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Effects of salinity stress on seed germination and seedling growth of tomato

Purba Chakma, Md. Mokter Hossain✉, Md. Golam Rabbani

Department of Horticulture, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

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Correspondence:
Md. Mokter Hossain
✉: mokter.agr@bau.edu.bd

ABSTRACT

Salinity is a major constraint in crop production in saline prone areas of Bangladesh. Therefore, a study was carried out in order to investigate the effect of different levels of NaCl salinity stress on seed germination and seedling growth of tomato. This study was consisted with five varieties of tomato (BARI Tomato-2, BARI Tomato-3, BARI Tomato-4, BARI Tomato-14, and BARI Tomato-15) and four levels of NaCl salt solution (0, 50, 100 and 150 mM). Seeds were placed in petridish for germination and the seedlings were allowed to grow for ten days. Results showed that percent seed germination decreased with increasing salt concentration in the germinating media. The highest seed germination (68.25%) was recorded in untreated control (0 mM) condition and the lowest in 150 mM salt solution ((5.92%). In combination of variety and salt concentration, BARI Tomato-2 gave the highest germination (88.33%) under 0 mM salinity condition and the lowest (2.92%) in BARI Tomato-3 with 150 mM salt solution. However, percent germination, germination coefficient, radicle and plumule length, seedling vigor index, fresh weight of plumule and radicle, mean germination time, germination index decreased with increasing salt concentration as compared to untreated control condition. The findings indicated that BARI Tomato- 2, BARI Tomato-4 and BARI Tomato-15 were relatively tolerant to salt stress than BARI Tomato-3 and BARI Tomato-14.

Introduction

Salinity is one of the most critical abiotic stress factor for limiting crop production particularly in arid and semi-arid regions of the world (Buchanan *et al*., 2005; Munns and Tester, 2008; Ahmed, 2009, Horie *et al*., 2012; Tu *et al*., 2014; Yang and Guo, 2018). In the world, 900 million hectares of land approximately 20% of the total agricultural land are affected by salt (FAO, 2007) and this amount is supposed to be increase due to climate change (Shabala, 2013; Suzuki *et al*., 2016). In Bangladesh, coastal areas about 2.86 million hectares covered by 30% of the total crop land of the country (SRDI, 2001). Plants have some mechanisms to cope with salinity stress at the biochemical and molecular levels (Zhu, 2002; Shinozaki *et al*., 2005; Hauser and Horie, 2010).

Seed germination is an important and vulnerable stage in the life cycle of terrestrial angiosperms and determines seedling establishment and plant growth. Despite the importance of seed germination under salt stress and the mechanism(s) of salt tolerance in seeds is poorly understood. In vegetative plants, salt stress causes reduced cell turgor and depressed rates of root and leaf elongation, suggesting that environmental salinity acts primarily on water uptake (Fricke *et al*., 2006). The different results were detected from the effect of salinity stress on the quantitative and qualitative parameters. Ashraf and Khanam (1997) reported that salinity treatment led to reduction of growth and plant developments. Hossain and Nonami (2012) noticed that the reduction of growth coincided with the reduction of water potential in fruit tissue due to salt stress.

Tomato (*Lycopersicon esculentum* Mill.) belongs to the family Solanaceae, is a self-pollinated vegetable crop. It is one of the important, popular, nutritious and palatable vegetables grown in Bangladesh in both winter and summer season around all parts of the country. It is cultivated in almost all homestead gardens and also in the field for its adaptability to wide range of soil and climate (Ahmed, 1995). It ranks next to potato and sweet potato in the world vegetable production and tops the list of canned vegetables (Choudhury, 1979). However, Bangladesh produces 368 thousand tons of tomatoes from 27 thousand hectares of land with an average yield of 13.57 tons/ha (BBS, 2016). It plays a vital role in providing a remarkable quantity of vitamin A and vitamin C in human diet. It is also a rich source of lycopene, which may help counteract the harmful effects of substances called free radicals, which are thought to contribute to age-related processes and a number of types of cancer. Cooked tomato and tomato products are the best source of lycopene since it is released from the tomato when cooked. Tomato is widely cultivated in

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tropical, sub-tropical and temperate climates. In Bangladesh, the major growing areas of tomato include Chittagong, Comilla, Jessore, Narshingdi, Manikganj and Rajshahi. However, tomato production is greatly hampered in southern areas of the country due to ever increasing soil salinity. Therefore, it is necessarily important to find out salt tolerant tomato varieties for cultivation in saline prone areas of the country.

Seed germination as well as seedling growth is a critical phase for profitable crop production. Various scientific reports noticed that maximum percent of seed germination attain under distilled water condition and the rate declined as increased media salinity (Pena and Hughes, 2007; Zhang *et al*., 2010; Devkota and Zha, 2010; Al-Taisan, 2010; Ratnakar and Rai, 2013). Considering this situation the study was conducted to find out the effects of NaCl salinity stress on seed germination and subsequent seedling growth of some selected varieties of tomato.

