Research in
ISSN : P-2409-0603, E-2409-9325
AGRICULTURE, LIVESTOCK and FISHERIES
An Open Access Peer-Reviewed International Journal

Article Code: 0279/2020/RALF
Article Type: Research Article
Res. Agric. Livest. Fish.
Vol. 7, No. 2, August 2020 : 199-207.

EFFECT OF NaCl ON GERMINATION AND SEEDLING GROWTH OF SOME COTTON GENOTYPES

Kamelia Mondal, Joyanti Ray* and Md. Yasin Ali

Agrotechnology Discipline, Khulna University, Khulna- 9208, Bangladesh.

***Corresponding author:** Joyanti Ray; E-mail: joyaku2005@yahoo.com

ARTICLE INFO

Received
12 July, 2020

Revised
24 August, 2020

Accepted
28 August, 2020

Online
31 August, 2020

Key words:
Cotton
Germination
Seedling growth
Salinity

ABSTRACT

Salinity is an emerging problem among the abiotic stresses of plants in Bangladesh. One easy way to cope with the problem of salinity is to exploit the genetic potential of plants for their adaptability to adverse soil conditions. Salt tolerance improvement might be achieved through selection from already existing germplasm which can be done by quick method particularly in early growth stages of crops. A laboratory experiment was conducted to determine the effect of salinity on germination and the seedling growth of five cotton genotypes. Two factors include genotypes (CB-9, CB-10, CB-12, CB-14 and CB-15) and salt solution of different concentrations (control -0 dS m^{-1}, 4 dS m^{-1}, 8 dS m^{-1}, 12 dS m^{-1} and 16 dS m^{-1}) were used. Relative to control treatment, germination energy and germination capacity at 16 dS m^{-1} was maximum in CB-12 (0.72 and 0.77 respectively) whereas germination percentage (0.99) was maximum in CB-9 and the relative value of all the above parameters was minimum in CB-15 (0.02, 0.13, 0.41 and 0.09, respectively). In case of seedling growth parameters, shoot length, seedling vigor index and dry weight at 16 dS m^{-1}were maximum in CB-9 (0.67, 0.64 and 0.77 respectively) relative to control whereas the relative value of all those parameters was minimum in CB-15 (0.5, 0.17, 0.31 and 0.59 respectively). Considering all germination and seedling growth parameters, CB-9 was supposed to be superior genotype followed by CB-12, CB-10 and CB-14 whereas genotype CB-15 was more susceptible than other genotypes against salinity stress.

To cite this article: Mondal K., J.Ray and M. Y. Ali, 2020. Effect of NaCl on germination and seedling growth of some cotton genotypes**.** Res. Agric. Livest. Fish., 7 (2): 199-207.

INTRODUCTION

Cotton is an important industrial crop grown under diverse soil and climatic conditions. It belongs to the genus *Gossypium* with four domesticated species including allopolyploids (2n = 52) *Gossypium hirsutum* and *Gossypium barbadense*, and diploids *Gossypium herbaceum* and *Gossypium arboretum* (2n = 26). Cotton is a perennial plant of tropical and subtropical origin, but is mostly grown as annual crop to get primarily lint, seed oil, and animal meal (Rehman and Farooq, 2019). In Bangladesh the area under cotton cultivation (2017-2018) is 31870 acres with a total production of 30790 MT. Chittagong, Dhaka, Khulna, Mymensing, Rajsahi and Rangpur are the cotton cultivated division in our country (BBS, 2018).

