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Effect of Salinity Stress on Different Root and Shoot Traits of Selected Tomato Cultivars

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Authors' contributions

This work was carried out in collaboration among all authors. Authors MOK, MLR, KA, MSH, MRK and MMK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MSH and DCP managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

An *in-vitro* test was conducted at the laboratory of the Department of Genetics and Plant Breeding, Hajee Mohammad Danesh Science and University (HSTU), Dinajpur, Bangladesh to screen out the tomato genotypes were screened for salt tolerance during germination. The test was conducted in the Completely Randomized Design (CRD) utilizing three replications. Ten tomato

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genotypes specifically BARI Tomato-2, BARI Tomato-3, BARI Tomato-5, BARI Tomato-11, BARI Tomato-14, BARI Tomato-16, Mintoo, Unnoyon, Mintoo Super and Sawsan were germinated on sand bed watered with five levels of salinity treatment i.e. 0, 4,8,12 and 16 dSm^{-1}. The test was laid out in completely randomized design (CRD) with three replications. The days to 50% germination was maximum in Unnoyon genotype in all the treatments [1]. BARI Tomato-3 showed the minimum value in most of the cases. Root and shoot parameters like root length, shoot length, shoot fresh weight, root fresh weight, shoot dry weight, root dry weight, ratio on root and shoot fresh weight, ratio on root and shoot dry weight were the highest in BARI Tomato-2, Mintoo and Unnoyon, in contrast, the lowest performance of these traits were revealed in BARI Tomato-16 and BARI Tomato-3 at higher salinity treatment (12 and 16 dSm^{-1}) than other genotypes in most of the cases. The overall results of the experiment exhibited BARI Tomato-2, Mintoo and Unnoyon found to be the more tolerant genotypes at higher salinity stress in respect of days to 50% germination and root and shoot characters than other genotypes.

Keywords: Tomato; salinity; root; shoot traits.

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the imperative vegetables grown throughout the world and possessing prime position among prepared vegetable. It belongs to the family Solanaceae. It is one of the foremost, well known and nutritious vegetable crop all over the world counting Bangladesh. It is a top choice cultivable vegetable generally grown within the winter season in Bangladesh. It likes the cold and dry climate for superior growth and development [2]. Presently, tomato is an all-around known vegetable and is one of the most noteworthy developed vegetables within the world which leads all other vegetables in the total volume of production [3]. It is the foremost commercially important widely developed vegetable all through the world. The production of tomato is expanding day by day due to its differential utilization and higher dietary value.

Among the abiotic components, salinity is as of now one of the most serious factors that limit agricultural production [4,5]. The efficiency of many agricultural crops counting tomato is diminished due to higher saltiness. For crop production over the topsoil, saltiness can be a major natural limitation. This increment is caused by both natural phenomena and human exercises [6]. Secondary salinization of cultivated lands is caused by improper agricultural practices such as the utilization of much chemical fertilization and lacking water system management. Besides, land debasement caused by secondary salinisation is getting increasingly an issue [6,7]. Agreeing to the USDA report, tomato is tolerably sensitive to saltiness out of all vegetables. Salinity stress decreases water potential and causes ion imbalance and toxicity [8,9]. The salt damage to seed development is credited to different variables such as a reduction in water accessibility, changes in the mobilization of stored reserves and influencing the basic organization of proteins [10,11,12,13]. Saltiness slows down tomato shoot development and the growth of younger seedlings; the higher the saline concentration the larger the reduction in shoot development [14]. The tomato response to salt stress is in an unexpected way controlled in several development stages [15]. In Bangladesh, the coastal region covers nearly 29,000 km^2 or approximately (20%) of the country which to covers more than (30%) of the overall cultivable lands of the country. Approximately (53%) of coastal zones are influenced by saltiness. In 147 Upazilas beneath 19 districts and 8, 33, 000 hectors (8, 330 km^2) of land are saltiness influenced. Out of which 48 Upazilas in 12 districts are exposed to the sea or lower estuaries and 99 Upazilas lies within the insides coast [16].

