
BD 713 × 12	3.0 l	17.6 o	1.0 g	25.0 e	0.4 r	51.9 g-j
BD 713 × 18	0.0 p	0.0 s	0.0 h	0.5 i	0.0 u	46.1 k-n
BD 720 × 0	20.0 d	100 a	5.0 c	100 a	2.5 e	100 a
BD 720 × 6	12.0 h	60.0 f	2.0 f	39.8 c	1.4 k	67.3 b
BD 720 × 12	5.0 l	25.1 lm	1.0 g	20.0 f	0.6 p	61.6 c
BD 720 × 18	0.0 p	0.0 s	0.0 h	0.0 i	0.0 u	55.5 d-h
BD 725 × 0	19.8 d	100 a	7.0 a	100 a	2.7 d	100 a
BD 725 × 6	13.1 g	66.3 e	1.0 g	14.4 h	1.4 k	55.4 d-h
BD 725 × 12	5.0 l	25.4 l	1.0 g	14.5 h	0.6 p	48.4 i-l
BD 725 × 18	2.0 n	10.1 p	0.0 h	0.0 i	0.2 s	41.7 n
BD 738 × 0	16.1 f	100 a	4.0 d	100 a	2.0 h	100 a
BD 738 × 6	13.1 g	81.3 b	1.0 g	24.5 e	1.4 k	60.4 cd
BD 738 × 12	5.0 l	31.2 j	0.5 gh	12.7 h	0.6 q	53.6 a-h
BD 738 × 18	0.7 o	4.3 q	0.0 h	0.0 i	0.1 t	46.8 j-n
Level of Sig.‡	***	***	***	***	***	***

† Salinity is expressed as dS m^{-1}; In a column, values having similar letter(s) do not differ significantly at 5% level of probability by Tukey's HSD *posthoc* test. Geno. and H. Sorgo denote genotypes and Hybrid Sorgo, respectively; ‡ = *** indicates significant at 0.1% level of significance

cantly measured up to the control plants. Reduction in growth may be caused by a reduced number of elongated cells and the reduced rate of cell elongation (Farooq et al., 2015; Sagar, 2017) and these happen due to lower transport rate of essential ions like NO_3^- due to salinity that reduce the N compounds and increased Na^+ in plant under high salinity (Hamid et al., 2008). Again, loss of turgor pressure and restricted water availability to the cell caused a reduction in fresh weight of the plant (Fig. 2). In accordance with the above results it is clear that all growth parameters were reduced by salinity at all levels.

5 Conclusions

Salinity adversely affected the plant growth and development in germination and seedling stage of sorghum. But in BD 713 and BD 720, lower salinity accelerated the germination process though they couldn't withstand later. In this study, Hybrid Sorgo, BD 703 and BD 707 showed the tolerance up to 12 dS m^{-1} on the basis of per cent germination, GSTI, SLSI, RLSI and many other physiological idices but no genotypes were tolerant up to 18 dS m^{-1}. On the other hand, Debgiri and BD 713 appeared as salt sensitive genotypes. Thus, these genetic differences present a good basis to provide information about genotypes of sorghum that could be produced in the saline area and also could be used further in breeding programs.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

Akram M, Ashraf M, Ahmad R, Rafiq M, Ahmad I, Iqbal J. 2010. Allometry and yield components of maize (*Zea mays* L.) hybrids to various potassium levels under saline conditions. Archives of Biological Sciences 62:1053–1061. doi: 10.2298/abs1004053a.

Ashraf MY, Hussain F, Akhter J, Gul A, Ross M, Ebert G. 2008. Effect of different sources and rates of nitrogen and supra optimal level of potassium fertilization on growth, yield and nutrient uptake by sugarcane grown under saline conditions. Pakistan Journal of Botany :1521–1531.

Farooq M, Hussain M, Wakeel A, Siddique KHM. 2015. Salt stress in maize: effects, resistance mechanisms, and management. A review. Agronomy for Sustainable Development 35:461–481. doi: 10.1007/s13593-015-0287-0.

Farsiani AR, Ghobadi ME. 2009. Effects of PEG and NaCl stress on two cultivars of corn (*Zea mays* L.) at germination and early seedling stages. World Academy of Science Engineering & Technology 57:382–285.

Hamid M, Ashraf MY, Arashad M, et al. 2008. Influence of salicylic acid seed priming on growth and some biochemical attributes in wheat grown under saline conditions. Pakistan Journal of Botany 40:361–367.

Hossain AKMZ, Subbarao GV, Pearse SJ, Subramaniam G, Ito O, Ishikawa T, Kawano N, Nakahara K, Yoshihashi T, Ono H, Yoshida M. 2008. Detection, isolation and characterization of a root-exuded compound, methyl 3-(4-hydroxyphenyl) propionate, responsible for biological nitrification inhibition by sorghum (*Sorghum bicolor*). New Phytologist 180:442–451. doi: 10.1111/j.1469-8137.2008.02576.x.

