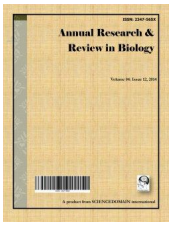

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Screening and Identification of Salt Tolerant Genotypes Based on Agromorphogenic Traits of Tomato (*Solanum lycopersicum* L.)

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Authors' contributions

This work was carried out in collaboration between all authors. Author MEH did the experiment driving, data analysis and wrote the work. Authors RA and BB did the experiment driving. Author NZ supervised the research and corrected the work. Author MHUR wrote and revised the work. All authors read and approved the final manuscript.

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ABSTRACT

A pot experiment was carried out to observe the performances of fifteen tomato genotypes under three different salinity treatments in the net house of Genetics and Plant Breeding Department of Sher-e-Bangla Agricultural University, Dhaka during November 2013 to March 2014. Two factorial experiment comprised of fifteen tomato genotypes viz. G_1 (BD-7289), G_2 (BD-7291), G_3 (BD-7298), G_4 (BD-7748), G_5 (BD-7757), G_6 (BD-7760), G_7 (BD-7761), G_8 (BD-7762), G_9 (BD-9011), G_{10} (BD-9960), G_{11} (BARI Tomato-2), G_{12} (BARI Tomato-3), G_{13} (BARI Tomato-11), G_{14} (BARI Hybrid Tomato-4), G_{15} (BARI Hybrid Tomato-5) and three salinity treatments T_1 (control), T_2 (8 dS/m), T_3 (12 dS/m) were laid out in Completely Randomized Design (CRD) with three replications. Seedlings were transplanted 30 days age to leading plastic pots, and two salinity treatments 8 dS/m and 12 dS/m were applied after seven days of transplanting. The results revealed that tomato genotypes and salinity treatments both significantly different with the agro-morphogenic traits of the tomato

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plant. Nearly all traits reciprocated negatively as the salinity level increased except days to first flowering and maturity. Average fruit weight was increased in genotype G_8 for both the stresses than the control condition. Yield per plant was recorded in the same G_8 genotype for T_2 and reduced the minimum for treatment T_3. Therefore, genotype G_8 could be recommended for higher yield in the coastal regions of Bangladesh. These genotypes could also be served as parent material for future hybridization or genetic transformation program.

Keywords: Agromorphogenic; genotypes; salinity.

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) belongs to the family Solanaceae is one of the most important vegetables in the world due to its more extensive adaptability, high yielding potentiality, and suitability for the variety of uses in fresh as well as processed food industries [1]. The cultivated tomato is the second most important vegetable crop in the world regarding consumption per capita and is the most popular garden vegetable that is eaten directly as raw vegetable or added as an ingredient to other food items. Tomatoes can be considered as an excellent source of minerals and vitamins [2,3,4]. Vitamin C content is unusually high in tomato [5] and is an excellent source of a powerful antioxidant like lycopene which reduces prostate cancer [6]. It ranks next to potato and sweet potato in respect of vegetable production in the world. It is widely cultivated in tropical, sub-tropical and temperate climates and thus it ranks third regarding world vegetable production [7]. Worldwide, a total of production of over 162 million metric tons tomatoes harvested from 4.83 million hectares of land [8].

In Bangladesh, the tomato is cultivated all over the country due to its flexibility to a wide range of soil and climate [9]. Tomato has a high demand in Bangladesh throughout the year and in consequence producing a good amount of tomatoes in Bangladesh. Total production of the plant was recorded 2,32,459 metric tons during 2010-2011 which was harvested from 61,213 acres of land [10]. In last few years tomatoes were cheaper and obtainable during the winter season but at present tomatoes are grown around the year in Bangladesh. This vegetable is becoming promising day by day and escalating the consumption of plant products.

Overindulgence salt in the soil solution may unfavorably affect plant growth through osmotic inhibition of water uptake by roots or specific ion effects. Plant metabolism is pretentious by salt stress in many aspects, and as a result, growth and yields are affected. The amount of land affected by secondary salinity (salinity caused by human activity) is gradually ever-increasing. At present, the salinity problem continues to increase, and a third of all irrigated lands in the world are affected by a greater or lesser quantity of salinity [11].

Salinity is one of the significant adverse selection pressure factors among the abiotic stresses. In the world, about 400 million hectares of land are affected by high salinity, and in Bangladesh, nearly 1 million hectares of land are affected in the coastal regions, and it is increasing day by day. Salinity influences almost every aspect of the morphology, physiology, and biochemistry of plants and significantly reduces yield [12,13,14]. As saline soils and saline waters are typical around the world, considerable effort has been devoted to understanding physiological aspects of tolerance to salinity in plants, as a basis for plant breeders to develop salinity-tolerant genotypes. In spite of this great effort, only a small number of cultivars, partially tolerant to salinity, have been developed. Salinity profoundly affects yield so that yield must be taken into account when breeding for salinity tolerance genotypes [15].