In saline zones, the yield of tomato diminishes with the expanding saltiness level. So salt-tolerant tomato breeding materials are required. The primary step towards identifying tolerant cultivars is the hereditary characterization of valuable germplasm. This study endeavoured to find out the level of salt tolerance in 10 tomato genotypes. The objective of the present investigation was to identify the tomato genotypes tolerant to expanding saltiness by evaluating 50% germination and different root-shoot characters.

2. MATERIALS AND METHODS

2.1 Study Materials

Ten hereditarily assorted tomato varieties were collected from BARI (Bangladesh Agriculture

Research Institute), Joydebpur, Gazipur, Bangladesh and Lal Teer seed Ltd. Dhaka 1205, Bangladesh with varying degree of salt tolerance named BARI Tomato 2, BARI Tomato 3, BARI Tomato 5, BARI Tomato 11, BARI Tomato 14, BARI Tomato 16, Mintoo, Mintoo Super, Unnoyon and Sawsan.

2.2 Study Design

The test was conducted in the Completely Randomized Design (CRD) utilizing three replications.

2.3 Preparation of Saline Solution

For making 4, 8, 12 and 16dSm^{-1} saline solution 0.64, 1.28, 1.92 and 2.56 g NaCl, separately were diluted in 250 mL distilled water in different volumetric flasks. Each plastic pot was prepared by soaking with 2 mL of refined water or one of the NaCl salt solutions (0, 4, 8, 12 and 16 dSm^{-1}NaCl solution) [17].

2.4 Preparation of Study Materials

The collected seeds were then cleaned with a solution of 10% sodium hypochlorite. After that, they were washed with refined water a few times to remove the adhering substances and put in sand containing planting medium. The Petri dishes were kept under artificial light (9 hrs/day) at 20°C in a culture room to complete the seedling development. The entire set up was replicated thrice.

2.5 Data Collection

On the 14th day of the experiment, data were recorded on days to 50% germination, root length, shoot length, shoot fresh weight, root fresh weight, shoot dry weight, root dry weight, the ratio on root and shoot fresh weight, the ratio on root and shoot dry weight.

2.6 Statistical Analysis of the Collected Data

The mean values of all the characters were assessed and analysis of change was performed by the 'F' test. To test the contrasts among the genotypes Duncan's Multiple Range Test (DMRT) was performed by utilizing Statistical Tool for Agricultural Research (STAR) form 2.0.1 2014.

3. RESULTS AND DISCUSSION

3.1 Effect of Tomato Genotypes and Different Concentration of NaCl Solution on Shoot Fresh Weight

The values of the shoot fresh weight of the ten tested tomato genotypes were found to be generally lower with the rise of salinization level (Table 1). The shoot fresh weight was obviously decreased in all genotypes with the increment of salinity level on comparing with the control (Table 2). Under control treatment (T_1) BARI Tomato-14 showed the maximum shoot fresh weight (45.07 g) which is statistically similar with BARI Tomato-5 and Mintoo produced minimum which also statically similar with BARI Tomato-16 (23.94 g). At lowest saline treatment (T_2) BARI Tomato-2 produced maximum and BARI Tomato-14 produced minimum fresh weight in both T_4 and T_5 treatment. With the highest elevation of salinity treatment shoot, fresh weight was reduced as compared to control. The reason may be that the shoot length is affected negatively by salt stress is due to the toxic effect of salts as well as inhibition of cytokinesis and cell expansion. Also, the decreases in hormones that invigorate the development and improvement can cause shorter root and shoot length [18]. The increment in osmotic pressure around the roots as a result of the saline environment can moreover prevent water take-up by root and comes about with short root and shoot length [19].

3.2 Effect of Tomato Genotypes and Different Concentration of NaCl Solution on Root Fresh Weight

The experiment results revealed that salt concentrations and interactions of genotype-concentration were significant at 1% respectively (Table 1). While the highest root fresh weight was obtained from the control treatment in Mintoo Super (4.76 g) and the lowest root, fresh weight (0.0 g) was obtained from (T_5) in BARI Tomato-5, BARI Tomato-14, BARI Tomato-16 and BARI Tomato-3 genotypes. As can be seen in Table 3 root fresh weight decreased as salt concentration increased in all the genotype. Though clear variation was observed in lower salinity treatment, in moderate to higher salinity (T_3 to T_5) no variation was observed in the genotypes in respect of root fresh weight. Therefore, the results obtained in the present study are in agreement with previous studies as reported that the increase in salt concentration negatively affects root and shoot development [20,21,22].

