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Impact of Water Salinity on upland Cotton Genotypes at Seedling Growth Stage

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ABSTRACT

Expansion of cotton in saline areas of Bangladesh requires to identify cotton genotypes that can thrive under saline environment. The study was performed to identify salinity tolerance cotton genotypes at seedling growth stage in 2019 at Salinity Management and Research Center, Batiaghata, Khulna, Bangladesh. Eight cotton genotypes namely CB-12, CB-14, CB- Hybrid-1, Rupali-1, DM-2, JA-17/6, JA-17/5 and JA—17/7 were evaluated under six saline 5, 10, 15, 20, 25 and 30 dS m^{-1} and one non-saline (control) condition. The experiment was conducted in a completely randomized design (CRD) with three replications. Different water salinity used in this study significantly influenced the growth of cotton genotypes. Under the growth at 30 dS m^{-1}, the less reduction of root length was in genotype JA-17/7 (44%), root fresh weight and dry weight of root were reduced lowest of 42% in CB Hybrid-1, the lowest reduction of shoot length of 37% was recorded in genotype JA-17/6, the genotype Ja-17/5 showed the lowest decrease fresh weight of shoot of 45% and the decrease of the dry weight of shoot was lowest in genotype JA-17/5 and JA-17/6. The genotype CB-14, CB Hybrid-1, Rupali-1, JA-17/6, JA-17/5 and JA-17/7 were identified as the moderately tolerant genotype against salinity based on relative performance of growth under the salinity level of 20 dS m^{-1}. These genotypes have the potentiality to grow under salinity stress condition.

KEY WORDS: Cotton Genotype, Dry Weight, Fresh Weight, Tolerance, Salinity, Seedling.

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1. INTRODUCTION

Cotton is an important cash crop of Bangladesh. The country currently produces only 3-4% (nearly 0.17 million bales) of the total requirements and the remaining raw cotton is imported from different countries. There is a scope to expand cotton cultivation in saline and drought prone areas, hilly areas in Bangladesh (ICCAD, 2018). The coastal area covers about 20% of the country and is characterized by severe soil and water salinity which is increasing in changing climate and seriously affects crop growth (Haque *et al*., 2014; Ahmed *et al*., 2017). The coastal and offshore area (2.85 million ha) of Bangladesh includes tidal, estuaries and river floodplains in the south along the Bay of Bengal. The magnitude and extent of soil salinity are increasing with time. Most of the agricultural land remains uncultivated in southern coastal belt during the dry season due to unavailability of quality irrigation water.

The effects of high salt concentration in soils are observed in plants includes physiological changes including stomatal closure, hyper osmotic shock, inhibition of cell division, and photosynthesis. However, the most common effect is the imbalance of nutrient uptake, low osmotic potential and ion-toxicity resulting stunting growth of plant or death (Aslam *et al*., 2011). Screening and improvement of salt tolerance genotypes have become crucial for crop cultivation in saline affected areas of Bangladesh. Cotton is well known as a moderate salt tolerant crop which can grow up to the salinity level of 7.7 dS m^{-1}. However, cotton seed germination and growth of seedlings are suppressed by salinity resulting lower yield and fiber quality (Bilal *et al*., 2016). Variations are observed among cotton gerplasms. So the existing genotypes should be screened out for increasing salt tolerance level of cotton genotypes. Screening of salt tolerant cotton genotypes could be achieved if it is conducted under controlled conditions. Hence, this study was designed to evaluate the effects of different levels of water salinity on growth of cotton seedlings and to identify the tolerant cotton genotypes that can thrive in saline soils of Bangladesh.

