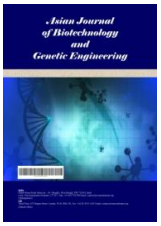

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Performance of Tomato (*Solanum lycopersicum* L.) Genotypes Based on Agro-morphogenic Traits under Drought Condition

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Authors' contributions

This work was carried out in collaboration among all authors. Authors NZ planned the experiment and lead the research. Authors RA, MEH and NZ designed and carried out the research. Author MEH performed the statistical analysis. Authors RA and BB carried out the research on the field. Authors RA and BB collected the data. Author MEH wrote the manuscript. Authors RA and BB managed the literature searches. All authors provided critical feedback and helped shape the research, analysis and manuscript. All authors read and approved the final manuscript.

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ABSTRACT

A pot experiment was conducted in the net house of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka-1207, during November 2013 to March 2014 to observe the performances of fifteen tomato genotypes under three different drought treatments. Two factorial experiments included fifteen tomato genotypes viz. G1 (BD-7759), G2 (BD-7292), G3

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(BD-7760), G4 (BD-7258), G5 (BD-7762), G6 (BD-7761), G7 (BD-7289), G8 (BD-7291), G9 (BD-7301), G10 (BARI Tomato-11), G11 (BARI Tomato-9), G12 (BARI Tomato-8), G13 (BARI Tomato-7), G14 (BARI Tomato-3) and G15 (BARI Tomato-2) and three drought treatments, T1 (Control), T2 (30 days withholding of water) and T3 (45 days withholding of water) were outlined in completely randomized design (CRD) with three replications. The results showed that both, the different tomato genotypes and drought treatments had significant influence independently and also in interaction on agro-morphogenic traits of the tomato plant. Almost all traits responded negatively as the drought level increased except days to first flowering, maturity. Considering the yield and yield contributing characters, genotype G4, G5 and G6 showed tolerance at moderate drought stress and G6, G7 and G13 showed tolerance at prolonged and severe drought stress. These genotypes could be recommended to the farmers for cultivation in the drought-prone areas of Bangladesh and also could be used in future hybridization or other gene transfer programs.

Keywords: Agromorphogenic; drought; plant; tomato and yield.

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) has been studied extensively owing to its high economic value in the market as a popular vegetable and high content in health-promoting antioxidant compounds. Tomato is also considered as an excellent model organism for both basic and applied plant research due to many reasons, including ease to culture under a wide range of environments, short life cycle, photoperiod insensitivity, high self-fertility and homozygosity, great reproductive potential, ease of controlled hybridization etc. [1]. The cultivated tomato is a well-studied crop species in terms of genetics, genomics and breeding [2]. Tomato species are diploid (2n=2x=24) and are a self-pollinated annual crop which belongs to the family Solanaceae. It is popular for its taste, nutritional status and various uses. It is extensively used in salad as well as for culinary purposes and a unique crop which provides a variety of processed products, namely, juice, pickles, paste, puree, sauces, soup, ketchup etc. Food value of tomato is very rich because of higher contents of vitamins A, B and C including calcium and carotene [3]. More than 7% of total vitamin-C of vegetable origin comes from tomato in Bangladesh.

The present leading tomato producing countries of the world are China, United States of America, Turkey, India, Egypt, Italy, Iran, Spain, Brazil Mexico, and Russia [4]. In Bangladesh, it is cultivated as a winter vegetable, which occupies an area of 58,854 acres in 2009-10 [5]. The total production of tomato in 2008 was 339 lac tons in China, 137 lac tons in the USA, 109 lac tons in Turkey, 103 lac tons in India and 92 lac tons in Egypt in 2008 [4]. In Bangladesh, in the year of 2009-2010, the total production of tomato was 190 thousand metric tons [5]. The average tomato production in Bangladesh is 50-90 tons/ha. The low yield of tomato in Bangladesh, however, is not an indication of low yielding potentially of this crop but of the fact that the low yield may be attributed to several reasons, viz. unavailability of quality seeds of high yielding varieties, land for production based on light availability, fertilizer management, pest infestation and improper irrigation facilities as well as production in abiotic stress conditions especially drought [6].