The tomato plant is moderately tolerant to salinity stress depending on cultivar or growth stage [16,17,18]. It can tolerate salinity up to 2.5-2.9 dS/m in root zone without yield losses [19]. Salinity adversely affects the vegetative growth of tomato, and it reduced plant length and dry weight [20]. Salinity also decreases the plant height, fresh and dry shoot and root weight as well as length of tomato [21,22,23,24]. Tomato cultivars varied considerably in response to different salinity levels [25]. It is necessary to find out a suitable variety for higher yield, and economic return for the salinity affected the Southern region of Bangladesh. This study was conducted to evaluate performance and to establish a reproducible protocol for selecting of different salt- tolerant tomato genotype in various concentrations of NaCl.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted besides the net house of Genetics and Plant Breeding Department, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh from November 2013-March 2014. The experimental site was 23°74' N latitude and 90°35' E longitude with an elevation of 8 meters above the sea level in Agro-ecological zone of "Madhupur Tract" (AEZ-28) [26]. It is located in the subtropical climatic area with plenty of sunshine, and moderately low temperature prevails during October to March (Rabi season) which is suitable for tomato growing. The soil was sandy loam in texture having pH 5.46- 5.62 and EC 0.60 dSm^{-1}.

2.2 Experiment Frame Work

The experiment was laid out in three replications in Completely Randomized Design (CRD) using two factors comprises of 135 plastic pots to evaluate the performance of fifteen tomato genotypes under different salinity treatments. Factor A and B included fifteen genotypes (Table 1) and three salinity treatments [T_1: Control condition; T_2:8 dSm^{-1} (4.4 g L^{-1} of water) and T_3:12 dSm^{-1}(6.6 g salt L^{-1} of water)], respectively.

Saline solution was applied to T_2 and T_3 at 7 DAT for the excellent establishment of young seedlings. The electrical conductivity of different salinity levels in soil was adjusted by a direct reading conductivity meter (EC-meter). The salt solution (calculated) was applied 3-4 days interval to maintain the exact salinity level in the pot. When soil in the pot seemed to reach water logging condition, then salty water was applied (visual observation).

2.3 Seed Bed Preparation and Raising of Seedlings

The sowing was carried out on November 4, 2013, in the seedbed. Before 10 cm apart row sowing, seeds were treated with Bavistin (Active ingredient: 500 g kg^{-1}carbendazim) for five minutes. Recommended cultural practices were applied before and after sowing the seeds. Fifteen days old seedlings were transplanted to the polybag for hardening and 30 days old to the central plastic pot.

Table 1. Name and origin of fifteen tomato genotypes used in the present study

S/N	Genotypes	Accession name	Origin
1	G_1	BD-7289	PGRC, BARI
2	G_2	BD-7291	PGRC, BARI
3	G_3	BD-7298	PGRC, BARI
4	G_4	BD-7748	PGRC, BARI
5	G_5	BD-7757	PGRC, BARI
6	G_6	BD-7760	PGRC, BARI
7	G_7	BD-7761	PGRC, BARI
8	G_8	BD-7762	PGRC, BARI
9	G_9	BD-9011	PGRC, BARI
10	G_{10}	BD-9960	PGRC, BARI
11	G_{11}	BARI Tomato-2	PGRC, BARI
12	G_{12}	BARI Tomato-3	PGRC, BARI
13	G_{13}	BARI Tomato-11	PGRC, BARI
14	G_{14}	BARI Hybrid Tomato-4	PGRC, BARI
15	G_{15}	BARI Hybrid Tomato-5	PGRC, BARI

**PGRC=Plant Genetic Resources Centre, BARI=Bangladesh Agricultural Research Institute*

2.4 Pot Preparation and Transplanting of Seedlings

Each plastic pot (20 cm × 30 cm × 20 cm) filled with well pulverized and the sundried 10 Kg soil free from weeds and stubbles, along with 100 g well-decomposed cow dung according to the fertilizer recommendation guideline of Bangladesh Agricultural Research Council (BARC), 2012. The soil was treated with Formaldehyde (45%) for 48 hours before transplanting to the polybag and plastic pot to keep the ground free from the pathogen. Three pores were made in each plastic pot, and then the pores were covered by gravels so that excess water could quickly drain out.

2.5 Data Recording and Analysis

Data were recorded for yield and its contributing characters. Recording based on different agro-morphogenic traits - days to first flowering, plant height (cm), number of clusters per plant, days to maturity, number of fruits per cluster, number of fruits per plant, average fruit length (mm), average fruit diameter (mm), average fruit weight per plant (g), and yield per plant (kg).

Collected data were statistically analyzed using MSTAT-C computer package program. Mean for every treatment were calculated and analysis of

variance for each of characters was performed by F-test (Variance ratio). Different between treatments was assessed by Least Significant Difference (LSD) test at 5% level of significance [27].