Salinity in topsoil and subsoil is one of the major abiotic environmental stresses to crop production. Worldwide, soil salinity is becoming a serious threat to agricultural productivity. Salinity affects 7% of the world's land area, which amounts to 930 million ha. The area is increasing; a global study of land use over the last 45 years found that 6% had become saline in that period (Chachar et al., 2008). Salinity has been increasing over period of time of southwest coastal region of Bangladesh and 0.223 million ha (26.7%) of total cultivated land is affected by various degree of salinity and badly hampered in the crop ecology (Iqbal, 2013).
Although cotton is classified as salt tolerant crop yet it is sensitive to salinity during the emergence and early growth stages than the later developmental stages. Soil salinity is a dominated factor affecting cotton's above-ground dry mass and root development (Chen et al., 2010). Generally, the salinity reduces vegetative growth of cotton but increase in growth with low concentration of salts has also been observed (Pessarakli, 1995). Salinity decreases shoot/root ratio because shoots are sensitive than roots to salt stress (Ahmad et al., 2002). For extending cotton production in Bangladesh, it is necessary to start cultivation of cotton to all possible location. Cotton is considered as a moderately salt tolerant crop, but its yield is markedly affected due to poor germination and subsequent abnormal plant development under severe saline conditions .The success of cotton production lies partly in cultivation of salt-tolerant cotton cultivars on salt affected soils (Chachar et al., 2008). In Bangladesh, a little number of works has been carried out about salinity effect on cotton. Considering this task, this work was undertaken to examine the effect of salinity (NaCl) on germination and seedling growth of some cotton genotypes.

MATERIALS AND METHODS

The experiment was conducted in Agronomy Laboratory of Agrotechnology Discipline, Khulna University, Khulna, Bangladesh from 24 July to 12 August, 2019 to determine the effect of salinity on germination and the seedling growth of five cotton genotypes. The experiment was conducted by using two factorial completely randomized designs (CRD) with four replications. The treatments were genotypes (CB-9, CB-10, CB-12, CB-14 and CB-15) and salinity levels (T_1= Control (0 dS m^{-1}), T_2= 4 dS m^{-1}, T_3= 8 dS m^{-1}, T_4= 12 dS m^{-1} and T_5= 16 dS m^{-1}). Seeds of all the genotypes were collected from Cotton Research, Training and Seed Multiplication Firm, Sreepur, Gazipur.

Glass petridishes with a tight fitting lid were used in conducting this experiment. Filter papers were used as a matrix for seed germination. Three filter papers were soaked with respective salt solutions (Control, 4, 8, 12 and 16 dS m^{-1} respectively). For preparing different salt solution, 1000 ml distilled water was kept in a beaker and then respective amount of salt (NaCl) was gradually added to this water. To assure the concentrations of solution, an electrical conductivity meter was used to measure the salinity levels. Before placing the seeds to petridishes, seeds were treated with Vitavex 200 @ 3 gm/ kg seed and kept them in a air tight packet for 24 hours. The number of petridishes that used in laboratory were = {5 (variety) × 5 (treatments) × 4 (replication)} = 100

A seed has considered germinated at the emergence of the radical (2 mm) (Chartzoulakis and Klapaki, 2000). After germination, seedlings were watered as and when necessary. The data were taken on following parameters-
(i) germination energy [% of seeds germinated at 72 h]; (ii) germination capacity [% of seeds germination at 168 h] (Bam et. al., 2006); (iii) germination percentage [(No. of seed germinated/total no. of seed in petridish) ×100]; (iv) germination speed (%) [(No. of seed germinated at 72 h/ No. of seed germinated at 168 h) ×100]; (v) root length (cm); (vi) shoot length (cm); (vii) seedling vigor index [(average shoot length+ average root

length) × germination percentage] (Podder et al., 2020) and (viii) dry weight of seedling (mg) [after 10 days of setting the seed for germination, seedlings of each petridish were dried in oven at 60^0C until a fixed weight which was measured by an electrical balance]. Relative performance was measured by using the following formula-

Relative performance = Variable measured under stress condition/ Variable measured under normal condition

Then the recorded data were analyzed with the help of statistical package program MSTAT-C, Microsoft Excel and the mean differences were adjusted with Duncan's New Multiple Ranges Test at 5% level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Interaction effect of salinity levels and genotypes on seed germination parameters of cotton

Germination energy

Germination energy varied from 1.25% to 85.00% due to the interaction between genotypes and different levels of salinity (Table 1). The highest germination energy (85.00%) was found in CB-9 at 8 dS m^{-1} EC which was statistically similar with control (82.50%), 4 dS m^{-1}(82.50%) and 12 dS m^{-1} (81.25%) of same genotype, control (80.00%), 4 dS m^{-1} (77.50%) and 8 dS m^{-1} (81.25%) of CB-10, control treatment (75.00%) and 4 dS m^{-1} EC (77.50%) of CB-14. The lowest germination energy 1.25% was found in CB-15 at 16 dS m^{-1} EC (Table 1). Relative to control (0 dS m^{-1}) treatment germination energy at 16 dSm^{-1} was maximum (0.72) in CB-12 followed by CB-14 and CB-9 and minimum in CB-15 (0.02) (Figure 1).