3.3 Effect of Tomato Genotypes and Different Concentration of NaCl Solution on Shoot Dry Weight

The analysis of variance showed significant variation for shoot dry weight among the genotypes in all the treatment (Table 1). Results in Table 4 also showed that saline conditions reduced the shoot dry weight in all mentioned genotypes. In control treatment (T_1) BARI Tomato-11 produced maximum shoot dry weight (0.90 mg) followed by BARI Tomato-2. And minimum shoot dry weight was obtained from the BARI Tomato-16 (0.147 mg) which is also statistically similar with Unnoyon and BARI Tomato-14 in control treatment (T_1). BARI Tomato-2, Mintoo along with Sawsan and BARI Tomato-3 performed better in relation to shoot dry weight than other genotypes in minimum to moderate salinity level (T_2 to T_4 treatment). On the other hand, BARI Tomato-14 produced the lowest value of shoot dry weight in the above-mentioned treatment. Finally, at higher salinity level (T_5) Mintoo Super showed maximum shoot dry weight value (0.057 mg) than other genotypes of the study. The result is linear with [21,22,23] who appeared that shoot dry weight diminished with the increase of saltiness level.

3.4 Effect of Tomato Genotypes and Different Concentration of NaCl Solution on Root Dry Weight

From the research work it was found that as the salt concentration increased, the root dry weights differed depending on genotype (Table 3). The highest root dry weights were obtained in the control treatment for all the genotype studied. A

Table 1. Analysis of variance of ten important characters of the tomato genotypes

Characters	Source of variation with mean square				
	Genotype (9 d.f.)	**Treatment (4 d.f)**	**Gen: treat (36 df)**	**Error (80 d.f.)**	**Coefficient of variation (%)**
Shoot fresh weight (g)	138.60**	2632.94 **	72.36**	2.39	6.25
Root Fresh weight (g)	2405.45**	81936.59 **	1758.39**	0.00	3.39
Shoot dry weight (mg)	237.49**	378.38 **	138.49**	0.00	12.93
Root dry weight (mg)	23.68**	154.56**	31.54**	0.00	8.11
Root and shoot fresh weight ratio (g)	63.99**	932.81**	75.78 **	420979.75	18.08
Root and shoot dry weight ratio (mg)	492.05 **	1099.08 **	144.48**	0.03	7.16
Number of lateral branches	385.35**	1825.42**	251.39**	0.00	6.11

*** Significant at 1% level * Significant at 5% level and d.f. indicates degrees of freedom*

Table 2. Mean performance of shoot fresh weight at different levels of NaCl solution on ten tomato genotypes

Genotypes	Salinity treatment				
	T_1 (0 dSm^{-1})	**T_2 (4 dSm^{-1})**	**T_3(8 dSm^{-1})**	**T_4 (12 dSm^{-1})**	**T_5 (16 dSm^{-1})**
BARI Tomato-5	42.31ab	49.61c	32.68a	22.60 b	0.00 b
Mintoo Super	40.26b	47.31cd	35.56a	18.07c	12.22a
Unnoyon	33.60 cd	41.59ef	27.66bc	6.26e	13.99a
BARI Tomato-14	45.07a	56.28 b	33.52a	26.23 b	0.00 b
BARI Tomato-16	27.11fg	29.49g	22.59 d	10.92d	0.00 b
BARI Tomato-11	29.27ef	39.82f	16.49 e	13.55 d	12.06a
BARI Tomato-2	32.10c-e	75.99a	26.57cd	36.22a	12.51a
Mintoo	23.94 g	42.05ef	25.02cd	22.65 b	14.31a
Sawsan	34.79 c	30.57g	25.79cd	22.10 bc	10.17a
BARI Tomato-3	29.54 d-f	44.22de	31.63ab	11.25 d	0.00b
LSD (0.05%)	2.512				
CV (%)	6.25				