3. RESULTS AND DISCUSSION

3.1 Days to First Flowering

Significant variation was found among the tomato genotypes in respect of days to first flowering (Table 2). The most prolonged period required (21.44 days) for flowering was in G_2 which was statistically identical with G_6 (20.44 days) and G_{15} (20.33 days) while the shortest period was in G_{13} (14.56 days) which was statistically similar with G_5 (15.22 days) (Table 3). Days to first flowering did not significantly vary by different salinity treatments (Table 2). T_3 (12 dS/m,18.24 days) associated genotypes showed earlier flowering than T_1 (18.24 days) (Table 4). The interaction between tomato genotypes and salinity treatments affects significantly on days to first flowering (Table 2). Thus $G_{15}T_1$ treatment required the maximum period (23.67 days) which was statistically identical with G_2T_1 (22.67 days) whereas the minimum was observed in G_5T_1, $G_{13}T_1$ and $G_{13}T_2$ (13.33 days) (Table 5). All the genotypes varied significantly under salinity treatments. The earliest flowering (maximum reduction) was observed in genotype G_{15} at both salinity stress conditions (Table 6) than control.

3.2 Plant Height

Plant height showed statistically significant variation among the genotypes (Table 2). The tallest plant was in G_9 (86.00 cm) whereas the shortest from G_{12} (57.28 cm) (Table 3). The tallest plant was found in T_1 (control) (74.00 cm)

Table 2. Analysis of variance of eight agromorphogenic traits

SV	df	MS							
		DFF	PH	NCP	DM	NFC	NFP	AFW	YP
A	14	33.39*	772.80*	38.32*	285.24*	26.61*	5124.72*	1515.02*	0.160*
B	2	3.94^{NS}	467.36*	8.14*	94.47*	2.40*	992.50*	1954.15*	2.755*
A×B	28	8.04*	162.38*	1.36*	36.09*	0.34^{NS}	94.04*	159.24*	0.095*
Error	90	1.56	1.33	0.47	3.76	0.24	29.55	7.24	0.002

**Significant at 0.01 level of probability; ^{NS} Non-significant, A=Genotype; B= Salinity; SV= Source of variation; MS= Mean Square of; df= Degrees of freedom; DFF= Days to first flowering; PH= Plant height (cm); NCP= No. of cluster plant^{-1}; DM= Days to maturity; NFC= No. of fruits cluster^{-1}; NFP= No. of fruits plant^{-1}; AFW= Average fruit weight plant^{-1} (gm); YP= Yield plant^{-1} (kg)

Table 3. Performance of tomato genotypes for agromorphogenic traits

Genotype	DFF	PH	NCP	DM	NFC	NFP	AFW	YP
G_1	16.78gh	70.98f	8.22b	72.89ef	5.00c	46.56d	15.03ef	0.72a
G_2	21.44a	84.58b	5.33e	77.67cd	3.11d	19.22f	13.40f	0.26h
G_3	18.56cd	62.66j	7.55c	78.22cd	4.66c	41.11e	12.67f	0.52de
G_4	16.11hi	61.14k	4.22f	78.78bc	2.88de	15.56f	38.29b	0.64bc
G_5	15.22ij	83.93b	9.22a	63.33h	6.66b	68.44bc	6.04h	0.43f
G_6	20.44ab	81.56c	8.33b	68.56g	6.77ab	65.89c	7.11h	0.52de
G_7	17.33e-g	64.03i	6.55d	72.22ef	4.55c	36.33e	16.35e	0.61c
G_8	18.22de	72.48e	7.00cd	73.33e	4.77c	39.11e	13.77f	0.55d
G_9	18.00d-f	86.00a	3.55g	76.56d	2.77de	11.56g	28.84c	0.34g
G_{10}	17.00f-h	67.20h	8.77ab	71.11f	6.66b	71.67ab	9.74g	0.74a
G_{11}	19.44bc	64.51i	4.77ef	80.33ab	2.55e	14.89f	43.50a	0.67b
G_{12}	18.11d-f	57.28l	3.55g	81.00a	2.66de	11.67g	41.88a	0.61c
G_{13}	14.56j	75.94d	8.44b	63.22h	7.22a	75.00a	5.74h	0.50e
G_{14}	18.33c-e	66.31h	4.33f	76.67d	3.00d	17.33f	25.16d	0.46f
G_{15}	20.33ab	68.69g	4.33f	77.78cd	3.00d	15.78f	26.67cd	0.46f
CV%	6.95	1.62	10.96	2.62	11.18	14.28	13.27	9.06
$LSD_{(0.05)}$	1.17	1.08	0.64	1.81	0.42	3.29	2.52	0.042

Note: Values with same letter are not significantly different

whereas the shortest from T_3 (12 dSm^{-1}) (67.66 cm) (Table 4). The study referred that plant height was found to decrease gradually with an increase of salinity level for all the tomato lines, and similar results were also found by [28,29]. The inhibition of plant growth under saline conditions may either be due to decreased availability of water or to the toxicity of sodium chloride [30]. Accumulation of Na^+ and Cl^- and reduction in the uptake of macronutrients mainly Na^+ and Ca^+ causing a retardation of plant growth [31]. Plant height performed significant variation among interaction of genotypes and treatments. As a result, the tallest plants were found in G_9T_1 and G_2T_1 (90.60 cm) whereas the shortest plant was found in $G_{12}T_3$ (49.93 cm) (Table 5). The lowest reduction in plant height was observed in genotype G_{12} at T_2 (8 dSm^{-1}) and genotype G_3 at T_3 (12 dS m^{-1}) (Table 6) comparing control condition.