Germination capacity

The interaction between salt concentration and cultivars emphasize the variation in germination capacity. Germination capacity ranged from 11.25% to 100%. The highest germination capacity (100%) was found in CB-9 at 8 dS m^{-1} which was statistically similar to control (97.50%), 4 dS m^{-1} (97.50%) and 12 dS m^{-1} (96.25%) of same genotype, control (95.00%), 4 dS m^{-1} (92.50%) and 8 dS m^{-1} (96.25%) of CB-10, control (90.00%) and 4 dS m^{-1} EC (92.50%) of CB-14. The lowest value was recorded in CB-15 (11.25%) at 16 dS m^{-1} EC (Table 1). Germination capacity was reduced with increasing salinity level though their reduction varied genotypically. Relative to control (0 dS m^{-1}) treatment germination capacity at 16 dS m^{-1} was maximum (0.77) in CB-12 followed by CB-14 (0.74) and CB-9 (0.72) and minimum in CB-15 (0.13) (Figure 2).

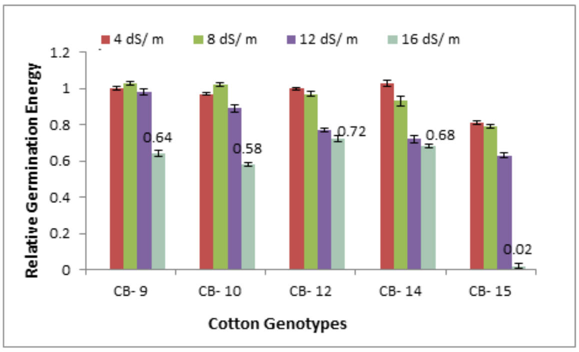

Figure 1. Relative germination energy of five cotton genotypes at different salinity levels (4, 8, 12 and 16 dS m^{-1}).

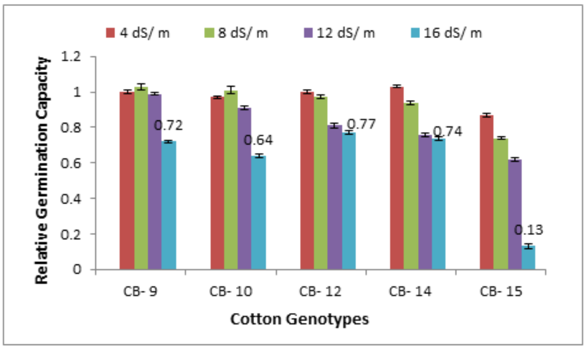

Figure 2. Relative germination capacity of five cotton genotypes at different salinity levels (4, 8, 12 and 16 dS m^{-1}).

Germination percentage

The interaction between salinity levels and genotypes in relation to germination percentage was significant at 5% level. Germination percentage varied from 37.50% to 100%. The highest germination percentage (100%) was found in CB-9 in 8 dS m^{-1} which was statistically similar with CB-10 in 8 dS m^{-1} (97.50%). The lowest germination percentage was recorded in CB-15 (37.50%) at 16 dS m^{-1} (Table 1). Relative (ratio between salt stress and control) to control treatment (0 dS m^{-1}) germination percentage at 16 dS m^{-1} was maximum (0.99) in CB-9 followed by CB-10 (0.95) and CB-12 (0.84) and minimum in CB-15 (0.41) (Figure 3).

Germination speed

The interaction between salinity levels and genotypes in relation to germination speed was significant at 5% level. Germination speed varied from 84.60% to 6.25%. The highest germination speed (84.60%) was found in CB-9 in control which was statistically similar with 4 dS m^{-1} (84.60%), 12 dS m^{-1} (84.39%) of same genotype and CB-10 at 8 dS m^{-1} treatment (84.41%). The lowest germination speed was recorded in CB-15 (6.25%) at 16 dS m^{-1} (Table 3). Germination speed was reduced with increasing salinity level though their reduction varied genotypically. Relative to control (0 dS m^{-1}) treatment germination speed at 16 dS m^{-1} was maximum in CB-14 (0.92) followed by CB-12 (0.91), CB-9 (0.88), CB-10 (0.88) and CB-15 (0.09) (Figure 4).