Drought is considered the single most devastating environmental stress, which decreases crop productivity more than any other environmental stress. A continuous shortfall in precipitation (meteorological drought) coupled with higher evapotranspiration demand leads to agricultural drought [7]. Agricultural drought is the lack of ample moisture required for normal plant growth and development to complete the life cycle. Drought severely affects plant growth and development with substantial reductions in crop growth rate and biomass accumulation. Crop growth models predict that this issue will be more severe in future. Drought impairs normal growth, disturbs water relations and reduces water use efficiency in plants. Due to drought, the rate of photosynthesis is reduced mainly by stomatal closure, membrane damage, and disturbed activity of various enzymes, especially those involved in ATP synthesis [8]. Plants display a range of mechanisms to withstand drought, such as reduced water loss by increased diffusive resistance, increased water uptake with prolific and deep root systems, and smaller and succulent leaves to reduce transpirational loss. Low-molecular-weight osmolytes, including glycine betaine, proline and other amino acids, and polyols also play vital roles in sustaining

cellular functions under drought. Plant growth substances such as salicylic acid, auxins, gibberellins, cytokinins, and abscisic acid modulate plant responses toward drought. Plant drought stress can be managed by adopting strategies such as mass screening and breeding, marker-assisted selection, and exogenous application of hormones and osmoprotectants to grow plants, as well as engineering for drought resistance [8].

Generally, tomato is grown during Rabi season and inadequate soil moisture in this season limits the use of fertilizers and consequently results in decreased yield. Deficiency of water considered as one of the major constraints to successful upland crop production in Bangladesh [9]. The growth, yield and fruit quality of tomatoes can be affected by drought stress, common abiotic stress for tomato. The cultivation of tomato requires a proper supply of water and this requirement can meet by applying irrigation. In spite of its broad adaptation, production is concentrated in a few areas and a rather dry area [10]. The screening of drought-tolerant lines to identify a tolerant genotype is quite necessary which may hopefully sustain a reasonable yield on drought-affected soils. Screening can be an easier method to determine drought tolerant genotypes. The study was prepared to identify the best drought tolerant genotypes based on agro-morphogenic traits of tomato.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was accomplished beside the net house of Genetics and Plant Breeding Department, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during the period from November 2013 to March 2014. Location of the site is 23°74' N latitude and 90°35' E longitude with an elevation of 8 meters from sea level [11] in Agro-ecological zone of "Madhupur Tract" (AEZ-28) [12]. The experimental site was located in the subtropical climatic zone, set apart by plenty of sunshine and moderately low temperature prevails during October to March (Rabi season) which is suitable for tomato growing in Bangladesh. The soil is sandy loam in texture having pH 5.46- 5.62 and EC 0.60 dS/m.

2.2 Design and Layout of the Experiment

The experiment was laid out and evaluated during Rabi season 2013-14 in Completely Randomized Design (CRD) using two factors. Factor A included 15 genotypes (Table 1) and Factor B included 3 drought treatments. The experiment was conducted in 3 replications and a total of 135 plastic pots were used. Different drought treatments were employed by the withholding of water. Three drought treatments are T1 (0 days withholding of water/Control), T2 (30 days withholding of water) and T3 (45 days withholding of water). Plants in control treatments (T1) were not exposed to drought; whereas plants in T2 and T3 treatments were exposed to drought for 30 days and 45 days respectively. Plants in control treatments (T1) were always irrigated with fresh water. T2 and T3 drought treatments were employed on plants in the plastic pots seven days after transplanting from the polybag. For T2 treatment the application of water was stopped for 30 days. After 30 days of withholding of water, plants were re-watered for recovery. For T3 treatment the water was withheld for 45 days, and then re-watered for recovery.