2. MATERIALS AND METHODS

The treatments consisted of eight cotton genotypes (CB-12, CB-14, CB Hybrid-1, Rupali-1, DM-2, JA-17/6, JA-17/5 and JA-17/7) and seven saline conditions viz. 0 (control, non-saline distilled water), 5, 10, 15, 20, 25 and 30 dS m^{-1} salinity level. This experiment was laid out in a factorial RCBD design with three replications. Ten liter size 168 plastic pots were weighed and lined with polyethylene sheet so that rain water could not enter into the pot. Thereafter, pots were filled with 10 kg of water washed soil. Three seeds for each treatment were sown on 19 August 2017 at a uniform depth of 5 mm of soil in the pot. After emergence the seedlings were thinned to one per pot. Plants were irrigated on 15, 20, 25 and 30 days after seed sowing (DAS) with six saline and one non-saline water as per treatment. After salinization, the final EC levels of soil was determined (0.86, 4.01, 9.54, 13.92, 20.87, 24.61 and 29.06 dS m^{-1} as per treatment) at seedling harvesting time. Plants were uprooted at 35 DAS and washed in running water for the data recording. Data on root length (cm), root fresh weigh (g), root dry weight (g), shoot length (g), shoot dry weight (g) were recorded. All data were statistically analyzed. Analysis of variance was done with the help of computer package, MSTAT- C. Duncan's multiple range test (DMRT) was applied to compare the means at 5% level of probability.

In the study reported herein, cotton genotypes were categorized for salt-tolerance at EC level 20 dS m^{-1}. Differentiation of genotypes into salinity tolerant was performed based on percent reduction of relative performance of a characteristic (Dever *et al*., 2015 and Elkins, 2017). Salt tolerance for each genotype was evaluated using the relative performance of a character, the relative performance of a characteristic was calculated by the following formula:

$$\text{Relative performance (\% of control)} = \frac{\text{Performance of trait under salinity}}{\text{Performance under control condition}} \times 100$$

% Reduction under salinity stress = 100 - relative performance%
Then, it was classified into following four groups:
a) < 20% reduction = tolerant, denoted by T
(b) 20% to 40% reduction = moderately tolerant, denoted by MT
(c) 41 to 60% reduction = moderately sensitive, denoted by MS
(d) > 60% reduction to discriminate = sensitive to salinity, denoted by S
For easy of discussion both tolerant and moderately tolerant genotypes have been termed as tolerant and likely sensitive and moderately sensitive as sensitive (Azad *et al.*, 2013).

3. RESULTS AND DISCUSSION

3.1 Root length

Different salinity levels used in this study significantly affected the growth of cotton genotypes. The interaction effect of genotype and salinity on root length was significant at probability level of 0.01 (Figure 1). The relative performance of root length clearly shows the adverse effect of increasing salinity for all the genotypes (Table 1). The root length of some genotypes was extremely reduced when exposed to the 20 dS m^{-1} level of salinity and under this concentration root length of the genotype CB-12, DM-2, JA-17/6 and JA-

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17/5 were affected the most and appeared to be moderately sensitive (MS) to salinity and the genotype CB-14, CB Hhbrid-1, Rupali-1 and JA-17/7 appeared to be moderately tolerant (MT) to salinity. The reduction of the seedlings' root length agrees the findings of Zhang *et al*., 2014. Reductions in root growth are probably due to factors associated with water stress caused by salinity or specific ion toxicity caused by the uptake of salt (Meloni *et al*., 2001).