Table 4. Performance of treatments on agromorphogenic traits

Salinity	DFF	PH	NCP	DM	NFC	NFP	AFW	YP
T_1	17.67	74.00a	6.75a	75.76a	4.68a	42.09a	27.86a	0.821a
T_2	18.07	71.80b	6.15b	72.02b	4.48b	34.22b	15.93b	0.396b
T_3	18.24	67.66c	5.93b	70.56c	4.28c	33.71b	17.05b	0.389b
CV%	6.95	1.62	10.96	2.62	11.18	14.28	13.27	9.06
$LSD_{(0.05)}$	---	0.48	0.28	1.27	1.91	2.27	1.12	0.019

Note: Values with same letter are not significantly different at 0.05 level of probability

Table 5. Interaction effect of tomato genotypes and salinity treatments on agromorphogenic traits

Interaction	DFF	PH	NCP	DM	NFC	NFP	AFW	YP
G_1T_1	17.00i-l	74.50ij	8.66b-d	80.00b-e	5.00	48.00f-h	17.44i-l	0.876d
G_1T_2	17.00i-l	72.63jk	8.33b-e	69.33lm	5.33	50.33fg	12.57m-q	0.656ef
G_1T_3	16.33j-m	65.80n-p	7.66d-f	69.33lm	4.66	41.33h-j	15.09k-p	0.641ef
G_2T_1	22.67ab	90.60a	5.00j-l	81.67bc	3.33	19.67l-n	17.89h-k	0.347p-t
G_2T_2	20.67b-d	80.83d-f	5.66h-j	76.00f-i	3.00	19.33l-o	11.05p-s	0.223w
G_2T_3	21.00bc	82.30de	5.33i-k	75.33g-i	3.00	18.67m-p	11.26o-s	0.219w
G_3T_1	16.00k-m	64.00pq	7.33e-g	83.00ab	4.66	42.00g-j	16.62j-m	0.707e
G_3T_2	19.67c-g	60.40t	7.66d-f	77.00e-h	4.33	39.00ij	11.88n-r	0.441k-o
G_3T_3	20.00c-f	63.57qr	7.66d-f	74.67hi	5.00	42.33g-j	9.50q-t	0.415m-p
G_4T_1	14.33m	63.13q-s	5.33i-k	80.00b-e	3.66	24.00lm	55.49b	1.278a
G_4T_2	17.67g-l	64.93o-q	4.66j-m	81.33b-d	2.66	14.67n-q	22.01f-h	0.333q-t
G_4T_3	16.33j-m	55.37v	2.66o	75.00hi	2.33	8.00r	37.37c	0.309r-v
G_5T_1	13.33n	80.80ef	9.00bc	64.67n	7.33	72.33bc	8.06r-t	0.607fg
G_5T_2	16.33j-m	84.80c	9.33ab	62.67o	5.66	60.00de	4.94u	0.302s-v
G_5T_3	16.00k-m	86.20bc	9.33ab	62.67o	7.00	73.00bc	5.13t	0.381o-r
G_6T_1	20.67b-d	85.97c	9.00bc	73.00i-k	7.33	80.00ab	11.80n-r	0.968bc
G_6T_2	20.00c-f	80.33fg	8.33b-e	67.00mn	6.66	62.33de	4.85u	0.320r-u
G_6T_3	20.67b-d	78.37h	7.66d-f	65.67n	6.33	55.33ef	4.70u	0.276t-v
G_7T_1	18.00f-k	72.13 k	7.66d-f	77.00e-h	5.00	47.00f-i	21.11g-i	0.940cd
G_7T_2	17.00i-l	67.27l-n	6.33g-i	70.00k-m	4.66	34.33jk	12.38m-r	0.425l-o
G_7T_3	17.00i-l	52.70w	5.66h-j	69.67lm	4.00	27.67kl	15.57k-o	0.470j-n
G_8T_1	19.00c-i	74.97i	7.33e-g	73.67ij	5.00	43.33g-i	12.35m-r	0.543g-i
G_8T_2	17.00i-l	68.77l	6.33g-i	71.33j-l	4.66	34.00jk	13.30l-q	0.635ef
G_8T_3	18.67d-i	73.70i-k	7.33e-g	75.00hi	4.66	40.00h-j	15.65k-n	0.456k-n
G_9T_1	18.67d-i	90.60a	3.66mn	71.33j-l	3.00	13.33n-q	38.42c	0.534h-j
G_9T_2	19.67c-g	84.73c	3.33no	76.00f-i	2.66	10.00pq	23.65e-g	0.249uv
G_9T_3	15.67lm	82.70d	3.66mn	82.33ab	2.66	11.33n-q	24.44e-g	0.250uv
$G_{10}T_1$	14.33m	62.07r-t	9.66a	69.33lm	7.00	85.67a	14.99k-p	1.238a
$G_{10}T_2$	18.33e-j	82.43de	8.66b-d	74.33h-j	6.66	68.33cd	7.10st	0.495i-l
$G_{10}T_3$	18.33e-j	57.10uv	8.00c-e	69.67lm	6.33	61.00de	7.13st	0.477i-m
$G_{11}T_1$	18.67d-i	63.67qr	5.66h-j	85.33a	2.66	18.00m-p	55.11b	1.014b
$G_{11}T_2$	19.33c-h	67.80lm	4.66j-m	78.33d-g	2.33	13.33n-q	38.56c	0.483i-m
$G_{11}T_3$	20.33c-e	62.07r-t	4.00l-n	77.33e-h	2.66	13.33n-q	36.83c	0.503i-k
$G_{12}T_1$	18.00f-k	61.47st	4.00l-n	82.67ab	3.00	15.33m-q	73.27a	1.280a

