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Effect of Salinity (NaCl) Stress on Root-shoot Traits of Tomato in Hydroponic Culture

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ABSTRACT

Background: Tomato is one of the most important and popular vegetable crop grown mainly in dry seasons in Bangladesh. The southern part of the country is suffering from soil salinity problem due to tidal floods. The increasing salinity in the cultivatable land causes huge crop failure. A dozen of tomato varieties have been developed but they are not been tested for salinity tolerance. Therefore, this study was conducted to evaluate the tolerance level of tomato varieties against NaCl salinity stress at the vegetative stage.

Methods: The study comprised of four levels of electrical conductivity (EC) based NaCl salinity *viz.,* EC 2 (control), EC 4, EC 6 and EC8 mS/cm and eight varieties of tomato. The two-factor pot experiment was carried out in a randomized complete block design with four replications. NaCl salinity was imposed on the tomato plants through a hydroponic culture system and the effects of salinity on shoot-roots traits were measured.

Result: Results showed that morphological traits of tomato plants varied significantly with the salinity levels and variety. It is also noticed that all the vegetative traits reduced as salt concentrations increased in the solution. In combined effects of variety and salinity levels, it was found that BARI Tomato-17 performed superior. It can be concluded that variety BARI Tomato-17 showed comparatively salt tolerant than the other varieties.

Key words: Electrical conductivity, Leaf area, Root shoot ratio, RWC, Tomato.

INTRODUCTION

Field crops are naturally experienced various biotic and abiotic stresses during growth and development. These stresses reduce their growth and productivity. Soil salinity is one the most critical abiotic stress factor for affecting the growth, development and yield of crop plant particularly in arid and semi-arid countries of the world (Ahmed, 2009, Horie *et al*. 2012; Tu *et al*. 2014; Yang and Guo, 2018). In the world, about 900 million hectares of land approximately 20% of the total agricultural land area affected by salt (FAO, 2016) and this area under salinity is increasing day by day mainly due to global climate change (Shabala, 2013; Suzuki *et al*. 2016). In Bangladesh, coastal areas of about 2.86 million hectares are covered by 30% of the total cropland of the country (SRDI, 2001). Saline soil is characterized by the presence of toxic levels of sodium and its chlorides and sulphates. Salt induces growth reduction of a plant which poses a major problem in crop productivity in the places where the lands are affected by salt (Chatterjee and Majumder, 2010).

Most of the plants have some mechanisms to survive with salinity stress at the biochemical and molecular levels (Shinozaki *et al*. 2005; Hauser and Horie, 2010). In plants, salt stress causes reduction of cell turgor pressure and suppressed the rate of root and leaf elongation, indicating that environmental salinity acts primarily on the water uptake mechanism of plants (Fricke *et al*. 2006).

It is reported that the salt-affected areas of Bangladesh are increasing every year and crop production is severely hampered in the southern part of the country.

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Tomato *(Lycopersicon esculentum* Mill.) is one of the most important, popular and nutritious vegetables in Bangladesh grown in both winter and summer seasons in all most all districts of the country. It is cultivated in almost all homestead gardens and also in the field for its adaptability to a wide range of soil and climate. Tomato is very rich in nutrients, especially potassium, folic acid, vitamin C and contains a mixture of different carotenoids, including vitamin A, effective â-carotene as well as lycopene.

According to BBS (2017), Bangladesh produces 388725 metric tons of tomato from 276788.54 hectares of land with an average yield of 14.04 ton/ha. It is necessarily important to increase the area under tomato cultivation to meet up the demand of the country. This target will achieve if saline areas of the country can bring under tomato cultivation using salt-tolerant tomato varieties. Bangladesh Agricultural University (BARI) has developed over a dozen of high tomato varieties

This study was designed to evaluate the electrical conductivity (EC) based NaCl stress responses on the shoot and root traits of BARI released tomato varieties which will support a selection of salt-tolerant tomato varieties for cultivation in saline prone areas of Bangladesh.

MATERIALS AND METHODS

Planting materials

This study was conducted with eight varieties of tomato. Seeds were collected from the Horticulture Division of BARI. Seedlings were raised in a wooden box using coco peat.