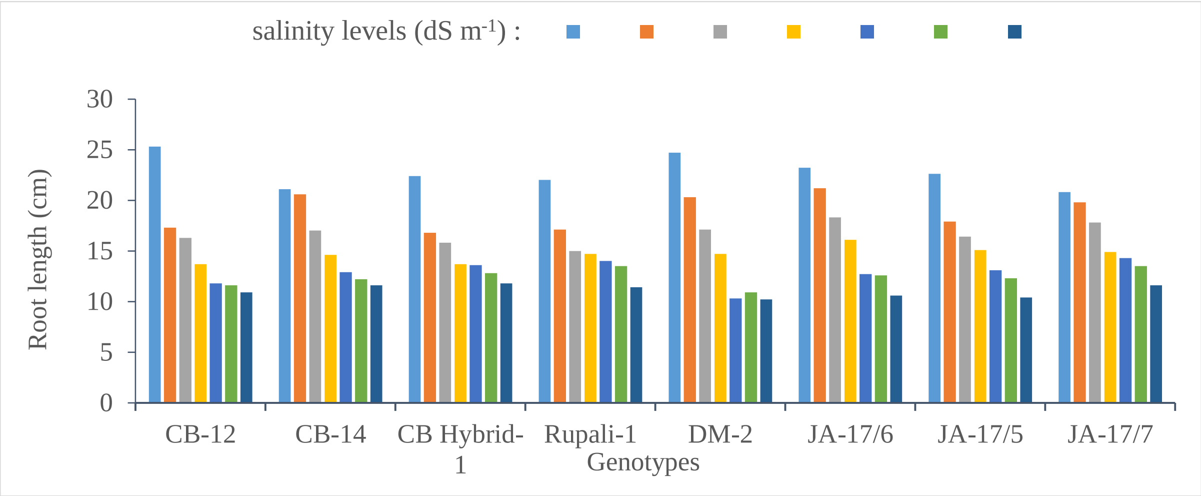

Figure 1: Interaction effects of salinity and genotype on root length of cotton
Genotype x Salinity = **, $p \leq 0.01$

Table 1. Percent reduction of relative performance of root length of cotton genotypes at different salinity levels

Genotypes	Percent reduction of root length over control at different salinity levels (dS m^{-1})						*Salinity tolerant classes based on salinity level of 20 dS m^{-1}
	5	10	15	20	25	30	
CB-12	32	36	45	53	54	56	MS
CB-14	3	19	30	39	42	45	MT
CB Hybrid-1	25	29	39	39	42	47	MT
Rupali-1	22	32	33	37	39	48	MT
DM-2	18	30	41	58	55	58	MS
JA-17/6	9	21	31	45	46	54	MS
JA-17/5	21	28	33	42	45	53	MS
JA-17/7	5	15	28	31	35	44	MT

*T= Tolerant, MT= Moderately Tolerant, MS= Moderately Sensitive and S= Sensitive

3.2 Fresh weight of root

Fresh weight of root was influenced significantly ($p < 0.01$) by the interaction of salinity and genotypes (Figure 2) and the trait was decreased as increased of salinity in the soil. The relative performance of fresh weight of root clearly shows the adverse effect of salinity for all the genotypes (Table 2). When seedlings were grown in 20 dS m^{-1} level of salinity, the fresh weight of root of some varieties was markedly reduced. Thus the genotype CB-12 was appeared to be sensitive to salinity (S) and the genotype CB-14, CB Hybrid-1, Rupali-1, JA-17/6 and JA-17/5 appeared to be moderately tolerant (MT) to salinity and the genotype DM-2 was appeared to be moderately sensitive (MS) to salinity and JA-17/7 was appeared as tolerant (T) genotype (Table 2). Similar results of decreasing fresh weight of root were attributed by Rauf *et al*., 2014

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and Shaheen *et al.* (2012) who reported a significant reduction in fresh weight of root and shoot of cotton genotypes with increasing salinity.

3.3 Dry weight of root

The results presented in Figure 3 shows that dry weight of root was significantly affected by the interaction of different salinity levels and genotypes. The relative performance of root dry weight clearly indicates that salinity reduced the dry weight of root of cotton genotypes (Table 3). The genotype CB-12 was extremely affected at 20 dS m^{-1} level with 62% reduction of root dry weight and appeared to be sensitive (S) to salinity and the genotype DM-2 appeared to be moderately sensitive (MS) to salinity and the genotypes CB-14, CB Hybrid-1, Rupali-1, JA-17/6 and JA-17/7 appeared to be moderately tolerant (MT) and the genotype JA-17/5 appeared to be salinity tolerant (T). Dry weight reductions due to imposed salinity are also the findings of Rezaee *et al*., 2015 which is in consistent with our results. The poor availability of nutrients and salt toxicity reduce root growth and sometime under saline condition when photosynthetic activity is low, govern reduction in root growth.