Interaction	DFF	PH	NCP	DM	NFC	NFP	AFW	YP
$G_{12}T_2$	17.00i-l	60.43t	3.33no	79.00c-f	2.66	10.67o-q	26.74e	0.297s-v
$G_{12}T_3$	19.33c-h	49.93x	3.33no	81.33b-d	2.33	9.00qr	25.63ef	0.246vw
$G_{13}T_1$	13.33n	81.37d-f	9.33ab	63.00o	7.33	85.00a	7.42st	0.673ef
$G_{13}T_2$	13.33n	58.40u	6.66f-h	63.33o	7.00	61.67de	3.98u	0.351p-s
$G_{13}T_3$	17.00i-l	88.07b	9.33ab	63.33o	7.33	78.33b	5.83t	0.489i-l
$G_{14}T_1$	17.33h-l	66.13m-o	4.66j-m	75.67g-i	3.00	18.67m-p	31.62d	0.605f-h
$G_{14}T_2$	19.00c-i	68.00lm	4.33k-n	74.33h-j	3.00	18.33m-p	22.87e-g	0.426l-o
$G_{14}T_3$	18.67d-i	64.80o-q	4.00l-n	80.00b-e	3.00	15.00n-q	21.00g-i	0.334q-t
$G_{15}T_1$	23.67a	78.63gh	5.00j-l	76.00f-i	3.00	19.00l-o	36.33c	0.710e
$G_{15}T_2$	19.00c-i	75.27i	4.66j-m	75.33g-i	3.00	17.00m-q	23.05e-g	0.397n-q
$G_{15}T_3$	18.33e-j	52.17w	3.33no	82.00bc	3.00	11.33n-q	20.63g-j	0.275t-v
CV%	6.95	1.62	10.96	2.62	11.18	14.28	13.27	9.06
$LSD_{(0.05)}$	2.02	1.87	0.29	1.63	----	1.93	1.15	0.023

Note: Values with same letter are not significantly different

3.3 Number of Clusters per Plant

Cluster per plant showed morphologically significant variation among the studied genotypes and also among salinity treatments (Table 2). The highest cluster plant^{-1} (9.22) was counted in G_5 which was statistically identical with G10 whereas the lowest number in G_{12} and G_9 (3.55 plant^{-1}) (Table 3). The maximum number of clusters per plant (6.75) was observed in T_1 whereas the minimum number (5.93) was recorded in T_3 which was statistically undifferentiated with T_2 (Table 4). Higher levels of salinity treatment decreased the number of clusters per plant in tomato [29,32]. It demonstrated significant inequality among the interaction of genotypes and salinity treatments (Table 2). The total number of clusters per plant (9.66) was counted in $G_{10}T_1$ which was statistically identical with $G_{13}T_1$, $G_{13}T_3$, G_5T_2, and G_5T_3 (9.33 plant^{-1}) whereas the minimum number of clusters per plant (2.66/plant) counted in G_4T_3 (Table 5). Clusters per plant increased in genotype G_2 at both the salinity treatments (Table 6) corresponding to control.

3.4 Days to Maturity

Days to first fruit harvest from the date of transplanting showed statistically significant variation among different tomato genotypes (Table 2). The most prolonged period (81days) was required for harvesting G_{12} genotype which was statistically identical with G_{11} (80.33 days) whereas the shortest time (63.22 days) was needed for G_{13} genotype which was equal to G_5 (Table 3). Early harvesting was performed in T_3 (70.56 days) and delayed in T_1 (75.76 days) (Table 4). Maturity time decreases with the increasing salinity levels and other ions in the root zone of tomato plant [33,34]. Interaction of genotypes and salinity treatments affects significantly on days maturity (Table 2). In this case earlier harvesting period (62.67 days) was observed in G_5T_2 and G_5T_3 which were statistically identical with $G_{13}T_1$, $G_{13}T_2$ and $G_{13}T_3$ treatment combination whereas $G_{11}T_1$ (85.33 days) was delayed which was statistically similar to G_3T_1, $G_{12}T_1$, and G_9T_3 (Table 5). The maximum reduction of days to maturity (early maturity) was observed in genotype G_1 at both the salinity levels (Table 6) compared to control condition.