Materials and Methods

This study was conducted at the Postgraduate Laboratory of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh during May to June 2016. The average temperature and relative humidity of the laboratory were 30±1° C and 74%, respectively. Seeds of BARI released tomato varieties were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Insects and disease free healthy seeds were used for the experiment. Laboratory grade sodium chloride (NaCl) salt was used to induce salinity during seed germination and salt concentration was expressed in milli mole (mM). The two-factor experiment was conducted using five tomato varieties *viz.*, V_1: BARI Tomato-2, V_2: BARI Tomato-3, V_3: BARI Tomato-4, V_4: BARI Tomato-14, V_5: BARI Tomato-15 and four levels of NaCl *viz.*, T_1= Control (0 mM, Tap water), T_2= 50 mM, T_3= 100 mM, T_4= 150 mM NaCl solution. The experiment was conducted following completely randomized design with three replications.

Twenty seeds of each variety were put on Whatman No. 1 filter paper (sterilized) in a petridish. Each filter paper was moistened with 2 ml of distilled water or one of the treatments. Germination was monitored from the day of seed sowing till 10th days. The moisture level and salt solution were monitored daily and respected solutions were applied time to time as per requirement. The germination was completed within 10th days. In the 10th day, data on germination rate and period; radicle and plumule length, fresh weight of radicles and plumules etc. were recorded.

A seed was considered to be germinated as seed coat ruptured, plumule and radicle came out. Germination is expressed in percentage. The germination percentage was calculated using the following formula-

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinate}}{\text{Total number of seeds set for test}} \times 100$$

Co-efficient of germination (CG) was calculated using the following formula (Copeland, 1976).

$$\text{Coefficient of germination} = \frac{A_1 + A_2 + \ldots\ldots\ldots\ldots + A_x}{A_1T_1 + A_2T_2 + \ldots\ldots\ldots\ldots + A_xT_x} \times 100$$

where, CG= Coefficient of germination (%), A= Number of seeds germinated, T= Time corresponding to A, x= Number of days to final count.

Randomly selected five seedlings were taken from each petridish to measure radical and plumule lengths using ruler and expressed in centimeter (cm). The vigor of the seedlings was calculated according to the following formula stated by Abdul-Baki and Anderson (1973):

Vigor index= {Mean of root length (cm) + Mean of shoot length (cm)} × Seed germination (%)

Plumules and radicles of five seedlings from each petridish were detached and their fresh weights were recorded using digital balance and expressed in milligram (mg).

Germination index was calculated as the product of number of days after sowing and number of germinated seeds divided by the total number of seeds sown (Li, 2008).

$$\text{Germination Index (GI)} = \frac{\sum diNi}{S}$$

where, di= Number of days after sowing seeds under a particular treatment, Ni= the number of germinated seeds and S= the total number of seeds sown for the experiment.

Mean germination time (MGT) was calculated using the following formula (Gairola *et. al*., 2011; Zewdie and Welka, 2015):

$$\text{MGT} = \frac{n_1 \times d_1 + n_2 \times d_2 + n_3 \times d_3 + \ldots\ldots\ldots + nm \times dm}{\text{Total number of days of counting}}$$

where, n= number of germinated seed, d = number of days, m = the mth day of counting.

The collected data were statistically analyzed following MSTAT-C computer package program. The means for all the treatments were calculated and the analyses of variance (ANOVA) for all the characters were

performed by *F* variance test. The significance of difference between the pairs of means was separated by Least Significant Difference (LSD) test according to Gomez and Gomez (1984).

Results

Seed germination

Seed germination was significantly influenced by different varieties of tomato. The maximum germination of seed (48.02%) was observed in BARI Tomato-2 followed by BARI Tomato-4 (28.75%), BARI Tomato-14 (24.08%) and the minimum germination percentage (16.77%) was observed in BARI Tomato-3 preceded by BARI Tomato-15 (22.58%) at 10 days after sowing (Figure 1). Different levels of NaCl salt concentrations also significantly influenced seed germination. It was noticed that seed germination decreased with increasing the concentration of NaCl. However, the maximum seed germination (68.25%) was found in untreated control condition (0 mM) followed by 50 mM (27.08%), 100 mM (9.92%) and the minimum germination (5.92%) was observed with 150 mM salt concentration at 10 days after sowing (Figure 2).

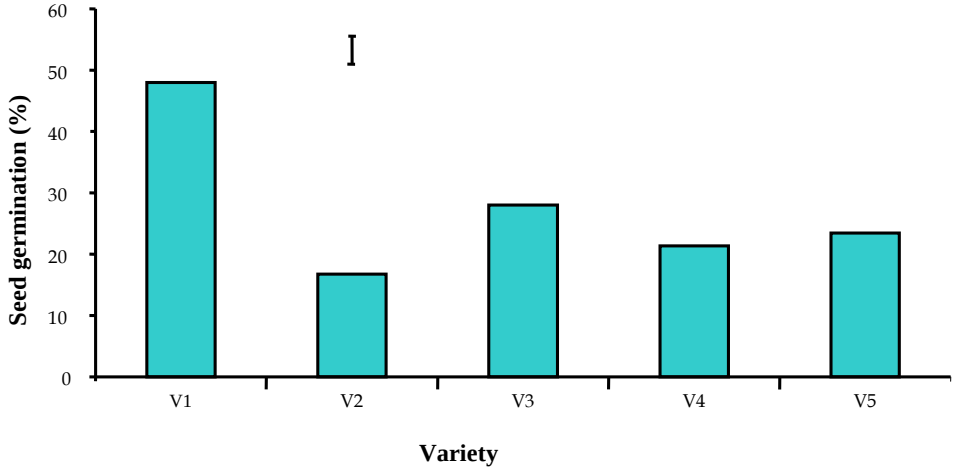

Fig. 1 Effect of variety on germination percentage of tomato seeds at 10 days after sowing. Vertical bar indicates LSD at 1% level of probability. V_1= BARI Tomato-2, V_2=BARI Tomato-3, V_3= BARI Tomato-4, V_4: BARI Tomato-14, V_5: BARI Tomato-15