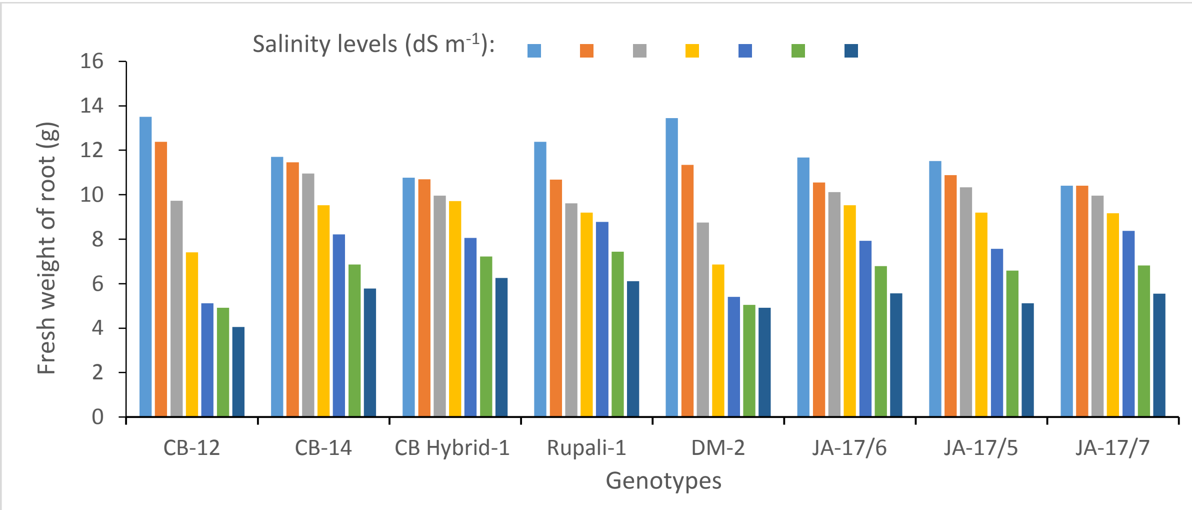

Figure 2: Interaction effects of salinity and genotype on root fresh weight of cotton
Genotype (G) = **, p ≤ 0.01; Salinity (S) = **, p ≤ 0.01; G × S = **, p ≤ 0.01

Table 2. Percent reduction of relative performance of fresh weight of root ofcotton genotypes at different salinity levels

Genotypes	Percent reduction of fresh weight of root over control at different salinity levels (dS m^{-1})						*Salinity tolerant classes based on salinity level of 20
	5	10	15	20	25	30	
CB-12	8	27	45	61	64	70	S
CB-14	2	6	19	30	41	51	MT
CB Hybrid-1	1	7	10	25	33	42	MT
Rupali-1	14	22	26	29	42	50	MT
DM-2	16	35	49	60	63	63	MS
JA-17/6	10	13	19	32	42	52	MT
JA-17/5	6	10	20	34	43	56	MT
JA-17/7	0.0	4	12	20	34	47	T

*T= Tolerant, MT= Moderately Tolerant, MS= Moderately Sensitive and S= Sensitive

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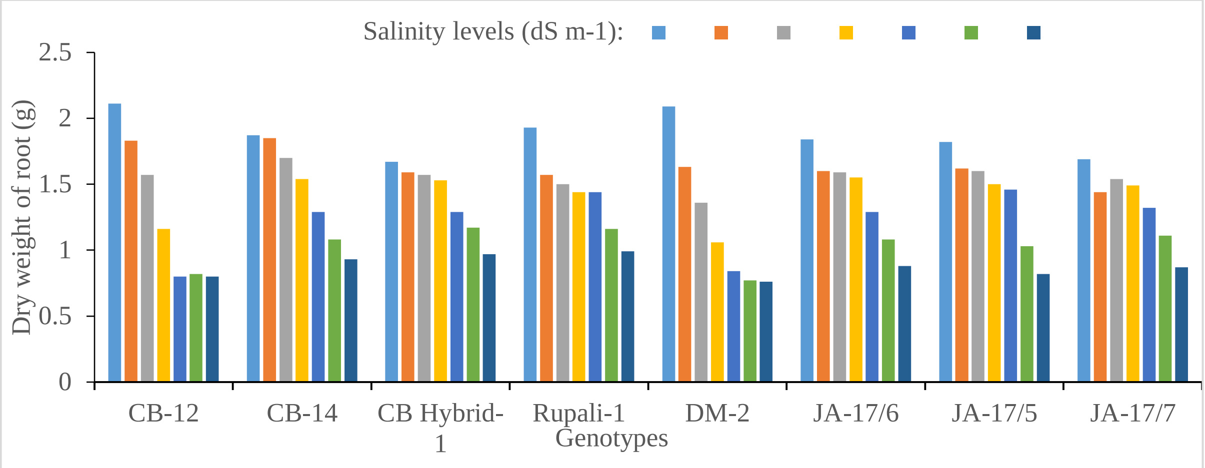