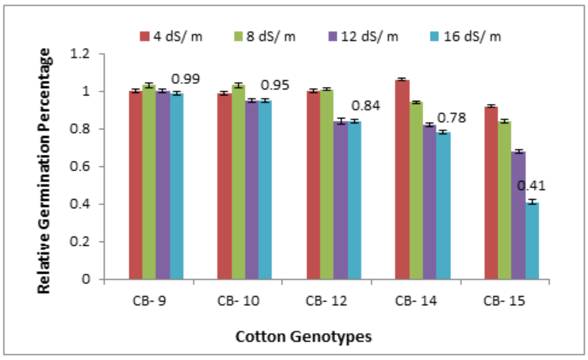

Figure 3. Relative germination percentage of five cotton genotypes at different salinity levels (4, 8, 12 and 16 dS m^{-1}).

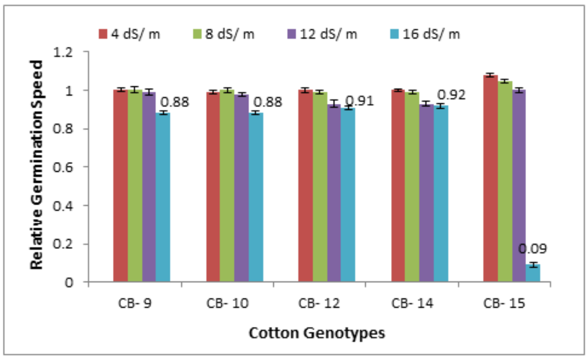

Figure 4. Relative germination speed of five cotton genotypes at different salinity levels (4, 8, 12 and 16 dS m^{-1}).

Interaction effect of salinity levels and genotypes on seedling growth parameters of cotton

Root length (cm)

The interaction between salinity levels and genotypes in relation to root length was significant at 5% level and varied from 1.46 cm to 4.42 cm. The highest root length was found in CB-10 (4.42 cm) at 8 dS m^{-1} which was statistically similar with 4 dS m^{-1} (4.28 cm) of same genotype. CB-9 also produced better results at control (3.88 cm) which was similar to CB-10 at control (3.96 cm). The lowest root length was noticed in CB-15 (1.46 cm) at 16 dS m^{-1} EC which was statistically similar at 12 dS m^{-1} (1.59 cm) of same genotype (Table 2). Root length was reduced with increasing salinity level though their reduction varied genotypically. Relative to control (0 dS m^{-1}) treatment root length at 16 dS m^{-1} was maximum (0.69) in CB-10 followed by CB-9 (0.63), CB-14 (0.63) and CB-12 (0.53) and minimum in CB-15 (0.5) (Figure 5).

Shoot length (cm)

The interaction between salinity levels and genotypes in relation to shoot length was significant at 5% level. The highest shoot length was found in CB-10 (2.80 cm) at control which was statistically similar with CB-9 (2.70 cm) and same genotype (2.6 cm) at 4 dS m^{-1}. The lowest shoot length was noticed in CB-15 (0.74 cm) at 16 dS m^{-1} (Table 2). Relative to control treatment shoot length at 16 dS m^{-1} was maximum in CB-9 (0.67) followed by CB-12 (0.64), CB-10 (0.64), CB-14 (0.49) and the minimum was in CB-15 (0.31) (Figure 6).

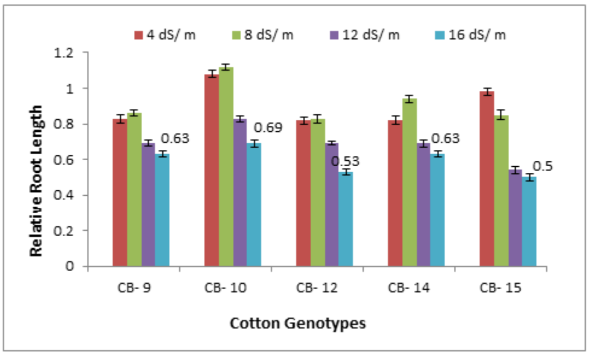

Figure 5. Relative root length of five cotton genotypes at different salinity levels (4, 8, 12 and 16 dS m^{-1}).