Experimental design and treatments

The two-factor study comprised of eight tomato varieties *viz.,* V_1: BARI Tomato-2, V_2: BARI Tomato-3, V_3: BARI Tomato-4, V_4: BARI Tomato-8, V_5: BARI Tomato-14, V_6: BARI Tomato-15, V_7: BARI Tomato-16; V_8: BARI Tomato-17 and four levels of EC based NaCl salinity *viz.,* EC 2 (Control), EC4, EC6 and EC8 mS/cm. The study was conducted following a randomized complete block design with three replications. The size of the plastic planter was 90 cm × 30 cm × 30 cm. The experiment was conducted at the Polyhouse of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh during November 2017 to February 2018.

Preparation and application of the salt solution

Hogland's nutrient solution was prepared by using different salts: $MgSO_4$, $NH_4H_2PO_4$, KNO_3, $Ca(NO_3)_2.4H_2O$, EDTA-Fe, H_3BO_4, $MnSO_4$, $ZnSO_4$, $NaMoO_4$, $CuSO_4$ and $CaCl_2$. The salinity level and pH of the solution was checked by EC and pH meter (Hanna HI99301). According to the design of this study, four levels of salinity were prepared to add an additional amount of NaCl salt to the solution. The salinity levels of the solution were closely monitored by the EC meter and pH, EC levels were also adjusted during the experiment period.

Transplanting of seedlings and other operations

Three-week-old healthy, disease-free, uniform seedlings were initially transplanted in a separate planter with EC1 solution for a week. Thereafter, uniformly grown seedlings were carefully shifted into the salt solutions.

Data collection

Data on various parameters were recorded at 35 days after transplanting (DAT). Stem diameter was measured using digital slide calipers and the number of branches was recorded. The leaf area of fully expanded mature fresh leaves was measured by leaf area meter (Li-3100C, Li-COR Biosciences, USA). Relative water content (%RWC) of leaves was determined using the following equation-

$$\%\,\text{RWE}=\frac{\text{Fresh weight-Dry weight}}{\text{Urged weight-Dry weight}}\times 100$$

The shoots and roots of a plant were detached from a planter, root length was recorded and dried in an electric oven at 70°C until constant weight. Finally, the root shoot ratio was calculated using the following equation-

$$\text{Root shoot ratio}=\frac{\text{Root dry weight}}{\text{Shoot dry weight}}$$

Statistical analysis

The data were statistically analyzed using MSTAT-C statistical software. The analyses of variance (ANOVA) for all the characters were performed by the *F* test. The significance of the difference between the pairs of means was separated by the LSD test at 5% and 1% levels of probability (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Stem diameter

Stem diameter varied significantly among the variety. The maximum stem diameter (1.10 cm) was observed from BARI Tomato-17 while the minimum (0.43 cm) was found from BARI Tomato-3 (Fig 1a). Significant variations were observed with different salinity levels. The highest stem diameter (0.92 cm) was recorded from EC2 while the least diameter (0.7 cm) was recorded from EC8 (Fig 1b). The maximum stem diameter (1.27 cm) was found in a combination of BARI Tomato-17 with EC2 and the minimum stem diameter (0.37 cm) was recorded in a combination of BARI Tomato-3 with EC8 (Table 1).

Number of branches

The number of branches varied significantly by the effect of variety. The highest number of branches per plant (4.83) was observed in BARI Tomato-17 while the lowest number of branches (0.83) was found in BARI Tomato-3 (Fig 2a). Significant variations were found due to salinity levels. The highest number of branches per plant (3.58) was recorded from EC2 and the lowest number of branches (2.42) was recorded from EC8 (Fig 2b). The maximum number of branches (5.33) was found in a combination of V_8EC2 and no branches (0.00) were found from the combination of V_2EC6 and V_2EC8 (Table 1).

Leaf area

Leaf area varied significantly by the influence of variety. The maximum leaf area (403.42 cm^2) was observed from BARI Tomato-17 while the minimum leaf area (39.79 cm^2) was found from BARI Tomato-3 (Fig 3a). Significant variations were also found due to different salinity levels. The largest leaf area (319.27 cm^2) was recorded from EC2, while the smallest leaf area (189.68 cm^2) was observed from EC8 (Fig 3b). The combined effects of variety and salt concentration showed a significant influence on leaf area. The maximum leaf area (451.67 cm^2) was found in a