3.5 Number of Fruits per Cluster

The maximum number of fruits per cluster (7.22) were obtained from G_{13} which was statistically identical with G_6 whereas the minimum (2.55) was found in G_{11} which was statistically similar to G_{12}, G_9, and G_4 (Table 3). It was significantly varied by salinity treatments (Table 2). The highest number of fruits per cluster (4.68 cluster^{-1}) was found in T_1 whereas T_3 provide the lowest number (4.28 cluster^{-1}) (Table 4). Reduction in fruit numbers per cluster due to the increase of salinity levels was found by [28,35]. The reduction in the fruit number is related to the decline in the flower number per truss and flowers per plant in higher salinity [36]. Increasing level of salinity reduces the fruit setting on trusses [37]. Interaction of tomato genotypes and salinity treatments were not significant on fruit number per cluster (Table 2). The maximum numbers of fruits (7.33 cluster^{-1}) were obtained from G_5T_1, G_6T_1, $G_{13}T_3$ and $G_{13}T_1$ whereas the minimum numbers (2.33 cluster^{-1}) were found in G_4T_3, $G_{11}T_2$, and $G_{12}T_3$ (Table 5). The number of fruits cluster^{-1} increased in genotype G_1 at slight salinity stress (8 dSm^{-1}) and in genotype G_5 at moderate salinity stress (12 dSm^{-1}) compare to the control (Table 6).

Table 6. Reduction percentage of agromorphogenic traits under increasing salinity compared to control condition

Genotype	DFF		PH		NCP		DM		NFC		NFP		AFW		YP	
	T_2	T_3	T_2	T_3	T_2	T_3	T_2	T_3	T_2	T_3	T_2	T_3	T_2	T_3	T_2	T_3
G_1	0.00	3.94	2.51	11.68	3.81	11.55	13.34	13.34	-4.85	13.90	-4.85	13.90	27.92	13.47	25.11	26.83
G_2	8.82	7.37	10.78	9.16	-13.20	-6.60	6.94	7.76	1.73	5.08	1.73	5.08	38.23	37.06	35.73	36.89
G_3	-22.94	-25.00	5.63	0.67	-4.50	-4.50	7.23	10.04	7.14	-0.79	7.14	-0.79	28.52	42.84	37.62	41.30
G_4	-23.31	-13.96	-2.85	12.29	12.57	50.09	-1.66	6.25	38.88	66.67	38.88	66.67	60.34	32.65	73.94	75.82
G_5	-22.51	-20.03	-4.95	-6.68	-3.67	-3.67	3.09	3.09	17.05	-0.93	17.05	-0.93	38.71	36.35	50.25	37.23
G_6	3.24	0.00	6.56	8.84	7.44	14.89	8.22	10.04	22.09	30.84	22.09	30.84	58.90	60.17	66.94	71.49
G_7	5.56	5.56	6.74	26.94	17.36	26.11	9.09	9.52	26.96	41.13	26.96	41.13	41.35	26.24	54.79	50.00
G_8	10.53	1.74	8.27	1.69	13.64	0.00	3.18	-1.81	21.53	7.69	21.53	7.69	-7.69	-26.72	-16.94	16.02
G_9	-5.36	16.07	6.48	8.72	9.02	0.00	-6.55	-15.42	24.98	15.00	24.98	15.00	38.44	36.39	53.37	53.18
G_{10}	-27.91	-27.91	-32.80	8.01	10.35	17.18	-7.21	-0.49	20.24	28.80	20.24	28.80	52.64	52.43	60.02	61.47
G_{11}	-3.54	-8.89	-6.49	2.51	17.67	29.33	8.20	9.38	25.94	25.94	25.94	25.94	30.03	33.17	52.37	50.39
G_{12}	5.56	-7.39	1.69	18.77	16.75	16.75	4.44	1.62	30.40	41.29	30.40	41.29	63.50	65.02	76.80	80.78
G_{13}	0.00	-27.53	28.23	-8.23	28.62	0.00	-0.52	-0.52	27.45	7.85	27.45	7.85	46.36	21.43	47.85	27.34
G_{14}	-9.64	-7.73	-2.83	2.01	7.08	14.16	1.77	-5.72	1.82	19.66	1.82	19.66	27.67	33.59	29.59	44.79
G_{15}	19.73	22.56	4.27	33.65	6.80	33.40	0.88	-7.89	10.53	40.37	10.53	40.37	36.55	43.21	44.08	61.27

Note: Reduction percentages of both the salinity treatments (T_2 and T_3) were calculated from control (T_1) condition