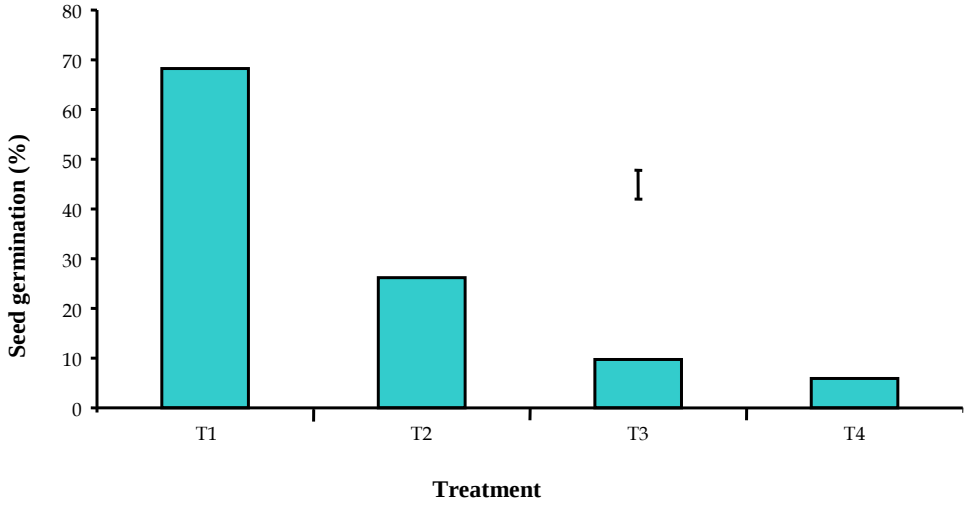

Fig. 2 Effects of salt concentration on seed germination of tomato. Vertical bar indicates LSD at 1% level of probability. T_1= Control (0 mM salt solution), T_2= 50 mM salt solution, T_3= 100 mM salt solution, T_4= 150 mM salt solution

The combined effects of variety and salt concentration had highly significant influenced on seed germination of tomato. The highest seed germination (88.33%) was achieved in the combination of BARI Tomato-2 with 0 mM salt concentration followed by 80% from the same variety with 50 mM salt solution and 77.50%, 65.42% and 61.67% from the combination of BARI Tomato-3, BARI Tomato-15 and BARI Tomato-14, respectively with 0 mM salt solution. The lowest seed germination (9.17%, 2.92%, 7.5%, 4.17% and 5.83%, respectively) was recorded from the combination of all varieties with 150 mM salt concentration (Table 1).

Table 1. Combined effects of variety and salt concentrations on germination, radicle and plumule length and mean germination time of tomato seeds at 10 days after seed sowing (DAS)

Tomato variety	Salt concentration (mM)	Germination (%)	Radicle length (cm)	Plumule length (cm)	Mean germination time
V_1 (BARI Tomato- 2)	T_1 (0)	88.33	8.06	6.51	35.07
	T_2 (50)	80.00	5.52	4.33	30.80
	T_3 (100)	14.58	1.91	1.60	5.87
	T_4 (150)	9.17	1.67	0.67	3.60
V_2 (BARI Tomato- 3)	T_1 (0)	48.33	4.75	4.10	19.27
	T_2 (50)	10.00	3.33	1.71	4.13
	T_3 (100)	5.83	0.67	0.33	2.27
	T_4 (150)	2.92	0.18	0.17	1.20
V_3 (1BARI Tomato- 4)	T_1 (0)	77.50	5.67	5.50	31.73
	T_2 (50)	15.83	4.67	3.51	6.60
	T_3 (100)	11.25	1.67	1.16	4.53
	T_4 (150)	7.50	1.00	0.33	2.93
V_4 (BARI Tomato-14)	T_1 (0)	61.67	5.02	4.53	25.13
	T_2 (50)	11.67	3.67	2.42	4.80
	T_3 (100)	7.92	1.00	0.40	3.20
	T_4 (150)	4.17	0.33	0.30	1.60
V_5 (BARI Tomato- 15)	T_1 (0)	65.42	5.45	5.21	27.13
	T_2 (50)	13.33	4.33	3.35	5.47
	T_3 (100)	9.17	1.33	0.70	3.80
	T_4 (150)	5.83	0.67	0.33	2.27
$LSD_{0.05}$		2.38	0.58	0.49	1.01
$LSD_{0.01}$		3.22	0.82	0.66	1.36
Level of significance		**	**	**	**

** = Significant at 1% level of probability

Germination coefficient:

The germination coefficient was significantly influenced by different varieties of tomato. The maximum germination coefficient (20.48%) was found in the variety BARI Tomato-2 followed by BARI Tomato-4 (19.97%), BARI Tomato-15 (19.85%), BARI Tomato-14 (19.75%) and the minimum germination coefficient (19.54%) was found in BARI Tomato-3 at 10 days after sowing (Table 2). The germination coefficient was significantly influenced different levels of NaCl salt concentration. At 10 DAS, the maximum germination coefficient (20.79%) was found with the control condition (0 mM) followed by 50 mM (19.96%), 100 mM (19.59%) and the minimum germination coefficient (19.34%) was noticed with 150 mM salt concntration (Table 3).