Figure 3: Interaction effects of salinity x genotype on dry weight of cotton roots
Genotype (G) = $_{**}$, $p \leq 0.01$; Salinity (S) $_{= **}$, $p \leq 0.01$; G × S = $_{**}$, $p \leq 0.01$

Table 3. Percent reduction of relative performance of dry weight of root of cottongenotypes at different salinity levels

Genotypes	**Percent reduction of dry weight of root over control at different salinity levels (dS m^{-1})**						***Salinity tolerant classes based on salinity level of 20 dS m^{-1}**
	5	**10**	**15**	**20**	**25**	**30**	
CB-12	13	26	45	62	61	62	S
CB-14	1	9	18	31	42	50	MT
CB Hybrid-1	5	6	8	32	30	42	MT
Rupali-1	19	22	26	26	40	48	MT
DM-2	22	35	49	60	63	64	MS
JA-17/6	13	13	16	30	41	52	MT
JA-17/5	11	12	17	21	43	55	T
JA-17/7	8	9	11	22	34	48	MT

*T= Tolerant, MT= Moderately Tolerant, MS= Moderately Sensitive and S= Sensitive

3.4 Shoot length

Interaction effect of cotton genotypes and salinity on shoot length was significant at the probability level of 0.01 (Figure 4). The shoot length was reduced with each increasing of salinity level (Table 4). The shoot length of the genotype CB-12, CB-14, CB Hybrid-1 and DM-2 were affected the most at 20 dS m^{-1} level of salinity and appeared to be moderately sensitive to salinity (MS), on the other hand the genotype Rupali-1 and Ja-17/5 appeared to be moderately tolerant (MT) and the genotype JA-17/6 and JA-17/7 appeared to be tolerant (T) to salinity (Table 4). Previous work of Iqbal *et al*., 2013, and Rauf *et al*., 2014 on cotton clearly described the significant reduction of shoot growth at higher salinity stresses which is consistent with our results.

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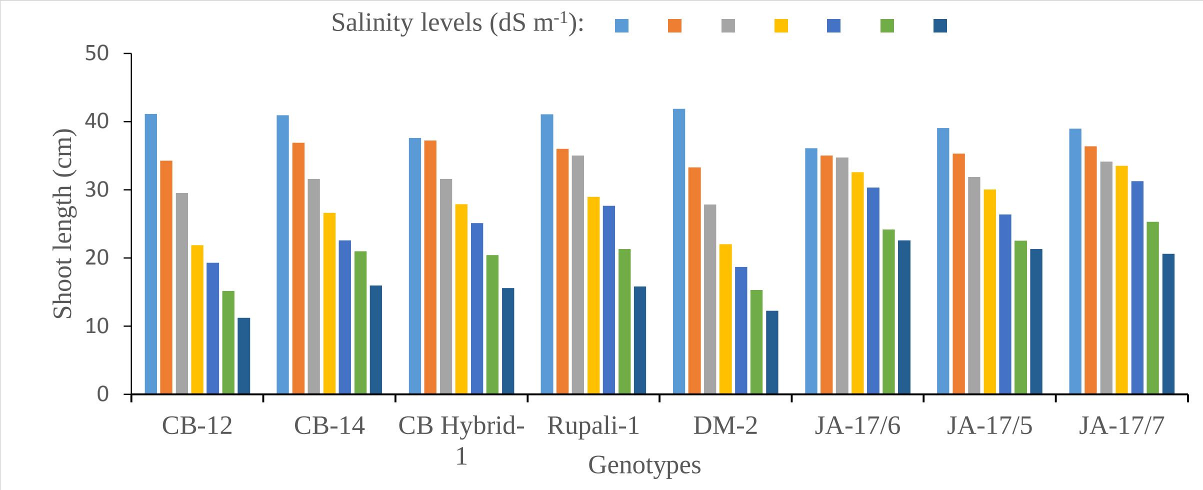