2.3 Seed Bed Preparation and Raising of Seedlings

The sowing was carried out on November 4, 2013, in the seedbed. Before sowing, seeds were treated with Bavistin for five minutes. Seedlings of all genotypes were raised in seedbeds in the net house of Genetics and Plant Breeding Department, Sher-e-Bangla Agricultural University, Dhaka-1207. Seeds were sown in rows spaced at 10 cm apart, beds were watered regularly. Seedlings were raised using regular nursery practices. Recommended cultural practices were taken up before and after sowing the seeds. When the seedlings become 15 days old those were transplanted in the polybag for hardening. After hardening when the seedlings become 30 days old were transplanted to the main plastic pot.

2.4 Pot Preparation and Transplanting of Seedlings

Weeds and stubbles were completely removed from the soil which was used for planting. The soil was treated with Formaldehyde (45%) for 48 hours before filling the polybags and plastic pots to keep the soil free from the pathogen. Pots were filled up two days before transplanting (December 4, 2013). Each pot was filled with 7 kg of soil. The pot size was 20 cm in height, 30 cm in top diameter and 20 cm in bottom diameter. Three pores were made in each plastic

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

Sl. no.	Genotypes no.	Name/Acc no. (BD)	Origin
1	G1	BD-7759	PGRC,BARI
2	G2	BD-7292	PGRC, BARI
3	G3	BD-7760	PGRC, BARI
4	G4	BD-7258	PGRC, BARI
5	G5	BD-7762	PGRC, BARI
6	G6	BD-7761	PGRC, BARI
7	G7	BD-7289	PGRC, BARI
8	G8	BD-7291	PGRC, BARI
9	G9	BD-7301	PGRC, BARI
10	G10	BARI Tomato-11	PGRC, BARI
11	G11	BARI Tomato-9	PGRC, BARI
12	G12	BARI Tomato-8	PGRC, BARI
13	G13	BARI Tomato-7	PGRC, BARI
14	G14	BARI Tomato-3	PGRC, BARI
15	G15	BARI Tomato-2	PGRC, BARI

PGRC = Plant Genetic Resource Centre, BARI = Bangladesh Agricultural Research Institute

pot and then the pores were covered by gravels so that excess water could easily drain out. When the seedlings become 15 days old, they were transplanted in the polybag for hardening and when the seedlings become 30 days old, they were transplanted in the main plastic pot (one plant/pot).

2.5 Data Recording and Analysis

Data were recorded from each pot 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 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 the characters was performed by F-test (Variance Ratio). Different between treatments was assessed by Least Significant Difference (LSD) test at 5% level of significance [13].

3. RESULTS AND DISCUSSION

3.1 Days to First Flowering

It was observed from the result of the experiment that statistically significant variation was found among the tomato genotypes in respect of days to first flowering (Table 2). The longest period required (38.67 days) for flowering in G11 whereas shortest period in G5 (20.44 days) which was statistically identical with G4 (21.33 days) and G14 (21.44 days) (Table 3). Days to flowering was not significantly varied by different drought treatments (Table 2). Days taken to first flowering was earlier in T2 (30 days) (26.69days) and late in T3 (45 days) (27.18days) (Table 4). Days taken to flowering from transplantation of tomato seedlings performed significant variation among interaction of tomato genotypes and drought treatments (Table 2). Similar results were founded by Wahb-Allah et al. (2011) [14]. G1T3 treatment required maximum period (43.00 days) which was statistically identical with G1T2 (42.67 days) and G12T1 (41.67 days) for flowering whereas minimum from G15T3 (19.33) which is significantly identical to G14T3, G6T3, G5T3, G5T2 (20.00 days) and G9T2 (20.67 days) (Table 5).