The combined effect of variety and salt concentration showed significant influence on the germination coefficient of tomato seeds. The maximum germination coefficient (21.41%) was obtained from the combination of BARI Tomato-2 with 0 mM salt solution while the minimum germination coefficient (18.89%) was recorded from the combination BARI Tomato- 3 with 150 mM salt concentration (Table 4).

Table 2. Effects of variety on germination coefficient, seedling vigor index, radicle fresh weight, plumule fresh weight and germination index of tomato seeds at 10 days after seed sowing (DAS)

Tomato variety	Germination coefficient (%)	Seedling vigor index (%)	Radicle fresh weight (mg)	Plumule fresh weight (mg)	Germination index (%)
V_1 (BARI Tomato-2)	20.48	537.09	2.42	17.26	9.42
V_2 (BARI Tomato-3)	19.54	121.30	0.95	2.58	3.36
V_3 (BARI Tomato-4)	19.97	259.03	1.77	12.14	5.73
V_4 (BARI Tomato-14)	19.75	168.39	1.04	3.85	4.34
V_5 (BARI Tomato-15)	19.85	206.40	1.42	10.33	4.83
$LSD_{0.05}$	0.05	15.38	0.39	0.46	0.44
$LSD_{0.01}$	0.07	20.75	0.53	0.62	0.59
Level of significance	**	**	**	**	**

** = Significant at 1% level of probability

Radicle length

It was significantly influenced by the effects of different varieties of tomato. At 10 DAS, the maximum radicle length (4.29 cm) was found in BARI Tomato-2 followed by BARI Tomato-4 (3.35 cm), BARI Tomato-15 (2.82 cm) and the minimum (2.23 cm) was observed in BARI Tomato-3 preceded by BARI Tomato-14 (2.56 cm) (Figure 3). Radicle length was also influenced by salt concentration. At 10 DAS, the maximum radicle length of seedling (5.79 cm) was found with the control (0 mM) and this value was rapidly declined with increment of salt concentration. However, the minimum radicle length (0.77 cm) was noticed with 150 mM salt concentration (Figure 4). The combined effect of variety and salt concentration had significant effect on the radicle length of tomato. The maximum radicle length (8.06 cm) was found in combination of the BARI Tomato-2 with the control (0 mM) and minmum radicle length (0.13 cm) was observed in the variety BARI Tomato-3 in 150 mM salt concentration (Table 1).

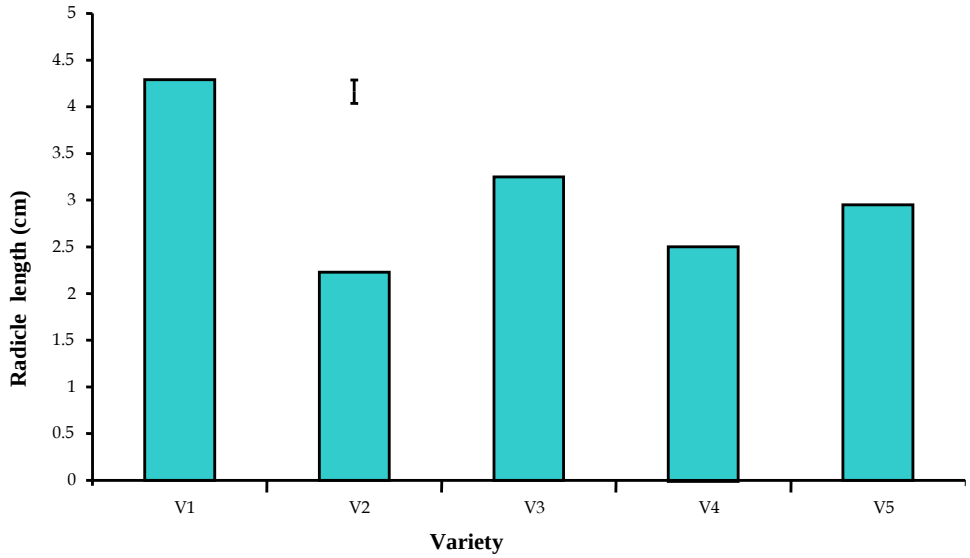

Fig. 3 Effect of variety on radicle length of tomato seeds at 10 days after sowing. Vertical bar indicates LSD at 1% level of probability. V1= BARI Tomato-2, V2=BARI Tomato-3, V3= BARI Tomato-4, V4= BARI Tomato-14, V5= BARI Tomato-15