Figure 4: Interaction effects of salinity x genotype on shoot length of cotton
Genotype (G) = **, $p \leq 0.01$; Salinity (S) = **, $p \leq 0.01$ and G × S = **, $p \leq 0.01$

Table 4. Percent reduction of relative performance of shoot length of cotton genotypes at different salinity levels

Genotypes	Percent reduction of shoot length over control at different salinity levels (dS m^{-1})						*Salinity tolerant classes based on salinity level of 20 dS m^{-1}
	5	10	15	20	25	30	
CB-12	17	28	46	53	63	73	MS
CB-14	10	23	35	45	48	61	MS
CB Hybrid-1	1	15	24	43	42	53	MS
Rupali-1	12	15	29	33	48	61	MT
DM-2	20	34	48	55	65	72	MS
JA-17/6	3	4	10	16	33	37	T
JA-17/5	10	18	23	32	43	45	MT
JA-17/7	7	12	14	20	35	47	T

*T= Tolerant, MT= Moderately Tolerant, MS= Moderately Sensitive and S= Sensitive

3.5 Fresh weight of shot

The results presented in Figure 5 shows the significant effect of salinity levels and genotypes on fresh weight of shoot. Under the salinity level of 20 dS m^{-1}, the fresh weight of shoot of the genotypes CB-12, CB-14, CB Hybrid-1 and DM-2 were affected severely and appeared to be moderately sensitive (MS) to salinity and the genotype Rupali-1, JA-17/6, JA-17/5 and JA-17/7 appeared to be moderately tolerant (MT) to salinity (Table 5). The reduction of the cotton seedlings' shoot fresh weight in response to increased salinity levels agrees with the findings of Rezaee *et al*. (2015) who showed that seedlings' fresh weight decreased with increasing concentrations of osmotic agents (NaCl and polyethylene glycol (PEG)).

3.6 Dry weight of shoot

The present study revealed that dry weight of shoot was influenced significantly ($P < 0.01$) by the interaction of cotton genotypes and different salinity levels (Fig. 5). The dry weight of shoot of some genotypes was remarkably reduced when seedlings were irrigated with the saline water with 20 dS m^{-1}. Thus the genotype CB-12 and DM-2 were affected the most at 20 dS m^{-1} level and appeared to be moderately sensitive to salinity (MT) and the genotype CB-14, CB Hybrid-1, Rupali-1, JA-17/6, JA-17/5 and JA-17/7 appeared to be moderately tolerant (T) to salinity (Table 6). The results are similar with those results which

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have been already reported by Shaheen *et al*. (2012) and Munis *et al*. (2010) in cotton cultivars with reduced growth.