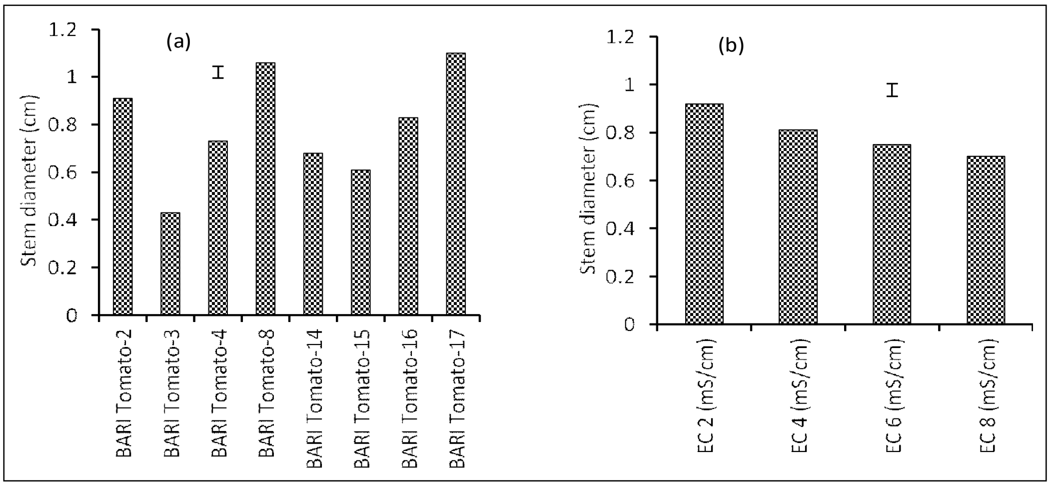

Fig 1: Main effects of variety (a) and treatments (b) on stem diameter of tomato. Vertical bars represent LSD at 1% level of significance.

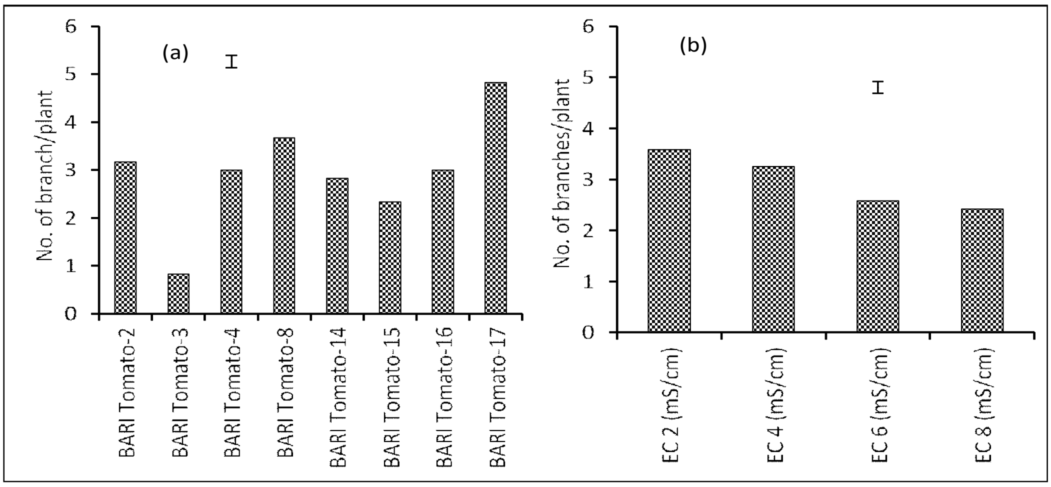

Fig 2: Main effects of variety (a) and treatments (b) on the number of branches per plant. Vertical bars represent LSD at 1% level of significance.

