



Effect of Different Salt Concentrations (NaCl) on Seed Germination and Seedling Growth of Tomato cv. BINA Tomato-10

Md. Rofekuggaman¹, Khadezatul Kubra¹ and Shreef Mahmood^{2*}

¹*Department of Agricultural Extension, Ministry of Agriculture, People's Republic of Bangladesh, Dinajpur 5200, Bangladesh.*

²*Department of Horticulture, Hajee Mohammad Danesh Science and Technology University, Dinajpur 5200, Bangladesh.*

Authors' contributions

This work was carried out in collaboration among all authors. Author MR designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Authors KK and SM edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The experiment was carried out at the Department of Horticulture, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh to evaluate the rate of seeds germination and early seedlings growth of tomato under different levels of salinity. Experimental treatments consisted on five levels of sodium chloride (NaCl) (0, 25, 50, 100 and 150 mM). Seeds of tomato cv. BINA Tomato-10 were placed on Petri dishes for germination. Data on germination percentage, germination coefficient, length of radicle and plumule, fresh and dry mass of radicle and plumule, seed vigor index were recorded at different days after sowing. NaCl solutions significantly affected seed germination and growth of germinated seedlings. At 11 DAS, the highest seed germination (94.67%), maximum germination coefficient (15.91), longest radicle (7.61 cm) and plumule (5.77

*Corresponding author: E-mail: shreefmahmood@yahoo.com;

cm), maximum seed vigor index (1266.34), highest fresh and dry mass of radicle (12.5 mg and 1.63 mg) and plumule (23.95 mg and 1.02 mg) were recorded in control treatment. High concentration of salt solution (150 mM NaCl) found to be detrimental for seed germination and seedling growth. BINA Tomato-10 can be recommended for the area having moderate level of salinity.

Keywords: Salt concentration; seed germination; seedling growth; tomato.

1. INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is an important vegetable throughout the tropical, subtropical and temperate climates, due to its high nutritional value, delicious taste and attractive color. Considering the world vegetable production, it took the 3rd place in respect of area and production of vegetables [1]. The fruits of tomato provide valuable nutritional components like ascorbic acid, β -carotene and phenolic compounds in the human diet [2]. It is also rich in pectin and different minerals *i.e.*, calcium, phosphorus, magnesium and iron [3]. Apart from vitamin and minerals, it contains high level of powerful antioxidant lycopene, which reduces the risk of chronic degenerative diseases, such as certain types of cancer and cardiovascular diseases [3]. The consumption of tomato is not only limited to curry or salad, rather it is widely use as ketchup, sauce, soup and puree.

In Bangladesh, it is the 3rd most important vegetable after potato and eggplant, in terms of both production and area [4]. Presently, the production of tomato in the country is about 385 thousand tons from 28.34 thousand hectares [4]. It is cultivated all over the country, due to its adaptability to wide range of soil and climate however the yield of tomato depends on various factors such as irrigation and soil management. Salinity is a major abiotic factor leading to physiological, morphological and biochemical modifications; it causes growth inhibition, crop yield reduction, lower photosynthesis and respiration, nutritional deficiencies and inhibition of protein synthesis [5]. These phenomena have been observed in different vegetables including tomato [6]. In the recent years, the sea level is gradually increasing and because of this, salinity is being increased in the southern part of Bangladesh. About 20% of the net cultivable land of Bangladesh, mainly in coastal region, is affected by different degrees of salinity [7]. The ability of seed to germinate and produce healthy seedlings in saline conditions are crucial for crop production in saline soils. Recently, Bangladesh Institute of Nuclear Agriculture (BINA) developed BINA Tomato-10 and it is necessarily important to assess its salt tolerance for higher production

in saline prone areas of the country. Therefore, the present research was undertaken to assess the salt tolerance of BINA Tomato-10 at seed germination and seedling stage.

2. MATERIALS AND METHODS

2.1 Experimental Site and Plant Material

The experiment was carried out at the Postgraduate Laboratory of the Department of Horticulture, Bangladesh Agricultural University, Bangladesh (BAU) to evaluate the germination characteristics and growth of seedlings of tomato cv. BINA Tomato-10 under different salt concentrations. Insect and disease free, healthy seeds of BINA Tomato-10 were collected from Bangladesh Institute of Nuclear Agriculture (BINA) and were used in the present study.

2.2 Treatments and Design of the Experiment

Five level of sodium chloride (NaCl) *i.e.*, distilled water (Control), 25 mM, 50 mM, 100 mM and 150 mM were used in the experiment. The single factor experiment was carried out using completely randomized design with three replications. Twenty-five seeds of each level of NaCl represented one replication.