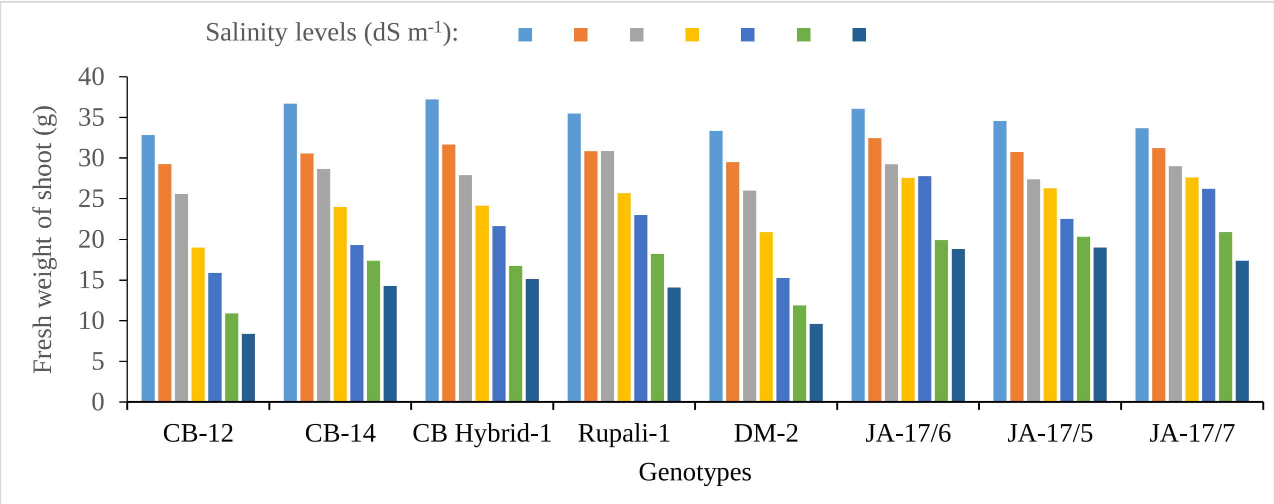

Figure 5: Interaction effects of salinity x genotype on fresh weight of cotton shoot Genotype (G) = **, $p \leq 0.01$; Salinity (S) = **, $p \leq 0.01$ and G × S = **, $p \leq 0.01$

Table 5. Percent reduction of relative performance of fresh weight of shoot of cotton genotypes at different salinity levels

Genotypes	Percent reduction of fresh weight of shoot over control at different salinity levels (dS m^{-1})						*Salinity tolerant classes based on salinity level of 20 dS m^{-1}
	5	10	15	20	25	30	
CB-12	11	22	42	52	67	74	MS
CB-14	17	29	34	47	52	61	MS
CB Hybrid-1	15	25	35	42	55	59	MS
Rupali-1	13	13	28	35	49	60	MT
DM-2	12	22	37	54	64	71	MS
JA-17/6	10	19	24	23	45	47	MT
JA-17/5	11	21	24	35	41	45	MT
JA-17/7	7	14	18	22	38	48	MT

*T= Tolerant, MT= Moderately Tolerant, MS= Moderately Sensitive and S= Sensitive

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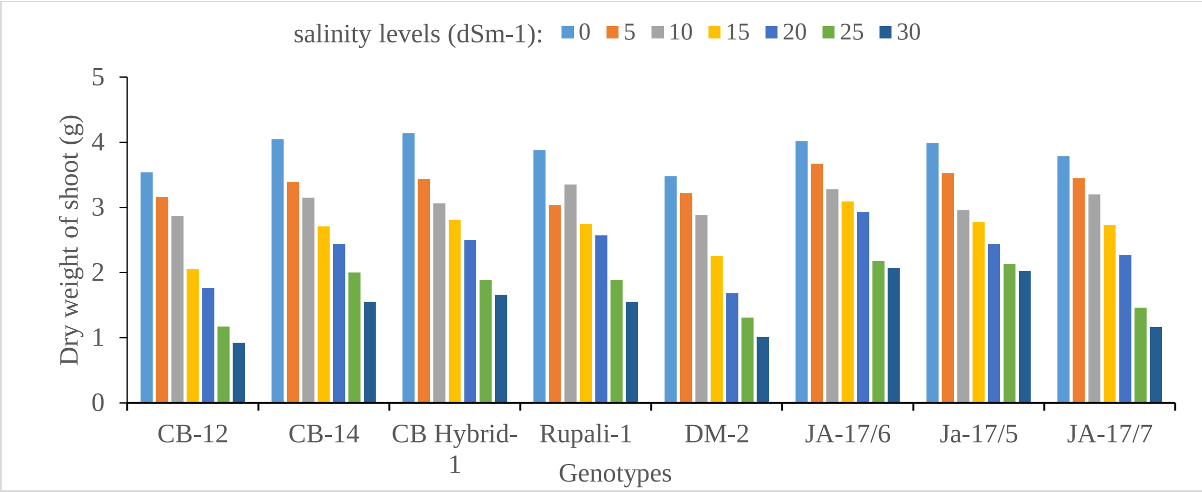

Figure 6: Interaction effects of salinity x genotype on dry weight of cotton shoot Genotype (G) = **, $p \leq 0.01$; Salinity (S) = ** $p \leq 0.01$; and G × S = **, $p \leq 0.01$.