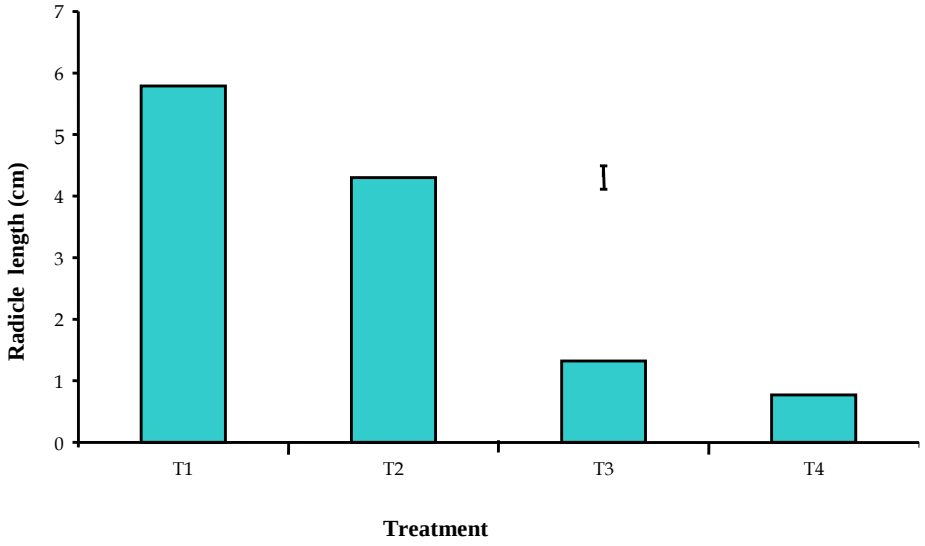

Fig. 4 Effect of salt concentration on radicle length of tomato seeds at 10 days after sowing. Vertical bar indicates LSD at 1% level of probability. T_1= Control (0 mM salt solution), T_2= 50 mM salt solution, T_3= 100 mM salt solution, T_4= 150 mM salt solution

Plumule length

It was significantly influenced by different varieties of tomato. The maximum plumule length (3.28 cm) was found in BARI Tomato-2 and the minimum (1.58 cm) was observed in BARI Tomato-3 at 10 days after sowing (Figure 5). Plumule length was also significantly influenced by different levels of salt concentration. The highest plumule length of seedling (5.17 cm) was achieved from 0 mM salt solution and this value rapidly reduced with increasing the concentration of salt in solution. The lowest length of plumule (0.36 cm) was observed in 150 mM salt concentration at 10 days after sowing (Figure 6). From the combined effects it was noticed that the maximum plumule length (6.51 cm) was recorded in the combination of BARI Tomato-2 with the control treatment (0 mM). The minimum plumule length (0.17 cm) was recorded from the combination of BARI Tomato- 3 with 150 mM salt concentration (Table 1).

Seedling vigor index

Seedling vigor index was significantly influenced by different varieties of tomato. At 10 DAS, the maximum seedling vigor index (537.09%) was noticed in BARI Tomato-2 followed by BARI Tomato-4 (259.03%), BARI Tomato-15 (206.40%), BARI Tomato-14 (168.39%) and the minimum was observed in BARI Tomato-3 (121.30%) (Table 2). Seedling vigor index was also influenced by different concentration of NaCl salt.

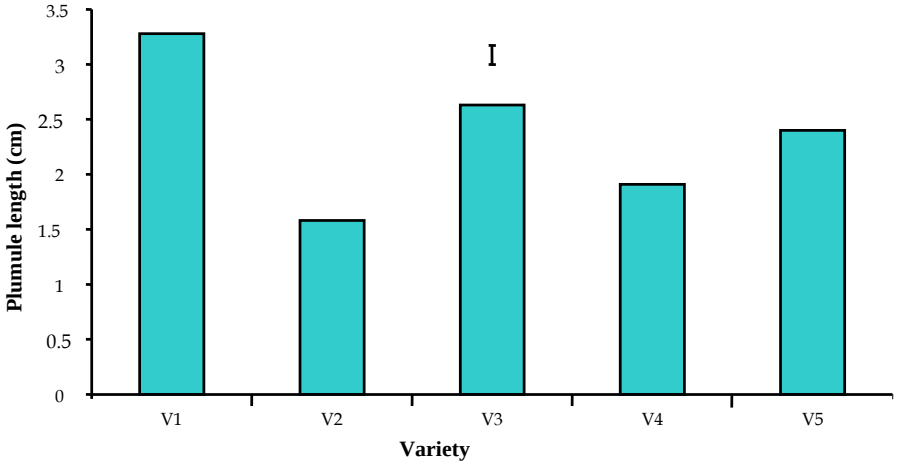

Fig. 5 Effect of variety on plumule length of tomato seeds at 10 days after sowing. Vertical bar indicates LSD at 1% level of probability. V_1= BARI Tomato-2, V_2=BARI Tomato-3, V_3= BARI Tomato-4, V_4= BARI Tomato-14, V_5= BARI Tomato-15