2.3 Procedure of Seed Germination

Seed germination was conducted using Petri dishes. Germination paper was folded thrice and cut in a size of Petri dish and were used in each Petri dish as support. Twenty five seeds of tomato were germinated in Whatman no.1 filter paper placed in Petri dishes (9 cm diameter). The Petri dishes were moistened with 5 ml of different salt solutions. The moisture level and salt solution were assessed daily and respected solutions were applied time to time as per requirement. The Petri dishes were kept in dark, under constant incubator temperature set at $25 \pm 1^\circ\text{C}$ for 11 days.

2.4 Data Collection

Data regarding germination percentage, length of radicle and plumule, fresh weight of radicle and

plumule and dry weight of radicle and plumule were recorded from 5 DAS and at 2-days interval up to 11 days after seed sowing (DAS). Coefficient of germination (CG) and seed vigor index were calculated at 11 DAS.

2.4.1 Germination percentage

A seed was germinated when seed coat ruptured, plumule and radicle came out. The Petri dishes were observed every day and the number of germinated seeds was recorded daily at 10:30 AM. The germination percentage was calculated using the following formula and expressed in percentage:

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

2.4.2 Coefficient of germination

Coefficient of germination was calculated using the following formula [8]:

$$\text{Coefficient of germination} = \frac{(A1 + A2 \dots \dots \dots + Ax)}{(A1T1 + A2T2 \dots \dots \dots + AxTx)} \times 100$$

where,

A = Number of germinated seeds; T = Time corresponding to A; x = Number of days to final count.

2.4.3 Length of radicle and plumule

Radicle and plumule length of seedlings were measured after five DAS. Randomly selected four seedlings were taken from each Petri dish to measure length of radicle and plumule. After separating radicle and plumule, length was measured in centimeters (cm) with the help of a measuring ruler.

2.4.4 Seedling vigor index

The vigor of the seedlings was determined by the following formula [9]:

$$\text{Seedling vigor index} = [\text{Mean of radicle length (cm)} + \text{Mean of shoot length (cm)}] \times \text{Percentage of seed germination.}$$

2.4.5 Fresh mass of radicle and plumule

Radicles and plumules of four seedlings from Petri dish were cut and their fresh weight were

determined in milligrams (mg) using a digital electronic balance (G & G, T100, Germany).

2.4.6 Dry mass of radicle and plumule

Randomly four radicles and plumula were taken from the Petri dishes and dried in an oven at 70°C for 48 hours, till the mass become constant. The radicle and plumule dry mass were measured with the help of digital electronic balance and expressed in milligrams (mg) and the mean value was calculated.

2.5 Statistical Analysis

One factor analysis of variance (ANOVA) was conducted for all variables using the MSTAT-C computer package program [10]. The means were compared using Fisher's Least Significant Difference (LSD).

3. RESULTS AND DISCUSSION

3.1 Seed Germination

Germination of seeds of tomato started after two days of seed sowing except in 100 mM NaCl treatment (Table 1). Similar delay germination in the higher salinity level has been also reported in onion [11]. However, no seed germinated in the highest applied concentration of salt solution *i.e.*, in 150 mM NaCl. Results also revealed that the germination percentage of seed was decreased with the increasing levels of NaCl concentration. The maximum seed germination percentage (94.67%) was observed with the control (0 mM) and the minimum germination percentage (0%) was observed with 150 mM salt concentration at 11 DAS (Table 1). Mobilization of seed reserves during seed germination is crucial because it supplies substrate for proper functioning of different metabolic processes that essential for growth of embryonic axis, which contributes translocation of reserves from seed, resulting seed germination. Salinity might affect mobilization of seed reserves, which leads to diminish in seed germination. Decrease in seed germination of spinach with the increasing concentration of NaCl is also observed [12].