3.2 Plant Height

From the result of the experiment, it was observed that plant height showed statistically significant variation among fifteen tomato genotypes (Table 2). Tallest plant was obtained from G2 (142.30 cm) whereas the shortest from G6 (55.44 cm) (Table 3). The tomato genotypes showed statistically significant variation to drought treatments in terms of plant height (Table 2). Tallest plant was found at T1 (control) (101.50 cm) which is statistically significant with T2 (30 days) (100.4 cm) while shortest plant height from T3 (45 days) (84.20 cm) (Table 4). Less irrigation water caused a significant reduction in plant height when the applied water is reduced; it affects physiological processes and exposes plants to drought stress, which is reflected in low water absorption and transmission to different parts of the plant, as a

result, plant height gradually decreases. Similar results were reported by Wahb-Allah et al. (2011) [14]. Plant height performed significant variation among interaction of tomato genotypes and drought treatments (Table 2). Tallest plant is observed in G2T1 (170.30 cm) whereas shortest plant was found from G6T3 (50.67 cm) which is significantly identical with G11T3, G6T1 (56.67 cm) and G6T2 (59.00 cm) (Table 5).

3.3 Number of Cluster per Plant

The number of cluster per plant showed statistically significant variation among fifteen tomato genotypes (Table 2). The maximum number of cluster per plant (15.89 / plant) was counted in G1 whereas the minimum number of cluster per plant (4.000 / plant) was counted in G13 (Table 3). The number of cluster per plant of tomato genotypes showed statistically significant variation among drought treatments (Table 2). The maximum number of cluster per plant (9.240 /plant) was counted in T1 (control) whereas the minimum number of cluster per plant (7.730 /plant) in T3 (45 days) (Table 4). Results showed higher levels of drought stress decreased the number of cluster per plant in tomato, a similar result was found by Wahb-Allah et al. [14].

Table 2. Analysis of variance of eight agro-morphogenic traits

SV	df	MS							
		DFF	PH	NCP	DM	NFC	NFP	AFW	YP
A	14	386.96*	5939.09*	75.05*	282.45*	8.15*	1824.17*	2094.26*	0.047*
B	2	2.71NS	4316.08*	25.87*	121.91*	5.18*	78.25*	2555.79*	0.799*
A×B	28	61.08*	598.78*	0.96NS	55.56*	0.46NS	30.72*	149.64*	0.011*
Error	90	1.43	28.52	0.67	0.87	0.37	4.22	3.23	0.001

Significant at 0.01 level of probability; NS Non-significant, A = Genotype; B= Drought; 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; DM= Days to maturity; NFC= No. of fruits/cluster; NFP= No. of fruits/plant; AFW= Average fruit weight/plant (gm); YP= Yield/plant (kg)

Table 3. Performance of tomato genotypes on agro-morphogenic traits

Genotype	DFF	PH	NCP	DM	NFC	NFP	AFW	YP
G_1	36.00b	119.30c	15.89a	89.00d	3.88b	54.33a	8.76j	0.480e
G_2	25.67d	142.30a	10.11c	92.11c	2.66de	20.33d	17.88h	0.388g
G_3	26.33d	117.80c	12.56b	80.44j	3.66bc	41.22c	12.87i	0.578a
G_4	21.33gh	72.56h	8.55de	85.78f	2.44e	16.33ef	22.56f	0.403g
G_5	20.44h	80.11g	7.55fg	84.00g	2.66de	18.22e	23.63f	0.441f
G_6	22.67e	55.44i	7.88e-g	83.33g	2.77de	20.56d	25.84e	0.567ab
G_7	22.56ef	119.80c	8.66d	82.44h	2.77de	18.00ef	32.84d	0.523cd
G_8	22.33e-g	125.00b	9.66c	82.33h	2.00f	16.22f	32.41d	0.541bc
G_9	28.00c	88.56f	8.00d-f	81.33i	2.77de	17.56ef	20.61g	0.403g
G_{10}	22.89e	112.00d	8.55de	74.67k	5.88a	45.67b	7.64j	0.400g
G_{11}	38.67a	73.11h	7.22g	96.00a	2.33ef	11.22g	38.27c	0.496de
G_{12}	36.89b	74.00h	6.00h	86.67e	3.22cd	10.11g	51.58b	0.577a
G_{13}	36.00b	99.78e	4.00i	94.67b	2.55e	7.33h	56.10a	0.445f
G_{14}	21.44f-h	73.11h	6.33h	86.67e	2.33ef	10.11g	50.04b	0.560ab
G_{15}	22.56ef	76.78gh	5.77h	86.11ef	2.44e	10.22g	36.70c	0.411f
CV%	1.09	18.52	9.66	1.09	18.54	9.7	6.16	7.34
$LSD_{(0.05)}$	1.12	5.02	0.76	0.87	0.42	1.92	1.68	0.029

