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Identification of tomato (*Lycopersicon esculentum* L.) genotypes for salt tolerance during emergence

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Abstract

Salinity in soil or water is one of the major stresses that affect crop production around the world. In Bangladesh the coastal areas are increasing day by day due to climate change. Therefore it is very important to investigate the mechanisms of salt tolerance. That is why, this study was undertaken to investigate the effect of salinity on tomato (*Lycopersicon esculentum* Mill.) by using ten genetically diverged tomato genotypes during seed germination and seedling growth stage. The study was carried out in Completely Randomized Design (CRD) with three replications under *invitro* condition. In the study, emergence percentage, radicle length, plumule length, Proline content, K^+/Na^+ of the seedling were assayed on five levels salinity; control (0), 4,8,12 and 16 dS m^{-1}. The growth and subsequent development of tomato seedling negatively affected with the rising of salinity. Emergence percentage, radicle length, plumule length were decreased from control when salt concentration increased. Na^+ content increased but K^+ content decreased with the increment of salinity. The mean values of Na^+/K^+ ratio, varied from 4.2367 in control treatment to 0.00 at higher salinity level. Proline content was also increased with the increment of salinity which ranges from 9.55 to 41.5373 mg prol/2ml/sample at control to 16 dSm^{-1}.The overall results of the experiment exhibited that among the genotypes BARI Tomato 2, Mintoo and Unnoyon were comparatively more tolerant to higher salinity on the basis of studied parameters.

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Introduction

Tomato (*Lycopersicon esculentum* L.) is the most commercially important widely grown vegetable throughout the world. The production of tomato is increasing day by day due to its diversified use and higher nutritional value. Among the abiotic factors, salinity is currently one of the most severe factor, limits the agricultural production. The productivity of many agricultural crops including tomato is reduced due to higher salinity. For crop production excessive soil salinity can be a major environmental constraint. So, to increase the productivity and profitability of vegetable crops knowledge about salinity tolerance is necessary. According to USDA report, tomato is moderately sensitive to salinity out of all vegetables. Salinity stress reduces water potential and causes ion imbalance and toxicity (de la Peña and Hughes, 2007). Some major processes such as germination, speed of germination, root/shoot dry weight and Na^+/K^+ ratio in root and shoot are affected by salinity stress (Parida and Das, 2005). The salt damage to seed emergence in various way like reduction in water availability, changes in mobilization of stored reserves and affecting structural organization of proteins (Foolad and Lin, 1997; Almansouri *et al.,* 2001; Machado *et al.,* 2004). The growth of plumule and younger seedlings of tomato slows down due to salinity (Flowers, 2004; Cuartero *et al.,* 2006). The response of tomato to salt stress is regulated differently in different development stages (Saranga *et al.,* 1992; Foolad 2004). Plants growing under salt or water-deficit conditions showed different physiological changes like stomatal conductance, water potential, osmotic potential etc. developed as effective indices for resistant screening in plant breeding programs (Ashraf and Harris, 2004; Parida and Das, 2005; Ashraf and Foolad, 2007; Chaum and Kirdmanee, 2009).

Tomato genotype possess large genetic variation of salt tolerance. Due to the complexity of the trait, insufficient genetic and physiological knowledge of tolerance-related traits and lack of efficient selection domain the salt tolerance breeding programs have been restricted. Without significant yield reduction, most of the commercial tomato cultivars are sensitive to moderate levels of salinity up to 2.5 dS m^{-1}. It has been reported that crops which are tolerant at seedling stage also show improved salinity tolerance at adult stage (Akinci *et al.,* 2004). Selection and breeding for salt tolerance can be a wise solution to minimize salinity effects as well as to improve the production efficiency as temporary correction of saline soil is expensive. So salt tolerant tomato breeding materials are needed. The first step toward releasing tolerant cultivars is the genetic characterization of useful garmplasm. This study attempted to find out the level of salt tolerance in 10 tomato genotypes. The objective of the present research work was to identify the tomato genotypes tolerant to increasing salinity during the germination and seedling stage.