3.2 Germination Coefficient

Seed germination coefficient was calculated at 11 DAS and it was observed that it decreased with the increasing levels of salt concentration (Table 1). Significant differences in germination

Table 1. Germination percentage (%) and germination coefficient of BINA Tomato-10 as influenced by different NaCl concentrations at different days after sowing (DAS)

NaCl concentration (mM)	Germination (%) at different DAS								Germination coefficient at 11 DAS
	2	3	4	5	6	7	9	11	
Control (0)	34.67	81.33	90.67	94.67	94.67	94.67	94.67	94.67	15.91
25	9.33	62.67	78.67	86.67	88.00	88.00	89.33	89.33	15.23
50	2.66	12.00	28.00	66.67	69.33	70.67	74.67	74.67	13.80
100	0.00	4.00	21.33	38.67	44.00	45.33	46.67	46.67	13.66
150	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LSD _{0.05}	2.18	1.82	2.58	2.75	2.75	3.15	3.22	3.15	0.23

coefficient were found among the treatments and the maximum germination coefficient (15.91) was recorded in the control (0 mM) and the minimum (13.66) was noticed with 100 mM salt concentration which was statistical identical with 50 mM NaCl treatment (Table 1). Furthermore, no germination coefficient was found in the highest concentration of salt solution (150 mM), as seeds were inhibited to germinate in this treatment. Germination coefficient or germination rate is more sensitive parameter than germination percentage. The present results showed that exposure of tomato seeds to high NaCl concentrations did not only inhibit germination but also decreased germination rate. Similar reduction in germination rate with increasing salt concentrations was reported in *Atriplex gliffithii* and *Haloxylon recurrum* [13].

3.3 Length of Radicle

The growth of radicle was detected at 5 DAS except in 100 mM NaCl treatment, where radicle started to grow at 7 DAS (Table 2). However, the radicle length was significantly influenced by the different levels of NaCl concentration and at 11 DAS the longest radicle of seedling (7.61 cm) was measured in the control treatment. Significant differences in radicle growth were observed among the salt treatments and at 11 DAS the maximum length of radicle (6.50 cm) was recorded in 25 mM NaCl concentration while the least length of radicle (3.11 cm) was in 100 mM treatment. In all cases, no growth of radicle was observed in 150 mM NaCl treatment. Water uptake of seed involves the movement of water across cell membranes into the cells of the seeds and is determined by the difference between the osmotic potential of seed and that of the medium [14]. The results of the experiment showed that higher concentrations of NaCl inhibited water uptake and radicle elongation. The roots which are directly in contact with growth media

containing toxic salts stop the long term root growth [15]. Furthermore, under saline condition, growth of root decreases because of low CO₂ assimilation which is the major energy source for growth and development of root [16].

3.4 Length of Plumule

Plumule started to grow at 5 DAS except in 100 mM NaCl treatment where plumule started to grow at 7 DAS (Table 3). Length of plumule increased with the advancement of time. In all cases, no growth of plumule was observed in the highest concentration of salt solution (i.e., 150 mM). However, the plumule length was significantly influenced by the different concentrations of NaCl. Similar as length of radicle, at 11 DAS, the tallest plumule (5.77 cm) was measured in control treatment. While comparing the salt solutions, the maximum length of plumule (5.25 cm) was noticed in 25 mM NaCl treatment and the lowest (2.58 cm) was in 100 mM salt solution. The seeds under control and low salt concentration level (25 mM) may have adjusted osmotically to the growing conditions, as a result of which they were successful in maintaining required cell enlargement and showed maximum length of plumule, compared to the higher salinity levels (50 and 100 mM). On the other hand, the seeds under the higher salt concentration failed to activate the dehydration avoidance mechanism and could not withstand high salt stress and experienced the reduction in growth. Similar growth of *Pupuls* seedlings under high salt concentration has been reported by Abbruzzese et al. [17].

3.5 Seedling Vigor Index

The present results indicated that the vigourity of seedlings decreased with the increased concentration of salt solution. The highest

Table 2. Length of radicle (cm) of seedlings of BINA Tomato-10 influenced by different NaCl concentrations at different days after sowing (DAS)

NaCl concentration (mM)	Radicle length (cm) at different DAS			
	5	7	9	11
Control (0)	3.13	6.83	7.51	7.61
25	2.86	5.54	6.40	6.50
50	1.85	4.29	5.25	5.54
100	0.00	1.74	3.06	3.11
150	0.00	0.00	0.00	0.00
LSD _{0.05}	0.09	0.05	0.05	0.34

Table 3. Length of plumule (cm) and seedling vigor index of BINA Tomato-10 influenced by different NaCl concentrations at different days after sowing (DAS)