decreasing trend was observed in accordance with salt concentrations as the highest root dry weight was obtained from BARI Tomato-3 in T_2 interaction (0.0207 mg) and the lowest root dry weight (0.00 mg) was obtained BARI Tomato-5, BARI Tomato-16, BARI Tomato-3 and BARI Tomato-14 in (T_5) interaction (Table 5). The rise in root dry weight in tomato beneath salt stress must be accompanied by changes within the allocation of assimilates between the root and shoot i.e. greater extent of assimilates for root compared with shoot [16,24,25,26].

3.5 Effect of Tomato Genotypes and Different Concentration of NaCl Solution on Root and Shoot Fresh Weight Ratio

Significant differences among the genotype were observed from the analysis of variance of the shoot and root fresh weight ratio except for control treatment (Table 3). But in lower salinity level (T_2) all the genotype produced statistically similar result except BARI Tomato-16 which produced minimum value (9.9400 mg) above them. With the increase of salinity treatment, the shoot and root fresh weight ratio increases up to T_4 treatment from the control treatment but decreases at T_5 treatment (Table 6).

Therefore, the results obtained in the present study are in agreement with previous studies reported by Albacete et al. 2008. But at a higher level of salinity shoot and root fresh weight ratio reduced due to salt concentration negatively affects root and shoot development. From this point of view, the results are in accord with the already published results which reported that increasing salt concentration negatively affects root development [20,21,22].

Table 3. Mean performance of root fresh weight at different levels of NaCl solution on ten tomato genotypes

Genotype	Salinity treatment				
	T_1(0 dSm^{-1})	T_2 (4 dSm^{-1})	T_3(8 dSm^{-1})	T_4 (12 dSm^{-1})	T_5 (16 dSm^{-1})
BARI Tomato-5	4.36 c	1.37a	0.03a	0.00a	0.00a
Mintoo Super	4.76a	1.27b	0.01 a	0.00a	0.00a
Unnoyon	0.83i	0.74 c	0.00a	0.01a	0.00a
BARI Tomato-14	3.58e	0.40 e	0.00a	0.00a	0.00a
BARI Tomato-16	1.02 h	0.50 d	0.07a	0.01a	0.00a
BARI Tomato-11	2.25 g	0.25 f	0.00a	0.00a	0.00a
BARI Tomato-2	3.38 f	0.28 f	0.00 a	0.00a	0.00a
Mintoo	4.02 d	0.32 f	0.00 a	0.00a	0.00a
Sawsan	4.566b	0.67c	0.00 a	0.00a	0.00a
BARI Tomato-3	3.99 d	0.01 g	0.00 a	0.00a	0.00a
LSD (0.05%)	0.04				
CV (%)	3.39				

Means with the same letter are not significantly different; dSm^{-1}: deciSiemens per metre; T: Treatment

Table 4. Mean performance of shoot dry weight at different levels of NaCl solution on ten tomato genotypes

Genotypes	Salinity treatment				
	T_1(0 dSm^{-1})	T_2 (4 dSm^{-1})	T_3(8 dSm^{-1})	T_4 (12 dSm^{-1})	T_5 (16 dSm^{-1})
BARI Tomato-5	0.12 c	0.01 c	0.08a	0.08a	0.00 b
Mintoo Super	0.06 b	0.01c	0.00c	0.01 e	0.05a
Unnoyon	0.02 c	0.05 b	0.01c	0.04 c	0.00 b
BARI Tomato-14	0.01c	0.01 c	0.01 c	0.01 e	0.00 b
BARI Tomato-16	0.01c	0.01 c	0.01 c	0.01 e	0.00 b
BARI Tomato-11	0.9a	0.09a	0.01 c	0.05 bc	0.00 c
BARI Tomato-2	0.9a	0.09a	0.01 c	0.05 bc	0.00 b
Mintoo	0.01 c	0.08a	0.11a	0.08a	0.00 b
Sawsan	0.01 c	0.08a	0.10a	0.01 e	0.00 b
BARI Tomato-3	0.01 c	0.08a	0.01 c	0.07 b	0.00 b
LSD (0.05%)	0.00				
CV (%)	12.93				