Materials and methods

Study materials

Ten genetically diverse 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.

Study design

The experiment was conducted in Completely Randomized design (CRD) using three replications.

Preparation of saline solution

For making 4dSm^{-1}, 8dSm^{-1}, 12dSm^{-1} and 16dSm^{-1} saline solution 0.64 g, 1.28 g, 1.92 g and 2.56 g NaCl, respectively were diluted at 250 ml distilled water in different volumetric flasks. Each plastic pot was prepared by moistened with 2 ml of distilled water or one of the NaCl salt solutions (0, 4, 8, 12 and 16 dSm^{-1}NaCl solution) (Zafar, 2006).

Preparation of study materials

The collected seeds were then disinfected with a solution of 10% sodium hypochlorite. After that they were rinsed with distilled water several times to remove the adhering substances placed 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 growth. Whole set up was replicated twice.

Data collection

On the 14th day of the experiment, emergence percentage, radicle length, plumule length, proline content, K^+/Na^+ratio in shoot was measured. Proline content was measured by Bates and bates method (1973) while Na^+ and K^+ concentration were determined by using atomic absorption spectrophotometer (Perkin Elmer 3110, United States).

Statistical analysis of the collected data

The mean values of all the characters were evaluated and analysis of variance was performed by the 'F' test. To test the differences among the genotypes Duncan's Multiple Range Test (DMRT) was performed by using Statistical Tool for Agricultural Research (STAR) version 2.0.1 2014.

Results and discussion

Effect of tomato genotypes and different salt concentration on germination percentage

The germination percentage of tomato seed was reduced at relatively low salinity 4 and 8 dSm^{-1} NaCl (Fig. 2 and Fig. 3) but at higher salinity i.e. 12 and 16 dSm^{-1} NaCl the germination percentage drastically declined and no germination observed in some cases (Fig. 4 and Fig. 5) compared to control treatment (Fig. 1). In all the treatment Unnoyon performed better (100%) than all other genotypes and BARI Tomato 3 showed lowest germination percentage. So, Unnoyon is more tolerant to higher salinity stress and BARI Tomato 3 is more sensitive to salt stress. The least affected genotypes may be the potential source of salinity tolerance for tomato breeding (Cuartero and Munoz, 1999; Hazer *et al.*, 2006; Hamed *et al.*, 2011; Amir *et al.*, 2011). It may be due to decrease of the water movement into the seeds during imbibition and also through osmotic effects which create specific ion toxicity.

The result is linear with Sardoei and Mohammadi, 2014; Basha *et al.*, 2015 and Mahendran and Sujirtha, 2015 and who reported that salt stress reduced germination percentage in tomato.

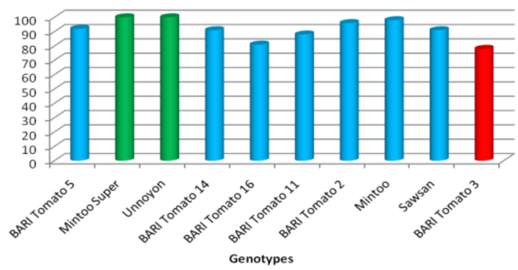

Fig. 1. Emergence percentage at T_1 (0 dSm^{-1}).

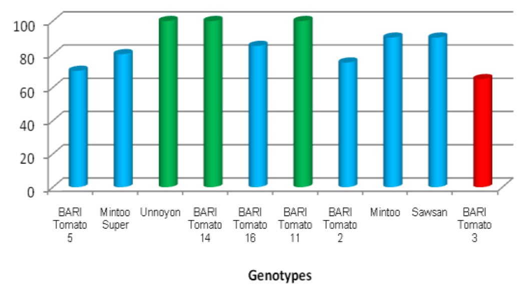

Fig. 2. Emergence percentage at T_2 (4 dSm^{-1}).