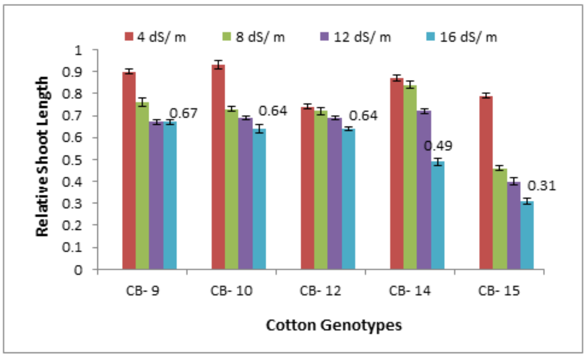

Figure 6. Relative shoot length of five cotton genotypes at different salinity levels (4, 8, 12 and 16 dS m^{-1}).

Seedling vigor index

Due to the interaction between genotypes and different level of salinity, seedling vigor index of cotton genotypes were greatly varied. The highest seedling vigor index was found in CB-10 (645.0) at 4 dS m^{-1} which is statistically similar at control (642.2) of same genotype and CB-9 (641.6) at control. The lowest seedling vigor index was noticed in CB-15 (82.5) at 16 dS m^{-1} (Table 2). Relative to control treatment seedling vigor index at 16 dS m^{-1} was maximum in CB-9 (0.64) followed by CB-10 (0.63), CB-12 (0.59), CB-14 (0.44) and minimum in CB-15 (0.17) (Figure 7).

Seedling dry weight

The interaction between salinity levels and genotypes in relation to seedling dry weight was significant at 5% level. The highest seedling dry weight was found in CB-9 (60.40 mg) at control which was statistically similar at 4dS m^{-1} (59.80 mg) of same genotype and CB-10 at control (58.80 mg). The lowest seedling dry weight was noticed in CB-15 (24.40 mg) at 16 dS m^{-1} (Table 2). Seedling dry weight was reduced with increasing salinity level though their reduction varied genotypically. Relative to control (0 dS m^{-1}) seedling dry weight at 16 dS m^{-1} was maximum in CB-9 (0.77) followed by CB-12 (0.77), CB-14 (0.72), CB-10 (0.71), and CB-15 (0.59) (Figure 8).

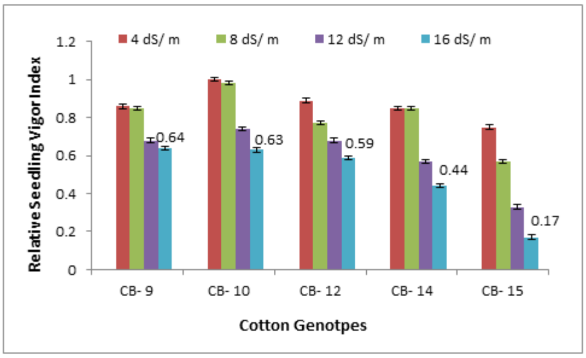

Figure 7. Relative seedling vigor index of five cotton genotypes at different salinity levels (4, 8, 12 and 16 dS m^{-1}).

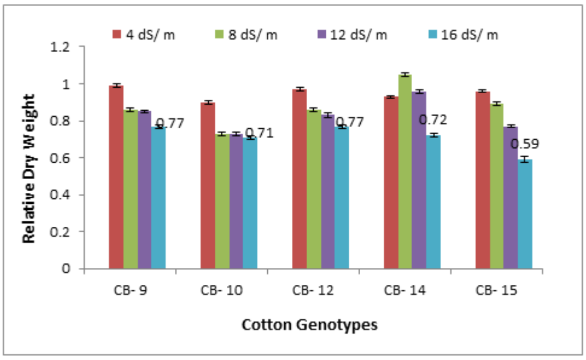

Figure 8. Relative dry weight of five cotton genotypes at different salinity levels (4, 8, 12 and 16 dS m^{-1}).