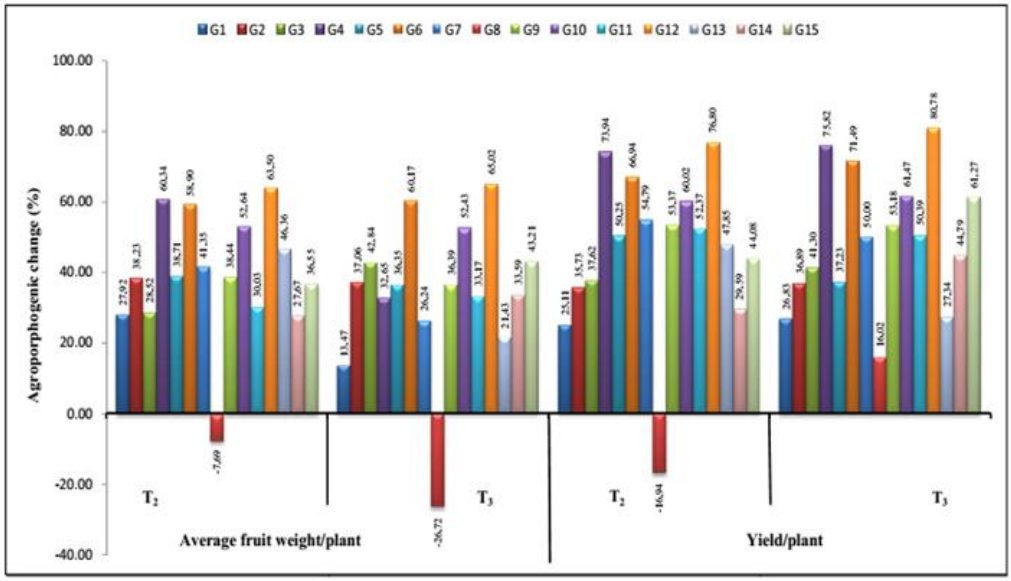

Fig. 1. Reduction percentage in average fruit weight per plant and yield per plant under increasing salinity level

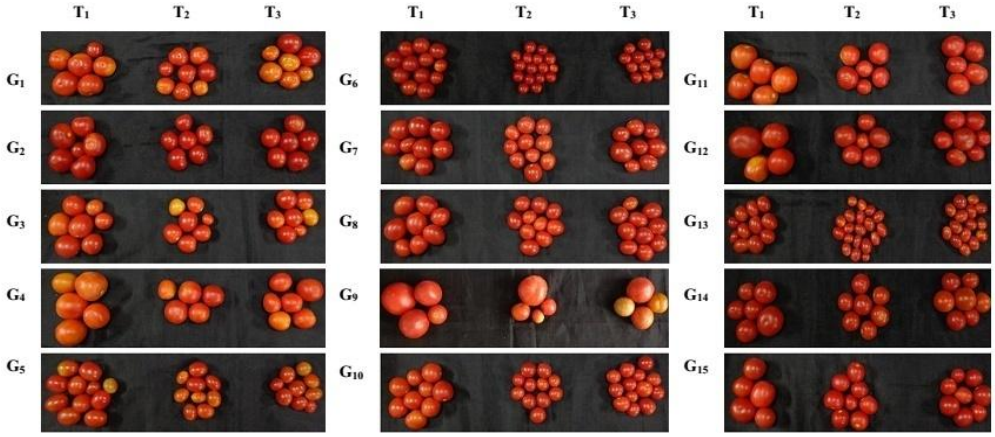

Fig. 2. Comparison of fruit morphology under control and stress conditions. G_1 (BD-7289), G_2 (BD-7291), G_3 (BD-7298), G_4 (BD-7748), G_5 (BD-7757), G_6 (BD-7760), G_7 (BD-7761), G_8 (BD-7762), G_9 (BD-9011), G_{10} (BD-9960), G_{11} (BARI Tomato-2), G_{12} (BARI Tomato-3), G_{13} (BARI Tomato-11), G_{14} (BARI Hybrid Tomato-4), G_{15} (BARI Hybrid Tomato-5) and T_1 (Control), T_2 (8 dS/m), T_3 (12 dS/m)

3.6 Number of Fruits per Plant

The number of fruits per plant was significantly varied among different tomato genotypes (Table 2). The maximum number of fruits (75 plant^{-1}) was obtained from G_{13} which was statistically identical with G_{10} (71.67 plant^{-1}) whereas the minimum number of fruits (11.56 plant^{-1}) was in G_9 which was identical with G_{12} (Table 3). It was varied significantly by salinity treatments (Table 2). The highest fruit number (42.09 plant^{-1}) was found in T_1 whereas T_3 provide the lowest number (33.71 plant^{-1}) statistically identical with T_2 (Table 4). These results are in agreement with the findings of [29]. Reduction in fruit number due to the increase of salinity levels was also found by [28,29,35]. The number of fruits per plant was restricted when the level of salinity in the root zone was 8 dSm^{-1} or higher [38]. The number of tomato fruits per plant depends on the number of trusses plant^{-1}, the number of flowers truss^{-1}, and the fruit set index at each truss. The