NaCl concentration (mM)	Radicle length (cm) at different DAS				Seedling vigor index at 11 DAS
	5	7	9	11	
Control (0)	3.13	6.83	7.51	7.61	1266.34
25	2.86	5.54	6.40	6.50	1050.18
50	1.85	4.29	5.25	5.54	729.96
100	0.00	1.74	3.06	3.11	257.80
150	0.00	0.00	0.00	0.00	0.00
LSD _{0.05}	0.09	0.05	0.05	0.34	29.53

seedling vigor index was obtained in control treatment (Table 3). Comparing the salt concentrations, the maximum seedling vigor index (1050.18) was found in 25 mM NaCl treatment and the minimum (257.80) was noticed in 100 mM NaCl treatment. It was revealed that seedling vigor index was directly dependent on the seed germination and seedling growth conditions. Seeds germinated under high concentration of NaCl had poor growth of radicle and plumule, which resulted in low seedling vigor index. It was also noticed that no seedling vigor index was found in the highest concentration of salt i.e., 150 mM NaCl treatment. It is logical as no germination of seed was observed in this treatment.

3.6 Fresh and Dry Mass of Radicle

The both radicle fresh and dry mass were significantly influenced with the increasing levels of NaCl concentration (Table 4). At 11 DAS, the maximum radicle fresh and dry mass (12.05 mg and 1.63 mg) was measured in the control treatment (0 mM) and the minimum radicle fresh and dry mass (6.03 mg and 0.82 mg) were noticed with 100 mM salt concentration. It was also observed that both radicle fresh and dry mass decreased gradually with the increasing levels of NaCl concentrations in different days

after seed sowing and no radicle growth was observed in 150 mM NaCl concentration in different DAS. The low fresh and dry mass of radicle at higher salinity levels might be due to the low water absorbance by germinated seed. Similar reduction of mass of radicle due to increasing the salinity levels also observed by Redman and Belyk [18].

3.7 Fresh and Dry Mass of Plumule

In general, both plumule fresh and dry mass increased with the advancement of time (Table 5). Significant differences were observed among the NaCl treatments for plumule fresh and dry mass. At different days after seed sowing, the highest fresh and dry mass of plumule was recorded in control treatment (0 mM NaCl) and no fresh and dry mass was measured in the highest level of salt solution (150 mM NaCl), because seed of this treatment was completely inhibited to germinate. While comparing the different salt treatments, the maximum fresh and dry mass of plumule (19.01 mg and 1.02 mg) was recorded in 25 mM NaCl treatment and the minimum was found in 100 mM salt treatment (11.99 mg and 0.31 mg). The higher fresh and dry mass of plumule under control and low levels of salinity could be due to low water uptake by germinated seeds.

Table 4. Fresh and dry mass of BINA tomato-10 radicles (mg) influenced by different NaCl concentrations at different days after sowing (DAS)

Salt concentration (mM)	Radicle fresh weight (mg) at different DAS				Radicle dry mass (mg) at different DAS			
	5	7	9	11	5	7	9	11
Control (0)	5.00	8.83	11.01	12.05	1.16	1.22	1.50	1.63
25	4.00	5.97	7.99	7.99	0.80	1.03	1.32	1.50
50	3.00	5.10	6.98	8.04	0.50	0.69	1.12	1.24
100	0.00	3.06	5.01	6.03	0.00	0.51	0.80	0.82
150	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LSD _{0.05}	0.16	0.21	0.05	0.07	0.05	0.04	0.05	0.04

Table 5. Fresh and dry mass of plumules (mg) as influenced by different NaCl concentrations at different days after sowing (DAS)

Salt concentration (mM)	Plumule fresh weight (mg) at different DAS				Plumule dry weight (mg) at different DAS			
	5	7	9	11	5	7	9	11
Control (0)	14.00	18.80	23.01	23.95	0.45	0.67	0.91	1.02
25	11.10	15.07	18.02	19.01	0.33	0.51	0.68	0.85
50	8.97	13.10	15.99	16.97	0.20	0.24	0.33	0.43
100	0.00	8.10	11.01	11.99	0.00	0.15	0.26	0.31
150	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LSD _{0.05}	0.16	0.19	0.05	0.17	0.02	0.02	0.02	0.03

4. CONCLUSION

Rate of germination, radicle and plumule growth may be used as potential selection criteria for salinity stress tolerance of tomato at the establishment stage. The result demonstrated that germination of seed and seedling growth of tomato cv. BINA Tomato-10 to salinity stress are dependent on salt (NaCl) concentrations. Increasing salt concentrations resulted in a delay and reduction in seed germination. Increasing salinity stress also reduced elongation of radicle and plumule however, the growth of radicle was more sensitive to salinity stress than plumule growth. Based on the results emerged from the present experiment it can be opined that BINA Tomato-10 is a medium salt tolerant cultivar.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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