3.6 Effect of Tomato Genotypes and Different Concentration of Nacl Solution on Root and Shoot Dry Weight Ratio

The shoot and root dry weight of tomato germplasm are presented in Table 7. In the control condition, tomato germplasm produces significant variation in shoot and root dry weight ratio (Table 3). Root and shoot dry weight ratio increases with the increase of salinity up to moderate salinity. At higher salinity treatment root and shoot dry weight ratio decreases from the control treatment. BARI Tomato-14 produced maximum root and shoot dry weight ratio value (3.80 mg) under control treatment (T_1) but the highest value obtained from BARI Tomato-2 (8.21 mg) statistically similar with Mintoo in moderate to higher salinity treatment (T_3 to T_5). On the contrary, BARI Tomato-16 produced the lowest value in all treatment (Table 7). This may be due to the genotypic contrasts of the genotypes and their resilience capability against salt stress, and the root and shoot dry weight ratio reduced as the salinity level elevated [27].

3.7 Effect of Tomato Genotypes and Different Concentration of Nacl Solution on a Number of Lateral Roots

The genotypes of the study showed a significant variation on a number of lateral branches in each salt treatment (Table 1). The maximum number of lateral root (4.23) was obtained in BARI

Table 5. Mean performance of root dry weight at different levels of NaCl solution on ten tomato genotypes

Genotype	Salinity treatment				
	T_1(0 dSm^{-1})	T_2 (4 dSm^{-1})	T_3(8 dSm^{-1})	T_4 (12 dSm^{-1})	T_5 (16 dSm^{-1})
BARI Tomato-5	2.35a-c	2.27de	4.22 cd	1.99 e	0.00 d
Mintoo Super	2.35a-c	2.93 c	4.56 cd	2.26 de	1.90 b
Unnoyon	2.55ab	2.56 c-e	6.39 b	4.85 b	1.18 c
BARI Tomato-14	2.77a	4.82a	4.04 d	2.19 de	0.00 d
BARI Tomato-16	0.66 d	2.08 e	1.59 e	0.81 f	0.00 d
BARI Tomato-11	2.57ab	2.85 cd	4.08 d	2.75 d	0.77c
BARI Tomato-2	2.58ab	3.65 b	7.07a	8.21a	5.22a
Mintoo	2.85a	3.92 b	7.00ab	8.19a	5.17a
Sawsan	1.87c	2.87cd	4.83 c	3.54 c	1.95 b
BARI Tomato-3	2.08 bc	2.92 c	3.99 d	2.34 de	0.00 d
LSD (0.05%)	0.00				
CV (%)	8.11				

Means with the same letter are not significantly different; dSm^{-1}: deciSiemens per metre; T: Treatment

Table 6. Mean performance of root and shoot fresh weight ratio at different levels of NaCl solution on ten tomato genotypes

Genotypes	Salinity treatment				
	T_1(0 dSm^{-1})	T_2 (4 dSm^{-1})	T_3 (8 dSm^{-1})	T_4 (12 dSm^{-1})	T_5 (16 dSm^{-1})
BARI Tomato-5	9.64abc	11.57 b	18.98 bc	28.37 bc	0.00 e
Mintoo Super	8.23 cd	12.49 b	18.28 c	26.98 cd	17.08ab
Unnoyon	9.25a-c	12.90 b	21.69 a	25.66 de	14.7513 c
BARI Tomato-14	8.90 b-d	11.42 bc	21.05 a	25.12 e	0.00 e
BARI Tomato-16	8.48 cd	9.94 c	18.33c	0.00 f	0.00 e
BARI Tomato-11	7.47d	12.20b	17.94 c	25.39 de	16.09 bc
BARI Tomato-2	10.67a	15.14 a	20.81 a	30.42 a	18.28 a
Mintoo	10.45 ab	15.25 a	20.80 a	31.32 a	17.99 a
Sawsan	8.76 cd	12.54 b	20.55 ab	28.79 b	18.33 a
BARI Tomato-3	5.81 e	11.92 b	19.04bc	26.92 cd	11.45 d
LSD (0.05%)	10.54				
CV (%)	18.08				