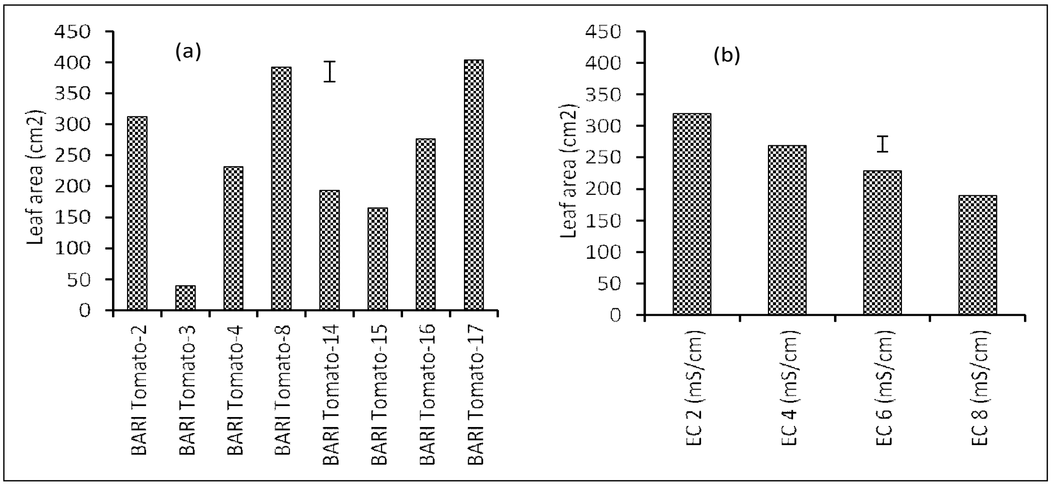

Fig 3: Main effects of variety (a) and treatments (b) on leaf area of tomato. Vertical bars represent LSD at 1% level of significance.

combination of BARI Tomato-17 with EC2 and the minimum leaf area (12.32 cm^2) was found from the combination of BARI Tomato-3 with EC8 (Table 1).

RWC

RWC of leaves varied significantly due to varietal effects. The maximum RWC (80.92%) was observed from BARI Tomato-17 and the minimum RWC (68.03%) was found from BARI Tomato-3 (Table 2). Significant variations were observed with different salinity levels. The maximum RWC (80.18%) was recorded from EC2, while the minimum RWC (64.48%) was found from EC8 (Table 3). In combination with variety and salinity levels, the highest RWC (86.86%) was found from the combination of BARI Tomato-17 with EC2 and the minimum RWC (60.25%) was recorded from the combination of BARI Tomato-3 with EC8 (Table 1).

Shoot dry weight

Shoot dry weight varied significantly by the effects of variety. The highest shoot dry weight (19.53 g/plant) was observed from BARI Tomato-17 and the lowest shoot dry weight (3.68 g/plant) was found from BARI Tomato-3 (Table 2). Significant variations were observed in shoot dry weight with different salinity levels treatment. The maximum shoot dry weight (12.91 g/plant) was recorded from EC2 and the minimum shoot dry weight (9.95 g/plant) was recorded from EC8 (Table 3). The combined effects showed a significant influence on shoot dry weight. The maximum shoot dry weight (21.26 g/plant) was found from the combination of BARI Tomato-17 with EC2and the minimum shoot dry weight (3.07 g/plant) was achieved from the combination of BARI Tomato-3 with EC8 (Table 1).

Root length

Root length per plant varied significantly among the variety. The highest root length (68.58 cm/plant) was recorded from BARI Tomato-17 while the least root length (26.50 cm/plant) was found from BARI Tomato-3 (Table 2). Significant variations were observed due to salinity levels and the height root length (51.29 cm/plant) was recorded from EC2, while the lowest root length (43.88 cm/plant) was recorded from EC8 (Table 3). The combined effects showed a significant influence on root length. The maximum root length (71.33 cm/plant) was observed under the combination of BARI Tomato-17 with EC2 and the minimum root length (23.67 cm/plant) was found under the combination of BARI Tomato-3 with EC8 (Table 1).

Root dry weight

Root dry weight varied significantly due to varietal effects. The maximum root dry weight (5.81 g/plant) was recorded from BARI Tomato-17 while the minimum root dry weight (1.25 g/plant) was recorded from BARI Tomato-3) (Table 2). Significant variations were observed in root dry weight with different salinity levels. The maximum root dry weight (3.68 g/plant) was found from EC2 while the minimum root dry

Table 1: Main effects of variety on shoot-root traits of tomato.

Variety	%RWC	Shoot dry wt. (g/plant)	Root length (cm)	Root dry wt. (g/plant)	Root shoot ratio
BARI Tomato-2	77.63	14.90	57.00	4.04	0.27
BARI Tomato-3	68.03	3.68	26.50	1.25	0.34
BARI Tomato-4	73.59	9.55	48.17	3.03	0.32
BARI Tomato-8	78.63	18.04	60.25	4.68	0.26
BARI Tomato-14	73.20	6.36	35.50	2.34	0.37
BARI Tomato-15	71.97	6.05	29.58	1.99	0.34
BARI Tomato-16	75.89	13.28	53.83	3.64	0.27
BARI Tomato-17	80.92	19.53	68.58	5.81	0.30
$LSD_{0.05}$	0.70	0.22	0.68	0.09	0.03
$LSD_{0.01}$	0.93	0.29	0.90	0.11	0.04
Level of significance	**	**	**	**	**

**indicates significant at 1% level of probability.

Table 2: Main effects of treatments on shoot-root traits of tomato.