Table 6. Percent reduction of relative performance of dry weight of shoot of cotton genotypes at different salinity levels

Genotypes	Percent reduction of dry weight of shoot over control at different salinity levels (dS m^{-1})						*Salinity tolerant classes based on salinity level of 20 dS m^{-1}
	5	10	15	20	25	30	
CB-12	11	19	42	50	67	74	MS
CB-14	16	22	33	48	51	62	MT
CB Hybrid-1	17	26	32	44	54	59	MT
Rupali-1	12	14	29	34	51	60	MT
DM-2	7	17	35	51	62	70	MS
JA-17/6	9	18	23	27	46	49	MT
JA-17/5	12	26	30	39	47	49	MT
JA-17/7	9	16	28	40	61	69	MT

*T= Tolerant, MT= Moderately Tolerant, MS= Moderately Sensitive and S= Sensitive

3.7 Summary of salinity tolerat classes of cotton genotypes based on root length, fresh weight of root, dry weight of root, shoot length, fresh weight of shoot and dry weight of shoot

It was observed from subsequent calculation of percent reduction of different important traits like root length, fresh weight of root, dry weight of root, shoot length, fresh weight of shoot and dry weight of shoot under different treatments over control that the salinity tolerance classes of those traits are not alike over genotypes and all the salinity tolerance classes of those traits are presented together in Table 7. Overall raking of cotton genotype for salinity tolerant classes was estimated according to maximum performances of a same genotype. Therefore, it was revealed from Table 7 that the genotype CB-14, CB Hybrid-1, Rupali-1, JA-17/6, JA-17/5 and JA-17/7 were in the moderately tolerant (MT) class and the genotype CB-12 and DM-2 were in moderately sensitive (MS) based on relative performances of studied parameters.

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Table 7. Summary of salinity tolerance classes based on root length, fresh weight ofroot, dry weight of root, shoot length, fresh weight of shoot and dry weightof shoot at salinity level of 20 dS m^{-1}

Genotypes	Salinity tolerance class as per salinity of 20 dS m^{-1}						Overall ranking of salinity tolerance*
	Root length	Root fresh weight	Root dry weight	Shoot length	Shoot fresh weight	Shoot dry weight	
CB-12	MS	S	S	MS	MS	MS	MS
CB-14	MT	MT	MT	MS	MS	MT	MT
CB Hybrid-1	MT	MT	MT	MS	MS	MT	MT
Rupali-1	MT	MT	MT	MT	MT	MT	MT
DM-2	MS	MS	MS	MS	MS	MS	MS
JA-17/6	MS	MT	MT	T	MT	MT	MT
JA-17/5	MS	MT	T	MT	MT	MT	MT
JA-17/7	MT	T	MT	T	MT	MT	MT

* T= Tolerant, MT= Moderately Tolerant, MS= Moderately Sensitive and S= Sensitive

4.CONCLUSION

The growth of cotton genotypes was influenced significantly by different level of water salinity and variation was observed among the genotypes. The genotype CB-12 shows the highest reduction of root fresh weight and root dry weight under the salinity of 20 dS m^{-1}, whereas JA-17/7 reduced lowest in respect of root dry weight and Ja-17/5 also reduced lowest for root fresh weight. DM-2 and CB-12 performed as moderately sensitive genotype against salinity and the genotype CB-14, CB Hybrid-1, Rupali-1, JA-17/6, JA-17/5 and JA-17/7 were fond moderately tolerant against salinity. The results offer salt tolerance data to the cotton germplasm pools of Bangladesh and enhance the way of identification of salt-tolerant cotton genotypes.

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