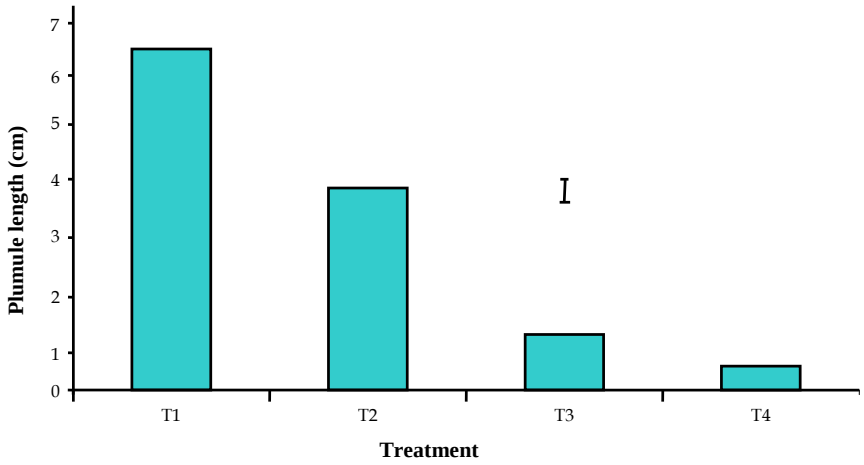

Fig. 6 Effect of salt concentration on plumule length of tomato seeds at 10 days after sowing. vertical bar indicates LSD at 1% level of probability. T_1= Control (0 mM salt solution), T_2= 50 mM salt solution, T_3= 100 mM salt solution, T_4= 150 mM salt solution

The superior seedling vigor index (773.40%) was found in control condition (0 mM) and this index quickly declined as salt concentration increased in the solution. The inferior vigor index (8.29%) was noticed in 150 mM salt concentration (Table 3). The combined effect of variety and salt concentration had significantly influenced on seed vigor index of tomato. The maximum seed vigor index (1287.02%) was found in the combination of BARI Tomato-2 with the control treatment (0 mM) and the minimum seed vigor index (1.13%) was recorded in the combination of BARI Tomato-3 with 150 mM salt concentration (Table 4).

Radicle fresh weight

The radicle fresh weight was significantly influenced by the effect of different varieties of tomato. The maximum radicle fresh weight (2.42 mg) was found in BARI Tomato-2 and the minimum (0.95 mg) was observed in BARI Tomato-3 (Table 2). This trait was also significantly influenced with the increasing of salt concentration. The maximum radicle fresh weight of seedling (3.51 mg) was found with the control (0 mM) and the minimum radicle fresh weight (0.25 mg) was noticed with 150 mM salt concentration (Table 3). The combined effect of variety and salt concentration had significant effect on the fresh radicle weight of tomato seedlings. The maximum radicle fresh weight (6.00 mg) was found in the combination of BARI Tomato-2 with the control condition (0 mM) and the minimum radicle fresh weight (0.13 mg) was recorded from the combination of BARI Tomato- 3 with 150 mM salt concentration (Table 4).

Plumule fresh weight

It was significantly varied with different varieties of tomato. The maximum plumule fresh weight (17.26 mg) was found in the variety BARI Tomato-2 and the minimum plumule fresh weight (2.58 mg) was observed

in BARI Tomato-3 at 10 days after sowing (Table 2). It was significantly affected by different levels of salt concentration. At 10 DAS, the maximum plumule fresh weight of seedling (15.06 mg) was found with the control condition (0 mM) and the minimum plumule fresh weight (2.40 mg) was noticed with 150 mM salt concentration (Table 3). The combined effect of variety and salt concentration had significant effect on the plumule fresh weight of tomato. The maximum plumule fresh weight (28.03 mg) was found in the combination of BARI Tomato-2 with the control condition (0 mM) and the minimum plumule fresh weight (1.33 mg) was recorded by the combination of BARI Tomato- 3 with 150 mM salt concentration (Table 4).

Table 3. Effects of salt concentration on germination coefficient, seedling vigor index, radicle fresh weight, plumule fresh weight and germination index of tomato seeds at 10 days after seed sowing (DAS)

Salt concentration (mM)	Germination coefficient (%)	Seedling vigor index (%)	Radicle fresh weight (mg)	Plumule fresh weight (mg)	Germination index (%)
T_1 (0)	20.79	773.40	3.51	15.06	13.83
T_2 (50)	19.96	228.38	1.59	13.15	5.18
T_3 (100)	19.59	23.69	0.73	6.31	1.97
T_4 (150)	19.34	8.29	0.25	2.40	1.16
$LSD_{0.05}$	0.05	13.76	0.35	0.41	0.39
$LSD_{0.01}$	0.06	18.56	0.48	0.55	0.54
Level of significance	**	**	**	**	**

** = Significant at 1% level of probability

Mean germination time

It was influenced significantly by different varieties of tomato. The maximum mean germination time (18.83) was found in BARI Tomato-2 and the minimum (6.72) was observed in BARI Tomato-3 (Figure 7). The mean germination time of tomato was significantly influenced by different levels of NaCl salinity. The maximum mean germination time (27.67) was observed with the control condition (0 mM) and the minimum mean germination time (2.32) was noticed with 150 mM salt concentration (Figure 8). The combined effect of variety and salt concentration had significant effect on the mean germination time of tomato. The maximum mean germination time (35.07) was found in the combination of BARI Tomato-2 with the control treatment (0 mM). The minimum mean germination time (1.20) was recorded from the combination of BARI Tomato-3 with 150 mM salt concentration (Table 1).

Germination index

The germination index was significantly influenced by different tomato varieties. The maximum germination index (9.42%) was found in BARI Tomato-2 and the minimum (3.36%) was observed in BARI Tomato-3 at 10 days after sowing (Table 2).