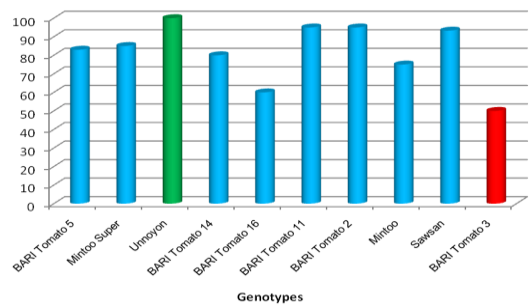

Fig. 3. Emergence percentage at T_3 (8 dSm^{-1}).

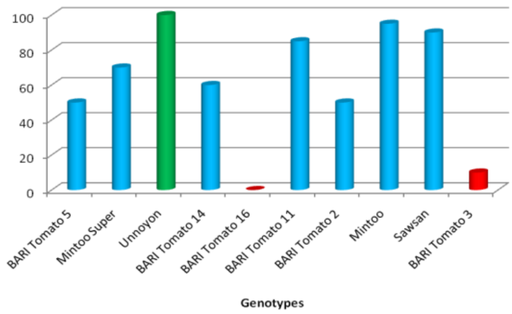

Fig. 4. Emergence percentage at T_4 (12 dSm^{-1}).

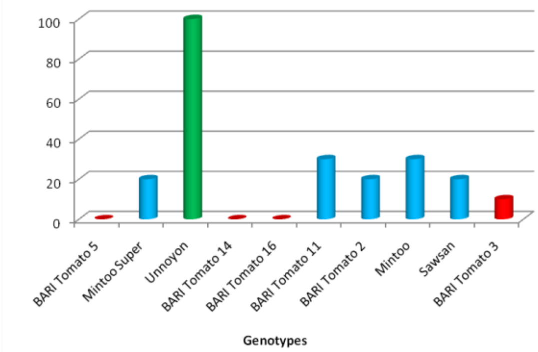

Fig. 5. Emergence percentage at T_5 (16 dSm^{-1}).
Means with the same letter are not significantly different.

Effect of tomato genotypes and different salt concentration on plumule length

One of the most important parameter for salt tolerance is plumule length because photosynthetic areas present on it. For this reason, plumule length provides an important clue to the response of plants to salt stress. At control to lowest salinity most of the genotypes showed similar performance but at moderate to higher salinity BARI Tomato 11 showed maximum plumule length statistically as similar as Mintoo Super, Unnoyon, BARI Tomato 2 and Mintoo in most of the cases. And no plumule length observed in BARI Tomato 5, BARI Tomato 14, BARI Tomato 16 and BARI Tomato 3 as no emergence occurred from those genotypes (Table 1).

So, with the rising of salinity plumule length was reduced in tomato genotypes. Similar observations have been reported by Foolad, 1996; Xiong and Zhu, 2002 and Othaman, 2006 as the salt stress inhibited the efficiency of translocation and assimilation of stored materials and might have caused a reduction in plumule growth.

Table 1. Effects of different salinity treatment on plumule length of 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	8.28a-c	7.35 a	5.30 b-d	4.41 ab	0.00 c
Mintoo Super	8.95 ab	7.49 a	6.57 a	4.14 ab	2.30 ab
Unnoyon	7.56 cd	6.96 a	6.22 ab	1.00 c	2.74 a
BARI Tomato 14	7.51 cd	6.85 ab	4.68 d	4.35 ab	0.00 c
BARI Tomato 16	5.79 e	5.66 bc	4.84 cd	1.70 c	0.00 c
BARI Tomato 11	9.30a	7.55 a	5.20 b-d	5.13 a	3.11 a
BARI Tomato 2	7.07 d	6.47 a-c	5.98a-c	4.47 ab	2.48 ab
Mintoo	7.37 cd	7.57 a	4.89 cd	4.31 ab	2.25 ab
Sawsan	9.08 ab	7.40 a	5.03 cd	4.47 ab	1.41 b
BARI Tomato 3	7.97 b-d	5.42 c	4.98 cd	3.37 b	0.00 c
LSD (0.05%)			0.74		
CV (%)			8.69		