Variety	%RWC	Shoot dry wt. (g/plant)	Root length (cm)	Root dry wt. (g/plant)	Root shoot ratio
EC 2 (mS/cm)	80.18	12.91	51.29	3.68	0.30
EC 4 (mS/cm)	77.55	11.91	48.21	3.53	0.31
EC 6 (mS/cm)	73.71	10.92	46.33	3.28	0.32
EC 8 (mS/cm)	68.48	9.95	43.88	2.90	0.32
$LSD_{0.05}$	0.49	0.15	0.48	0.06	0.02
$LSD_{0.01}$	0.66	0.20	0.64	0.08	0.03
Level of significance	**	**	**	**	**

**indicates significant at 1% level of probability.

weight (2.90 g/plant) was recorded from EC8 (Table 3). The combined effects of variety and salt concentration showed a significant influence on root dry weight. The highest root dry weight (6.44 g/plant) was found in the combination of BARI Tomato-17 with EC2 and the lowest root dry weight (0.89 g/plant) was observed from the combination of BARI Tomato-3 withEC8 (Table 1).

Root shoot ratio

Root shoot ratio varied significantly by the effects of variety. The maximum root shoot ratio (0.37) was noticed from BARI Tomato-14 and the minimum ratio (0.26) was found from BARI Tomato-8 (Table 2). Significant variations were observed with different salinity levels. The highest root shoot ratio (0.32) was recorded from EC6 and EC8, on the other hand, the lowest root shoot ratio (0.30) was recorded from EC2 (Table 3). In combination with both treatments, the highest root shoot ratio (0.41) was found from BARI Tomato-14-and BARI Tomato-15 with EC8 combination and the minimum root shoot ratio (0.25) was found from BARI Tomato-8 withEC8 combination (Table 1).

This study was conducted to examine EC based NaCl salt stress responses to vegetative traits of tomato in a hydroponic culture system. Four levels of NaCl salinity stresses were applied in hydroponic solution to eight tomato varieties at the early stage of growth. Results showed that

Table 3: Combined effects of variety and treatments on shoot-root traits of tomato.