Table 4. Combined effects of variety and salt concentration on germination coefficient, seedling vigor index, radicle fresh weight, plumule fresh weight and germination index of tomato seeds at 10 days after seed sowing (DAS)

Tomato variety	Salt concentration (mM)	Germination coefficient (%)	Seedling vigor index (%)	Radicle fresh weight (mg)	Plumule fresh weight (mg)	Germination index (%)
	T_1 (0)	21.41	1287.02	6.00	28.03	17.53
V_1 (BARI	T_2 (50)	20.48	788.00	2.00	25.00	15.40
Tomato- 2)	T_3 (100)	20.15	51.25	1.33	12.33	2.93
	T_4 (150)	19.89	22.08	0.33	3.67	1.80
	T_1 (0)	20.37	428.23	2.10	3.00	9.63
V_2 (BARI	T_2 (50)	19.58	50.43	1.31	3.67	2.07
Tomato-3)	T_3 (100)	19.33	5.42	0.27	2.33	1.13
	T_4 (150)	18.89	1.13	0.13	1.33	0.60
	T_1 (0)	20.78	865.42	3.80	19.33	15.87
V_3 (BARI	T_2 (50)	20.07	129.74	1.93	18.33	3.30
Tomato-4)	T_3 (100)	19.62	31.38	1.03	7.90	2.27
	T_4 (150)	19.44	9.58	0.33	3.00	1.47
	T_1 (0)	20.65	588.92	2.33	5.73	12.57
V_4 (BARI	T_2 (50)	19.84	70.73	1.33	4.67	2.40
Tomato-14)	T_3 (100)	19.33	11.08	0.33	3.33	1.60
	T_4 (150)	19.19	2.83	0.17	1.67	0.80
	T_1 (0)	20.74	697.45	3.33	19.20	13.57
V_5 (BARI	T_2 (50)	19.86	103.00	1.40	14.10	2.73
Tomato-15)	T_3 (100)	19.54	19.33	0.67	5.67	1.90
	T_4 (150)	19.29	5.83	0.27	2.33	1.13
Level of significance		**	**	**	**	**

** = Significant at 1% level of probability

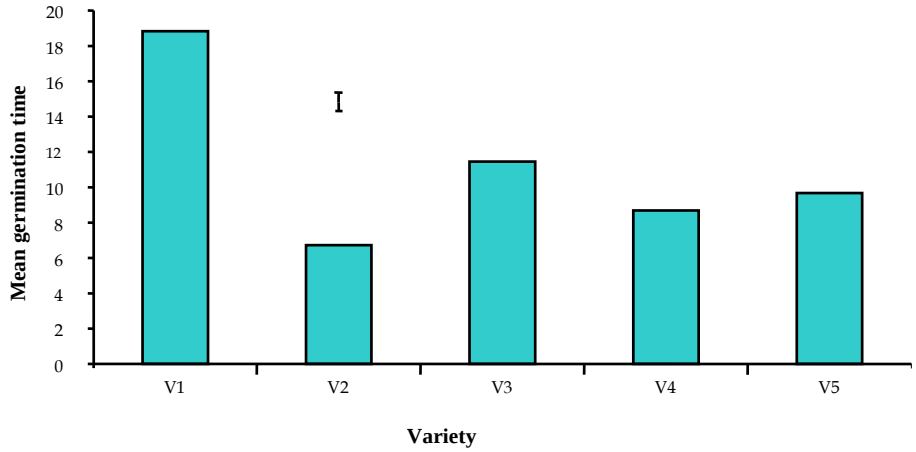

Fig. 7 Effect of variety on mean germination time of tomato seeds at 10 days after sowing. Vertical bar indicates LSD at 1% level of probability. V_1= BARI Tomato-2, V_2=BARI Tomato-3, V_3= BARI Tomato-4, V_4= BARI Tomato-14, V_5= BARI Tomato-15

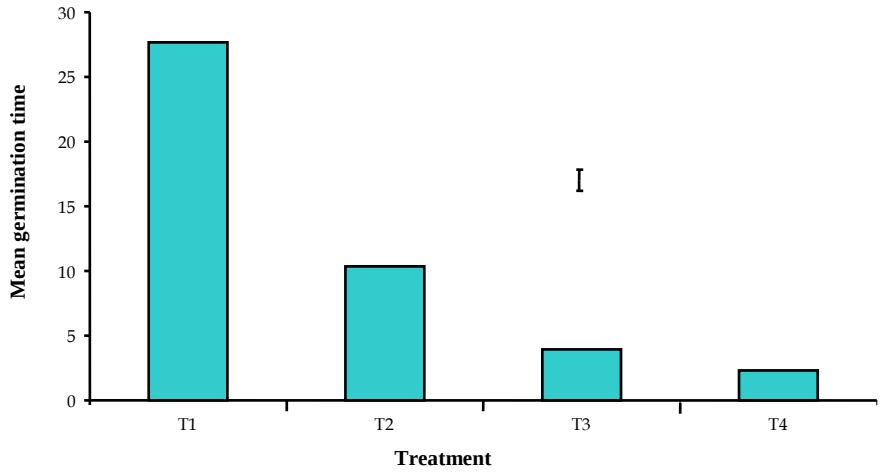

Fig. 8 Effect of salt concentration on mean germination time of tomato seeds at 10 days after sowing. Vertical bar indicates LSD at 1% level of probability. T_1= Control (0 mM salt solution), T_2= 50 mM salt solution, T_3= 100 mM salt solution, T_4= 150 mM salt solution

The germination index was significantly influenced by different levels of NaCl salinity. The maximum germination index (13.83%) was observed with the control treatment (0 mM) and the minimum germination index (1.16%) was noticed with 150 mM salt concentration at 10 days after sowing (Table 3). The combined effect of variety and salt concentration had significant effect on the germination index of tomato. The maximum germination index (17.53%) was found in the combination of BARI Tomato-2 with the control treatment (0 mM). The minimum germination index (0.60%) was recorded by the combination of the BARI Tomato- 3 with 150 mM salt concentration (Table 4).