Table 1. Interaction effect of salinity levels and genotypes on seed germination energy, germination capacity, germination percentage and germination speed of cotton

Genotype	Salinity level (EC dS m^{-1})	Germination energy (%)	Germination capacity (%)	Germination percentage (%)	Germination speed (%)
CB-9	0	82.50 a	97.50 a	97.50 ab	84.60 ab
	4	82.50 a	97.50 a	97.50 ab	84.60 ab
	8	85.00 a	100 a	100 a	85.00 a
	12	81.25 a	96.25 a	97.50 ab	84.39 ab
	16	52.50 def	70.50 cde	96.25 abc	74.47 fgh
CB-10	0	80.00 a	95.00 a	95.00 abc	84.21 abc
	4	77.50 a	92.50 a	93.75 abc	83.72 abc
	8	81.25 a	96.25 a	97.50 ab	84.41 ab
	12	71.25 abc	86.25 abc	90.00 abcd	82.42 a-e
	16	46.25 defg	61.25 defg	90.00 abcd	73.99 fgh
CB-12	0	71.25 abc	86.25 abc	86.25 abcd	80.13 a-f
	4	71.25 abc	86.25 abc	86.25 abcd	80.13 a-f
	8	68.75 abc	83.75 abc	87.50 abcd	79.50 a-g
	12	55.00 def	70.00 cde	72.50 cde	74.56 fgh
	16	51.25 def	66.25 defg	72.50 cde	73.10 gh
CB-14	0	75.00 ab	90.00 ab	90.00 abcd	83.31 abcd
	4	77.50 a	92.50 a	95.00 abc	83.75 abc
	8	70.00 abc	85.00 abc	85.00 bcde	82.11 a-e
	12	53.75 def	68.75 def	73.75 efgh	77.35 c-h
	16	51.25 defg	66.25 defg	70.00 fgh	76.68 d-h
CB-15	0	60.00 cde	85.00 abc	92.50 abc	70.59 h
	4	48.75 defg	63.75 defg	85.00 bcde	76.16 efgh
	8	47.50 defg	62.50 defg	75.50 def	74.40 fgh
	12	37.50 g	52.50 g	62.50 h	70.63 h
	16	1.25 h	11.25 h	37.50 i	6.25 i
CV (%)		14.92	12.50	10.51	5.36

In a column, values followed by the different letter(s) are significantly different from each other by DMRT at 5% level.

Table 2. Interaction effect of salinity levels and genotypes on seedling root length (cm), shoot length (cm), seedling vigor index and dry weight (mg) of cotton

Genotype	Salinity level (EC dS m^{-1})	Root length (cm)	Shoot length (cm)	Seedling vigor index	Dry weight (mg)
CB-9	0	3.88 ab	2.70 a	641.55 ab	60.40 a
	4	3.23 bcde	2.42 abc	550.88 abc	59.80 ab
	8	3.38 bc	2.05 bcd	542.5 abc	51.72 bc
	12	2.68 c-g	1.80 bcde	436.8 def	51.5 bc
	16	2.47 c-g	1.82 bcde	412.9 defg	46.22 cd
CB-10	0	3.96 ab	2.80 a	642.2 ab	58.80 ab
	4	4.28 a	2.60 a	645 a	52.92 bc
	8	4.42 a	2.05 bcd	630.83 ab	42.63 cd
	12	3.31 bcd	1.94 bcd	472.5 cde	42.73 cd
	16	2.73 c-g	1.80 bcde	407.7 defg	41.5 cd
CB-12	0	3.14 bcde	1.59 efg	382.09 d-h	48.80 bc
	4	2.58 c-g	1.38 efg	341.55 e-i	47.20 bc
	8	2.61 c-g	1.15 efg	293.5 ijk	41.80 cd
	12	2.48 efgh	1.10 efg	259.6 jk	40.40 cde
	16	2.08 fghi	1.01 fg	224.03 jkl	37.47 cde
CB-14	0	3.45 bc	2.43 abc	528.75 bc	46.25 bcd
	4	2.82 c-g	1.89 bcde	447.6 cdef	43.13 cde
	8	3.23 bcde	2.05 bcd	450.8 cde	48.78 bc
	12	2.37efgh	1.76 cdef	303.85 ijk	44.38 cd
	16	2.19 fghi	1.19 efg	234.4 jk	33.73 cde
CB-15	0	2.92 cdef	2.40 abc	492.1 cd	41.03 cd
	4	2.89 cdef	1.44 defg	368.05 d-i	39.53 cde
	8	2.48 defg	1.11 efg	278.23 jk	36.88 cde
	12	1.59 hi	0.96 fg	160 l	31.77 de
	16	1.46 i	0.74 g	82.5 l	24.40 e
CV (%)		18.59	12.86	11.61	10.60

In a column, values followed by the different letter(s) are significantly different from each other by DMRT at 5% level.