Table 2. Effects of different salinity treatment on radicle length of 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	8.21 a	2.43 e	4.200 bc	4.36a	0.00 d
Mintoo Super	8.69 a	4.98 ab	5.63 a	3.48 b	1.13 c
Unnoyon	2.24 e	5.21 a	4.30 b	0.74 d	1.53 c
BARI Tomato 14	4.04 d	5.29 a	5.40 a	3.98 ab	0.00 d
BARI Tomato 16	1.24 f	3.00 e	0.70 d	0.70 d	0.00 d
BARI Tomato 11	4.05 d	3.91 d	2.77 c	2.77 c	1.04 c
BARI Tomato 2	4.77 c	4.88 a-c	4.18 a	4.18 a	2.64 b
Mintoo	6.84 b	4.30 cd	4.28 a	4.28 a	3.36 a
Sawsan	6.84 b	2.94 e	3.47 b	3.47 b	1.36 c
BARI Tomato 3	4.76 c	4.53 bc	4.05 ab	4.05 ab	0.00 d
LSD (0.05%)			0.37		
CV (%)			6.67		

Means with the same letter are not significantly different.

Effect of tomato genotypes and different salt concentration on radicle length

In salt stress experiments radicle length is one of the most important character because radicles are in direct contact with the soil and absorb water from the soil.

Among the tomato genotypes Mintoo Super and BARI Tomato 5 produced maximum radicle length (8.69 and 8.21 cm) which is statistically different from other genotypes under control treatment.

At minimum to moderate salinity level (T_2 and T_3) Mintoo Super, BARI Tomato 14 and Unnoyon performed better radicle length while at higher salinity level (T_4 and T_5) BARI Tomato 5 followed by BARI Tomato 2 and Mintoo showed maximum radicle length. BARI Tomato 16 produced lowest radicle length in all the treatment (Table 2). As compared to plumule, radicles are more affected by salinity as they are the first organ to face the stress. Naseri *et al.,* 2011 showed radicle length more affected than plumule length with increasing salinity levels.

Table 3. Mean performance of Na^+/K^+ at different levels of salinity 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	3.03	3.11	2.70	2.99	0.00
Mintoo Super	3.10	3.20	2.65	2.29	1.6
Unnoyon	2.64	2.96	2.71	2.17	1.67
BARI Tomato 14	3.33	3.53	3.10	3.34	0.00
BARI Tomato 16	2.57	3.08	2.54	0.00	0.00
BARI Tomato 11	2.23	3.39	2.99	2.62	1.57
BARI Tomato 2	3.89	2.84	3.15	2.95	1.97
Mintoo	2.39	2.97	2.79	2.98	1.73
Sawsan	2.33	2.87	2.15	2.72	1.70
BARI Tomato 3	3.42	3.88	2.17	1.88	1.67
Mean	2.89	3.18	4.30	2.80	1.80
CV (P = 0.05)			1.99		
MS_E			0.24		
LSD (0.05%)			0.36		

Effect of tomato genotypes and different salt concentration on Na^+/K^+ ratio

The osmotic potential in tomato root or shoot increases and water uptake decreases due to higher Na^+ concentration while K^+ concentration in root or shoot changes little under saline environment. Thus, increased concentration of K^+ in tomato plant is advisable for further breeding programme based on salinity tolerance. Significant differences for Na^+/K^+ ratio were observed among the tomato genotypes and treatments (Table 3). The mean values of Na^+/K^+ ratio, varied from 4.2367 in control treatment (T_1) to higher salinity level 0.00 (T_4 and T_5).The mean values of Na^+/K^+ ratio in shoot, varied from 2.89 (control) to 1.80 (at 16 dSm^{-1}). More uptake of K^+ from soil/medium by plants occur if the Na^+/K^+ ratio value is lower and such types of plants are similar to non-salinized plant i.e. salt tolerant.