Discussion

In the context of this discussion, the term salt tolerance during seed germination was used only to refer to situations where the seed germinated rapidly under salt stress conditions. An increase in concentration of NaCl salt significantly affected seed germination and seedling growth of the tomato varieties under this investigation. The results demonstrated genotypic variation in seed germination and seedling growth responses of tomato seeds to salinity stress. The negative effects of NaCl were increased with the increase in salt concentrations.

In the experiment, five varieties of tomato named as BARI Tomato-2, BARI Tomato-3, BARI Tomato-4, BARI Tomato-14 and BARI Tomato-15 seeds were used in petridish to investigate the effect of variety on germination. From the results (Figure 1) it was observed that the percentage of seed germination was varied among different varieties of tomato. The maximum seed germination (88.33%) was observed in BARI Tomato-2 with control at 10 DAS while the minimum (2.92%) was observed in BARI Tomato-3 with 150 mM salt concentration at 10 DAS. The maximum radicle length (8.06 cm) was found in the variety BARI Tomato-2 with control condition and the minimum (0.13 cm) was observed in BARI Tomato-3 in 150mM salt concentration. The maximum plumule length (5.17 cm) was found in the variety BARI Tomato-2 with the control and the minimum (0.36 cm) was observed in BARI Tomato-3 with 150mM salt concentration. These results are in agreement with the findings of Turhan *et al.* (2011) where the effects of different varieties of spinach were investigated. Several authors reported that salinity stress affected seed germination either by decreasing the rate of water uptake (osmotic effect) and or facilitating the intake of ions, may change by certain enzymatic or hormonal activities inside the seed

(ion toxicity) (Bliss *et al*., 1986; Dubey and Rani, 1990; Huang and Redmann, 1995; Zhang *et al.*, 2010). In the experiment, the rate of germination decreased progressively with an increase in salt concentration. A severe decrease in the rate of germination was observed in highest salt concentration of 100 and 150 mM NaCl salt. Comparison between genotypes indicated genotypic differences depending on the salt concentration.

Germination percentage of tomato seeds was decreased with the increase in salt concentration. Similar reductions in germination with increasing salt concentration were reported in *Atriplex gliffithii* (Khan *et al.*, 2000), *Haloxylon recurvum* (Khan and Ungar, 1996). Exposure of tomato seeds to high salt concentration did not only inhibit germination but also decreased germination rate. The delay in germination in the higher salinity level had been also reported in tomato (Miyamoto, 1989), jojoba (Kayani *et al.*, 1990) and sugar beet (Ghoulam *et al.*, 2002). Sharma *et al.* (2005) reported that salinity levels below 4 dSm^{-1} resulted in a delay of 1-2 days in rice. Ungar (1995) observed that germination rate was a more sensitive parameter than germination percentage in *Atriplex platula*.

According to Green and Munns (1980) salinity may activate or stimulate the genesis of some proteins during germination and these salt stress proteins have been associated with a protective function in wheat embryos. Redman *et al.* (1994) showed that this reduction in dry weight of plumule and radicle which is the result of enhancing the salinity concentration and is a normal phenomenon and probably it is the result of low water absorbance by germinated seeds.

The tomato plants under normal and low salinity level (50 mM) may have adjusted osmotically to the growing conditions as a result of which they were successful in maintaining required cell enlargement and showed the maximum root/shoot lengths as compared to the higher salinity levels (100 and 150 mM). The plants grown under the higher salinity (150 mM) failed to activate the dehydration avoidance mechanism like making root membranes impermeable for toxic ions of Na^+ and Cl^- so plants did not maintain stomatal conductance up to desired rate (Abbruzzese *et al.*, 2009), thus could not with-stand high salt stress and experienced the reduction in growth.

The tomato plants able to grow under low salinity level (50 mM) might have developed osmotic adjustment mechanism, hormonal imbalance and ion exchange to alleviate the drastic effects of toxic ions, so, these plants exhibited better growth in terms of maximum root/shoot length and weight while under high salt stress (150 mM) they failed to develop the efficient osmotic adjustment mechanism and showed reduction in the above-mentioned growth attributes.

Conclusion

In petridish condition, five varieties of tomato were evaluated against four levels of NaCl salinity stress. The germination of seed was varied significantly with the variety and salt concentration. The results showed that the performance of BARI Tomato-2 was comparatively better in 0 mM and 50 mM salt concentrations. In case of the combined effect of variety and salt concentration, BARI Tomato-4, BARI Tomato-14 and BARI Tomato-15 showed better performance than the other varieties when combined with the low salt concentration i.e. 50 mM NaCl salt concentration. On the other hand, BARI Tomato-3 showed poor performance in all salt concentrations. From the results of this study it can be concluded that BARI Tomato-2, BARI Tomato-4 and BARI Tomato-15 are comparatively salt tolerant than the other varieties have studied.

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