DISCUSSION

Increased salinity caused a significant reduction in germination percentage, germination rate, root and shoots length and fresh root and shoots weights of plants (Jamil et al., 2006). Ahmad et al., (2002) reported that the germination of cotton seed and emergence of seedling is generally delayed and reduced by salinity. However, varietal differences in response to salinity have also been observed. Muhammad and Hussain, (2012) reported that soil salinity can significantly inhibit seed germination and seedling growth, due to the combined effects of high osmotic potential and specific ion toxicity. Salinity decreases germination and vegetative growth with significant difference among the cultivars. Seed germinations were 47- 84 % and 17-54 % at 10 and 20 dSm^{-1} respectively (Qadir and Shams, 1997). In present study, germination percentage was decreased with increasing salinity levels and varied from 37.50% to 100%. Relative to control, CB- 15 suffered more (0.41) than CB-9 (0.99) followed by CB-10 (0.95) and CB-12 (0.84).

In root growth, no such significant genotypic difference was observed up to 8 dSm^{-1} rather it was increased in some cases in present study. But it was reduced with increasing salinity levels. Similar observation was found by Zhong and Lauchli, 1993. Although salinity generally causes reduced development of root but there are some findings which show increase in root growth in mild salinity. Similarly Leidi (1994) reported longer primary roots in cotton when treated with 100 mol m-3 NaCl but not in control. An inhibition, both in length and number of secondary roots was also observed at that salt concentration. Khan et al, 1995 found that reduction in shoot fresh weight and dry weight of 15 cotton cultivars with an increase salt concentration (0, 150 and 250 mol NaCl m^{-3}). At 10- 20 dSm^{-1}, decrease in leaf area, stem thickness, shoot and root weight of four cotton cultivars have been reported by Qadir and Shams, 1997. Similar pattern of result was recorded in present study root length, shoot length and dry weight of biomass was reduced with increasing levels of salinity. Sattar (2010) suggested that soil salinity affects plant growth and development by way of injurious effects of toxic ions, osmotic stress, reduced water use efficiency and the resulting nutrient imbalance. Podder et al., (2020) examined that all the parameters regarding germination and seedling growth of mungbean were affected by the increase of salinity levels though their reduction varied from genotype to genotype. Sardoei et al., (2013) recommended that salt stress affects many physiological aspects of plant growth. Shoot growth was reduced by salinity due to inhibitory effect of salt on cell division and enlargement in growing point.

Saleh (2012) found that salt treatment exhibited deleterious effect on vegetative growth with genotypic variation among the four tested cotton genotypes. Salt stress impaired both seedling height and root length of all tested genotypes. Rauf et al., (2014) also found that treatments and genotypes showed significant effect on reduction of shoot length, root length and root, shoot fresh weight. He also suggested that phenolic content was found to increase significantly in all genotypes at increased salinity. Data also showed that variation in increase of phenol content was the function of salinity and not due to genotypes specificity.

CONCLUSION

Considering germination and seedling growth parameters, CB-9 was supposed to be superior genotype followed by CB-12, CB-10 and CB-14 whereas genotype CB-15 was more susceptible than other genotypes against salinity stress. Similar study should be conducted in the field to better understand the effects of salinity stress on growth and yield performance of cotton.

COMPETING INTEREST

The authors declare that they have no competing interests to write this manuscript.

ACKNOWLEDGEMENT

The author expresses her heartfelt respect to Khulna University Research Cell for providing fund and Agrotechnology Discipline, Khulna University for giving technical supports for conducting this research. The author also shows heartiest gratefulness and thanks to all the co-authors for their valuable advice, suggestions and constructive criticism.