Table 7. Effect of genotypes and different concentration of NaCl solution on root and shoot dry weight ratio

Genotype	Salinity treatment				
	T_1(0 dSm^{-1})	T_2 (4 dSm^{-1})	T_3 (8 dSm^{-1})	T_4 (12 dSm^{-1})	T_5 (16 dSm^{-1})
BARI Tomato-5	2.35 bc	2.27 e	4.22de	1.98 de	0.00d
Mintoo Super	1.4362d	2.93 cd	4.56cd	2.26 cd	1.90b
Unnoyon	2.55 bc	3.03cd	6.39b	4.85 b	1.18 c
BARI Tomato-14	3.80a	4.82a	3.98e	2.19 d	0.00d
BARI Tomato-16	0.66e	2.08 e	1.59g	0.81f	0.00 d
BARI Tomato-11	2.57bc	3.45 bc	2.16f	2.75 c	0.77c
BARI Tomato-2	3.44a	3.65 b	7.07a	8.21a	5.22a
Mintoo	2.85 b	3.92 b	7.00a	8.19a	5.17a
Sawsan	1.51d	2.87 d	4.83 c	1.48 e	1.95 b
BARI Tomato-3	2.08c	3.08 cd	2.47f	2.34cd	0.0 d
LSD (0.05%)			1.17		
CV (%)			7.16		

Means with the same letter are not significantly different; dSm^{-1}: deciSiemens per metre; T: Treatment

Table 8. Mean performance of a number of lateral root of at different levels of NaCl solution on ten tomato genotypes

Genotypes	Salinity treatment				
	T_1(0 dSm^{-1})	T_2 (4 dSm^{-1})	T_3(8 dSm^{-1})	T_4 (12 dSm^{-1})	T_5 (16 dSm^{-1})
BARI Tomato-5	1.16 e	2.25 b	2.05e	1.51d	0.00c
Mintoo Super	2.03 c	2.19 b	3.61b	1.52d	0.00c
Unnoyon	1.02 e	1.42de	1.32g	0.00e	1.13b
BARI Tomato-14	1.73 d	2.97a	4.23a	2.58b	0.00c
BARI Tomato-16	1.99 c	1.61cd	2.49c	0.00e	0.00c
BARI Tomato-11	0.14 f	1.76 c	0.00h	2.03c	0.00c
BARI Tomato-2	2.75ab	2.12 b	1.64f	2.03c	0.00c
Mintoo	1.66a	1.63 cd	1.31g	2.98a	1.66a
Sawsan	1.49d	1.35 e	2.36cd	2.63b	0.00c
BARI Tomato-3	2.52 b	3.01a	2.24de	0.00e	0.00c
LSD (0.05%)	0.15				
CV (%)	6.11				

Means with the same letter are not significantly different; dSm^{-1}: deciSiemens per metre; T: Treatment

Tomato 14 at moderate salinity treatment (T_3) whereas the minimum (0.0) from higher salinity level (T_4 to T_5 treatment) in most of the genotype (Table 8). But only Mintoo genotype thrives at higher salinity level than other genotypes. This may due to genetical diversity among the genotypes and defence component of the genotype against salt stress by expanding their lateral branch number. The density of risen laterals is regularly decided for the whole length of the parent root [28,29,30].

4. CONCLUSION

In this study, the genotype Unnoyon, Mintoo super and BARI Tomato-2 were showed maximum tolerance to salinity than other genotypes in all the treatment. The overall results of the test revealed that salinity stress influenced the germination and subsequent root and shoot growth of the tomato seedling and the genotype BARI Tomato 2, Mintoo and Unnoyon were comparative more tolerant to higher salinity stress in respect of germination, root and shoot characters than the other genotypes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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