The tomato genotypes which have low Na^+/K^+ ratio may be used in further salt tolerance breeding program (Asch *et al.,* 2000; Al-Karaki, 2001; Dasgan *et al.,* 2002 and Juan *et al.,* 2005).

Effect of tomato genotypes and different salt concentration on Proline synthesis

In tomato plants Prolineis generally consider a good indicator of environmental stress (Clausen, 2005) and there are many reports those describes Prolinecontent increases as a response to water or salt stress in this species (Yokas *et al.,* 2008; Umebese Yokas *et al.,* 2009; Babu *et al.,* 2012; Ghorbanli *et al.,* 2013 and Giannakoula and Ilias, 2013;). In the present study, the content of Proline increases with increasing salt concentration as compared with control treatment (T_1).

All the genotypes displayed reduction of Na^+/K^+ ratio with the increment of salinity from control. BARI Tomato 11 produced more Na^+/K^+ ratio (4.2367) under control treatment (T_1) and at lowest salinity level (T_2). On the other hand BARI Tomato 2 and BARI Tomato 14 produced maximum value in moderate salinity level (3.1500 and 3.3467). But at higher salinity level (T_5) Na^+/K^+ ratio was reduced from control treatment (Table 4). The lower value of Na^+/K^+ ratio, indicated more uptake of K^+ from soil/medium by plants and such types of plants are similar to non-salinized plant i.e. salt tolerant. The genotypes those have low Na^+/K^+ ratio may be used in further breeding for salinity tolerance in tomato (Al-Karaki 2000; Asch *et al.,* 2000; Dasgan *et al.,* 2002 and Juan *et al.,* 2005).

Though Prolinecontent increased with the increment of salinity in all the treated genotypes but Mintoo Super synthesized more Prolinethan other genotype under control to moderate salinity (T_1: 13.73 mg prol/2ml/sample, T_2: 23.57 mg prol/2ml/sample and T_3: 28.55 mg prol/2ml/sample) which is statistically similar with BARI Tomato 14, while BARI Tomato 16 synthesized lowest value (9.66 to 17.10 mg prol/2ml/sample). But at higher salinity (T_4 and T_5) both BARI Tomato 2 and Mintoo synthesized highest value (37.88 to 41.7 mg prol/2ml/sample) than all other genotypes since BARI Tomato 16 again synthesized lowest Proline content (0.00) (Table 4). This infers that higher Proline accumulated in the stressed plants than in the unstressed plant.

The result are in good agreement with those obtained by Mansour *et al.,* 2005; Manikandan and Design 2009 and Djerroudi *et al.,* 2010; who found with the increasing of salinity level Proline content increased in tomato genotypes.

Table 4. Mean performance of Proline synthesis at different levels of salinity 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	12.73a-c	20.89 b	25.66 b	33.02c	0.00d
Mintoo Super	13.73a	23.57a	28.55a	34.70 bc	36.21 b
Unnoyon	10.78 cd	18.81 bc	24.29 b-d	36.35ab	38.45 b
BARI Tomato 14	13.21ab	19.19 bc	26.58ab	27.91 d	0.00 d
BARI Tomato 16	9.66 d	15.05 e	17.10 g	0.00 f	0.00 d
BARI Tomato 11	11.84ab-d	18.71 bc	25.07 bc	27.87 d	36.26b
BARI Tomato 2	11.18 b-d	16.88 c-e	23.25 cd	38.19a	41.53a
Mintoo	11.10bcd	17.69 cd	22.53 de	37.88a	41.97a
Sawsan	10.58 cd	15.50 de	20.23 ef	26.17 de	27.06 c
BARI Tomato 3	12.07abc	14.973 e	17.96 fg	25.43 e	0.00 d
LSD (0.05%)			1.33		
CV (%)			4.69		

Means with the same letter are not significantly different.

Conclusion

In this study, the genotypes 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 present study revealed that salinity stress influenced the emergence and subsequent 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 seedling emergence and other characters than the other genotype have studied in this experiment.

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