REFERENCE

1. Ahmad S, N Khan, MZ Iqbal, A Hussain and M Hassan, 2002. Salt tolerance of cotton (*Gossypium hirsutum L*.). Asian Journal of Plant Sciences, 1(6): 715-719.
2. Bam RK, FK Kumaga, K Ofori and EA Asiedu, 2006. Germination, vigor and dehydrogenase activity of naturally aged rice (*Oryza sativa L*.) seeds soaked in potassium and phosphorus Salts. Asian Journal of Plant Sciences, 5: 948-955.

3. BBS (Bangladesh Bureau of Statistics), 2018. Agricultural Statistics of Bangladesh, Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.
4. Chachar QI, AG Solangi and A Verhoef, 2008. Influence of sodium chloride on seed germination and seedling root growth of cotton (*Gossypium hirsutum L*.). Pakistan Journal of Botany, 40(1): 183.
5. Chartzoulakis K and G Klapaki, 2000. Response of Two Greenhouse Pepper Hybrids to NaCl Salinity During Different Growth Stages. Scientia Horticulturae, 86(3): 247-260.
6. Chen W, Z Hou, L Wu, Y Liang and C Wei, 2010. Effects of salinity and nitrogen on cotton growth in arid environment. Plant and soil, 326(1-2): 61-73.
7. Gomez KA and AA Gomez, 1984. Statistical Procedures for Agricultural Research. John Wiley & Sons.Pp: 1-91.
8. Iqbal MH, 2013. Nexus between Salinity and Ecological Sustainability of Crop Production of Southwest Coastal Region of Bangladesh: Approach of Translog Production Function. Working Paper, Department of Economics, Government Edward College, Pabna, Bangladesh.
9. Jamil M, DB Lee, KY Jung, M Ashraf, SC Lee ans SE Rha, 2006. Effect of salt (NaCl) stress on germination and early seedling growth of four vegetable species. Journal of Central European Agriculture, 7(2): 273-282.
10. Khan A N, R H Qureshi and N Ahmed, 1998. Performance of cotton cultivars as affected by types of salinity. I. Growth and yield. Sarhad Journal of Agricultural Science, 14: 73- 77.
11. Leidi E O, R Nogales and S H Lips,1991. Effect of salinity on cotton plant grown under nitrate or ammonium nutrition at different calcium levels. Field Crops Research, 26: 35-44.
12. Muhammad Z and F Hussain, 2012. Effect of NaCl salinity on the germination and seedling growth of seven wheat genotypes. Pakistan Journal of Botany, 44(6): 1845-1850.
13. Pessarakli M, 1995. Physiological Responses of Cotton (*Gossypium hirsutum* L.) to Salt Stress. In: Handbook of Plant and Crop Physiology, Pessarakli, M. (Ed.). Marcel Dekker, New York, pp: 679-693.
14. Podder S, J Ray, D Das and BC Sarker, 2020. Effect of salinity (NaCl) on germination and seedling growth of mungbean (*Vigna radiata L*.). Journal of Bioscience and Agriculture Research, 24(02): 2012-2019.
15. Qadir M and M Shams,1997. Some agronomic and physiological aspects of salt tolerance in cotton (Gossypium hirsytum L.). Journal of Agronomy and Crop Science, 179: 101-106.
16. Rauf A, MJ Zaki and D Khan, 2014. Effects of NaCl salinity on growth of some cotton varieties and the root rot pathogens. International Journal of Biology and Biotechnology, 11(4): 661-670.
17. Rehman A and M Farooq, 2019. Morphology, Physiology and Ecology of cotton. Cotton Production, 23-46.
18. Saleh B, 2012. Salt stress alters physiological indicators in cotton (*Gossypium hirsutum L*.). Soil & Environment, 31(2): 113-118.
19. Sardoei AS, MN Zad, MS Fazel, BA Gerdeh & M Shahvardi, 2013. Effect of salinity stress on germination in *Lycopersicon esculentum L. var Cal-ji*. International Journal of Advanced Biological and Biomedical Research, 1(12): 1543-1550.
20. Sattar S, T Hussnain and A Javaid, 2010. Effect of NaCl salinity on cotton (*Gossypium arboreum L.*) grown on MS medium and in hydroponic cultures. The Journal of Animal and Plant Sciences, 20(2): 87-89.
21. Zhong H and A Lauchli, 1993. Spatial and temporal aspects of growth in the primary root of cotton seedlings. Effect of NaCl and CaCl2. Journal of Expl. Botany, 44: 763- 771.