Treatment combinations		Stem diameter (cm)	Branches/ plant	Leaf area (cm^2)	% RWC	Shoot dry wt. (g/plant)	Root length (cm/plant)	Root dry wt. (g/plant)	Root shoot ratio
BARI Tomato-2	EC 2	1.00	4.00	354.12	84.26	16.43	60.67	4.26	0.26
	EC 4	0.93	3.33	344.82	83.13	15.44	57.67	4.21	0.27
	EC 6	0.87	2.67	282.22	75.24	14.43	56.67	3.86	0.27
	EC 8	0.83	2.67	266.41	67.89	13.32	53.00	3.84	0.29
BARI Tomato-3	EC 2	0.60	2.00	57.10	72.68	4.18	28.00	1.43	0.35
	EC 4	0.40	1.33	51.23	70.72	3.81	27.67	1.37	0.36
	EC 6	0.37	0.00	38.54	68.47	3.67	26.67	1.31	0.36
	EC 8	0.37	0.00	12.32	60.25	3.07	23.67	0.89	0.29
BARI Tomato-4	EC 2	0.87	3.33	291.04	77.54	11.12	55.67	3.16	0.28
	EC 4	0.73	3.33	230.44	75.10	9.51	47.67	3.07	0.32
	EC 6	0.67	2.67	214.46	72.91	8.88	47.67	3.00	0.34
	EC 8	0.63	2.67	191.21	68.81	8.69	41.67	2.88	0.33
BARI Tomato-8	EC 2	1.13	4.67	499.87	86.54	19.41	64.67	5.07	0.26
	EC 4	1.10	4.00	448.73	84.17	18.98	63.00	4.98	0.26
	EC 6	1.03	3.33	354.39	76.30	17.89	57.33	4.68	0.26
	EC 8	0.97	2.67	264.93	67.51	15.87	56.00	3.96	0.25
BARI Tomato-14	EC 2	0.83	3.33	255.12	77.80	8.15	38.33	2.85	0.35
	EC 4	0.67	2.67	193.00	74.88	7.03	36.00	2.48	0.35
	EC 6	0.63	2.67	184.29	72.29	5.49	34.33	2.07	0.38
	EC 8	0.57	2.67	141.63	67.83	4.76	33.33	1.94	0.41
BARI Tomato-15	EC 2	0.73	2.67	314.28	75.67	7.83	35.33	2.13	0.28
	EC 4	0.67	2.67	129.30	72.19	7.07	29.00	2.06	0.29
	EC 6	0.57	2.00	119.33	70.16	4.90	27.33	1.95	0.40
	EC 8	0.47	2.00	97.11	69.86	4.42	26.67	1.80	0.41
BARI Tomato-16	EC 2	0.90	3.33	330.95	80.11	14.94	56.33	4.07	0.27
	EC 4	0.87	3.33	316.11	77.04	13.52	55.33	3.81	0.28
	EC 6	0.80	2.67	251.58	74.00	12.89	52.67	3.60	0.28
	EC 8	0.73	2.67	206.91	72.41	11.76	51.00	3.09	0.26
BARI Tomato-17	EC 2	1.27	5.33	451.67	86.86	21.26	71.33	6.44	0.30
	EC 4	1.10	5.33	438.19	83.13	19.89	69.33	6.26	0.32
	EC 6	1.03	4.67	386.92	80.34	19.20	68.00	5.75	0.30
	EC 8	1.00	4.00	336.92	73.35	17.75	65.67	4.81	0.27
$LSD_{0.05}$		0.14	0.25	17.33	1.40	0.43	1.36	0.17	0.05
$LSD_{0.01}$		0.18	0.34	23.04	1.86	0.57	1.81	0.23	0.07
Level of significance		NS	**	**	**	**	**	**	**

**indicates significant at 1% level of probability, NS= Non-significant.

different varieties of tomato responded differently to shoot and root traits under salinity treatments. It was observed that stem diameter, number of branches, leaf area, RWC, shoot dry matter content, root length and root dry weight declined with an increment of salinity levels. These results are supported by the findings of D'Souza and Devaraj (2010). They stated that salt stress reduced leaf surface area, shoot and root length of hyacinth bean. Fricke *et al*. (2006) noticed that salt stress causes reduction of cell turgor and restrict the rate of leaf and root elongation by reclining water uptake by plants.

In this study, the number of branches was found to be reduced due to progressive salinity stress. Yadav *et al*. (1998) noticed that the number of branches was reduced in high salinity conditions. Morphologically the most typical symptom of saline injury to plants was the reduction of a branch (Jaleel *et al*., 2008). A significant reduction of RWC in leaves was noticed as salinity levels increased. Salinity causes a reduction in leaf RWC in field crops reported by many authors, in hyacinth bean (D'Souza and Devaraj, 2010), maize (Cicek and Cakirlar, 2002). Among the tested tomato variety, BARI Tomato-17 maintained the highest RWC (80.92%) followed by BARI Tomato-8 (78.63%).

In this study, root dry weight per plant was the highest at maximum growth stage because of rapid cell elongation and cell division. The root dry weight was highest in BARI tomato-17 due to accumulation of food materials against different salinity level. It is reported that the capacity of ion accumulation of plants under stress condition is associated with their tolerance level. Amini and Ehsanpour (2005) reported that Na+/K+ ration increased in plants under salt stress condition indicating its salt-tolerant capacity. In this study, two varieties BARI tomato 17 and BARI tomato 8 showed relatively tolerant to salt stress as they maintained comparatively higher RWC in leaves as well as root length.

CONCLUSION

Different tomato varieties performed differently in response to the electrical conductivity (EC) based NaCl salinity stress-induced in the hydroponic culture system. Shoot-root traits varied significantly with the varieties and salinity levels. The morphological responses *viz*., number of branches, leaf area, RWC, root shoot ratio, shoot dry weight, root dry weight, root length of BARI tomato-17 were better than other varieties even when treated with the highest level of salinity *i.e*. 8EC (mS/cm). So, it can be concluded that BARI tomato-17 is comparatively more salt tolerant than the other varieties studied in this experiment.

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