ICRISAT. 2009. International Crop Research Institute for Semi-Arid Tropics. Hyderabad, India.

Islam M, Karim M. 2011. Evaluation of rice (*Oryza sativa* L.) genotypes at germination and early seedling stage for their tolerance to salinity. The Agriculturists 8. doi: 10.3329/agric.v8i2.7578.

Kausar A, Ashraf MY, Ali I, Niaz M, Abbass Q. 2012. Evaluation of sorghum varieties/lines for salt tolerance using physiological indices as screening tool. Pakistan Journal of Botany 44:47–52.

Kazemi K. 2011. Effects of salt stress on germination and early seedling growth of rice (*Oryza sativa*) cultivars in Iran. African Journal of Biotechnology 10:17789–17792. doi: 10.5897/ajb11.2219.

Khan AA, Rao SA, McNeilly T. 2003. Assessment of salinity tolerance based upon seedling root growth response functions in maize (*Zea mays* L.). Euphytica 131:81–89. doi: 10.1023/a:1023054706489.

Khan AH, Ashraf M, Azmi A. 1990. Effect of sodium chloride on growth and nitrogen metabolism of sorghum. Acta Physiologiae Plantarum 12:233–238.

Khaton MA, Sagar A, Tajkia JE, Islam MS, Mahmud MS, Hossain AKMZ. 2016. Effect of moisture stress on morphological and yield attributes of four sorghum varieties. Progressive Agriculture 27:265–271.

Khodarahmpour Z. 2011. Screening maize (*Zea mays* L.) hybrids for salt stress tolerance at germination stage. African Journal of Biotechnology 10:15959–15965. doi: 10.5897/ajb11.2493.

Krishnamurthy L, Serraj R, Hash CT, Dakheel AJ, Reddy BVS. 2007. Screening sorghum genotypes for salinity tolerant biomass production. Euphytica 156:15–24. doi: 10.1007/s10681-006-9343-9.

Maas E, Poss J, Hoffman G. 1986. Salinity sensitivity of sorghum at three growth stages. Irrigation Science 7:1–11. doi: 10.1007/bf00255690.

Munns R, Tester M. 2008. Mechanisms of salinity tolerance. Annual Review of Plant Biology 59:651–681. doi: 10.1146/annurev.arplant.59.032607.092911.

Niu G, Xu W, Rodriguez D, Sun Y. 2012. Growth and physiological responses of maize and sorghum genotypes to salt stress. ISRN Agronomy 2012:1–12. doi: 10.5402/2012/145072.

Panuccio MR, Jacobsen SE, Akhtar SS, Muscolo A. 2014. Effect of saline water on seed germination and early seedling growth of the halophyte quinoa. AoB PLANTS 6:plu047–plu047. doi: 10.1093/aobpla/plu047.

Qu C, Liu C, Gong X, Li C, Hong M, Wang L, Hong F. 2012. Impairment of maize seedling photosynthesis caused by a combination of potassium deficiency and salt stress. Environmental and Experimental Botany 75:134–141. doi: 10.1016/j.envexpbot.2011.08.019.

Rahnama A, James RA, Poustini K, Munns R. 2010. Stomatal conductance as a screen for osmotic stress tolerance in durum wheat growing in saline soil. Functional Plant Biology 37:255–263. doi: 10.1071/fp09148.

Roy RC, Sagar A, Tajkia JE, Razzak MA, Hossain AZ. 2018. Effect of salt stress on growth of sorghum germplasms at vegetative stage. Journal of the Bangladesh Agricultural University 16:67–72. doi: 10.3329/jbau.v16i1.36483.

Sagar A. 2017. Screening of sorghum germplasms for salinity tolerance based on morphophysiological and biochemical traits. MS Thesis, Bangladesh Agricultural University, Bangladesh.

SRDI. 2010. Saline Soils of Bangladesh. Soil Resource Development Institute, Dhaka, Bangladesh.

Sun Y, Niu G, Osuna P, Zhao L, Ganjegunte G, Peterson G, Peralta-Videa JR, Gardea-Torresdey JL. 2014. Variability in salt tolerance of *Sorghum bicolor* L. Agricultural Science 2:9–21. doi: 10.12735/as.v2i1p9.

Tabatabaei SA, Anagholi A. 2012. Effects of salinity on some characteristics of forage sorghum genotypes at germination stage. International Journal of Agriculture and Crop Sciences 4:979–983.

Tari I, Laskay G, Takács Z, Poór P. 2012. Response of sorghum to abiotic stresses: A review. Journal of Agronomy and Crop Science 199:264–274. doi: 10.1111/jac.12017.

The Official Journal of the **Farm to Fork Foundation**
ISSN: 2518–2021 (print)
ISSN: 2415–4474 (electronic)
http://www.f2ffoundation.org/faa