reduction in the fruit number is related to the decline in the flower number truss^{-1}, and flower plant^{-1} in higher salinity [36]. The interaction between tomato genotypes and salinity treatments significantly affects the number of fruits per plant (Table 2). The maximum number of fruits (85.67 plant^{-1}) were obtained from $G_{10}T_1$ which was statistically identical with G_6T_1 and $G_{13}T_1$ whereas the minimum number of fruits (8 plant^{-1}) was found in G_4T_3 that was statistically identical with $G_{12}T_3$ (Table 5). The number of fruits per plant increased in genotype G_1 at slight salinity stress (8 dSm^{-1}) and in genotype G_5 at moderate salinity stress (12 dSm^{-1}) compared to the control (Table 6).

3.7 Average Fruit Weight per Plant

G_{11} provided the maximum average fruit weight (43.50 g plant^{-1}) which was statistically identical with G_{12} while the minimum (5.74 g plant^{-1}) was found in G_{13} which was statistically identical with G_5 and G_6 (Table 3). It showed statistically significant variation associated with different salinity treatments (Table 2). The maximum average fruit weight (27.86g plant^{-1}) was obtained from T_1 whereas the minimum (15.93 g plant^{-1}) was found from T_2 which was statistically identical with T_3 (17.05g plant^{-1}) (Table 4). Reduction in single fruit weight per plant due to the increase of salinity levels was also found by [29,35]. In the saline area, the plants are affected by the excessive amount of salt (mainly NaCl). Excessive amounts of soluble salts in the root environment cause osmotic stress, which may result in disturbance of the plant water relations, uptake, and utilization of essential nutrients, and also in toxic ion accumulation [30]. Supply of water into the fruit under saline conditions is restricted by a lower water potential in the plant [39]. Less water flows in the fruit cause reduction in fruit size and thus reduces the fruit weight [40]. Interaction of tomato genotypes and salinity treatments significantly affects the average fruit weight (Table 2). The highest average fruit weight (73.27 g plant^{-1}) was obtained from $G_{12}T_1$ while the lowest (3.98 g plant^{-1}) was in $G_{13}T_2$ which was statistically identical with G_5T_2, G_6T_2, and G_6T_3 (Table 5). Average fruit weight per plant increased in G_8 at both the salinity treatments (Table 6 and Fig. 1).

3.8 Yield per Plant

The highest yield (0.737 kg plant^{-1}) was found in G_{10} which was statistically identical with G_1 whereas the minimum yield (0.263 kg plant^{-1}) was obtained from G_2 (Table 3). The yield per plant was significantly influenced by salinity treatments (Table 2). The yield per plant was the maximum (0.821 kg plant^{-1}) in control whereas the minimum (0.389 kg plant^{-1}) in T_3 which was statistically identical with T_2 (Table 4). Salinity stress reduces the yield per plant. In this experiment, the fruit number and average fruit weight per plant were cut in the case of high salinity, and thus the total fruit weight per plant was reduced [28,29]. Growth and plant yield reduction affected by salinity can be the reason of variation in photosynthetic products translocation toward the root, decrease of plant top especially leaves, partial or total enclosed of stomata, the direct effect of salt on photosynthesis system and ion imbalance [41]. Interaction of tomato genotypes and salinity treatments significantly affects the yield per plant of tomato (Table 2). The maximum yield (1.28 kg plant^{-1}) was obtained from $G_{12}T_1$ which was statistically identical with G_4T_1 (1.278 kg plant^{-1}) and $G_{10}T_1$ (1.238 kg plant^{-1}) while the minimum yield (0.219 kg plant^{-1}) from G_2T_3 which was statistically identical with G_2T_2 and $G_{12}T_3$ (Table 5). Yield increased in genotype G_8 at slight salinity stress (8 dSm^{-1}), and the minimum reduction was also found in the same genotype G_8 at moderate salinity stress (12 dSm^{-1}) (Table 6 and Fig. 1).

4. CONCLUSION

During stressed condition, the plants became stunted; leaves showed chlorosis, fruits became smaller and gradually died**.** Significant amounts of land in the southern region of Bangladesh remain uncultivable due to the high level of soil salinity. The salinity affected areas of Bangladesh are increasing rapidly. To overcome the salinity problem, saline soils can be used to grow salt-tolerant plants. Thus the development of salt- tolerant crops is a key to agricultural goal. Considering the growth and yield of tomato, fruits per plant increased in genotype G_1 at slight salinity and in genotype G_5 at moderate salinity. Average fruit weight per plant and yield per plant is grown in genotype G_8 at small salinity conditions. Based on yield, genotype G_8 (BD-7762) could be recommended to the farmers for cultivation under slightly saline to the moderate saline soil in the coastal regions of Bangladesh as well as it could be used as a parent material for future hybridization program to develop the salt tolerant genotypes.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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