Note: Values with the same letter are not significantly different

Table 4. Performance of treatments on agro-morphogenic traits

Drought treatments	DFF	PH	NCP	DM	NFC	NFP	AFW	YP
T_1	26.89	101.50a	9.24a	84.64b	3.33a	22.16a	36.45a	0.608a
T_2	26.69	100.40a	8.37b	84.87b	2.88b	20.66b	29.70b	0.493b
T_3	27.18	84.02b	7.73c	87.60a	2.66c	19.67c	21.40c	0.342c
CV%	1.09	18.52	9.66	1.09	18.54	9.7	6.16	7.34
$LSD_{(0.05)}$	----	2.24	0.44	0.39	0.20	0.98	0.75	0.013

Note: Values with the same letter are not significantly different

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

Interaction	DFF	PH	NCP	DM	NFC	NFP	AFW	YP
G_1T_1	22.33m-p	128.30cd	16.67	90.33d	4.66	57.67a	9.81w-y	0.584e-h
G_1T_2	42.67a	123.00c-e	16.67	86.00e	3.33	55.33a	8.99xy	0.495j-l
G_1T_3	43.00a	106.70g-i	14.33	90.67d	3.66	50.00b	7.527y	0.362p-r
G_2T_1	31.33f	170.30a	11.33	84.00fg	3.33	23.00gh	21.18op	0.508i-l
G_2T_2	24.00j-m	149.30b	9.66	95.33c	2.33	18.00i-l	19.15pq	0.362p-r
G_2T_3	21.67n-q	107.30gh	9.33	97.00b	2.33	20.00h-j	13.32s-v	0.294st
G_3T_1	28.33gh	130.30c	13.67	80.67i	4.00	46.33cd	14.90es	0.729a
G_3T_2	25.33ij	121.30de	13.33	74.67m	3.66	44.67d	11.75u-x	0.606d-f
G_3T_3	25.33ij	101.70g-i	10.67	86.00e	3.33	32.67f	11.95t-w	0.399n-p
G_4T_1	21.67n-q	73.67m-p	9.33	85.33ef	2.66	17.67i-l	25.42n	0.485k-m
G_4T_2	20.67pq	67.67pq	8.33	86.00e	2.33	17.33i-l	28.42m	0.481lm
G_4T_3	21.67n-q	76.33l-o	8.00	86.00e	2.33	14.00m-p	13.84r-u	0.244tu
G_5T_1	21.33o-q	98.33i	8.33	85.33ef	2.66	20.00h-j	24.68n	0.520i-l
G_5T_2	20.00qr	68.33o-q	7.66	76.67l	2.66	17.33i-l	29.50lm	0.484k-m
G_5T_3	20.00qr	73.67m-p	6.66	90.00d	2.66	17.33i-l	16.71qr	0.319rs
G_6T_1	23.00l-o	56.67rs	8.33	86.00e	2.33	19.00i-k	32.35j-l	0.638cd
G_6T_2	25.00i-k	59.00rs	7.00	78.67jk	3.33	22.33gf	22.59no	0.535h-k
G_6T_3	20.00qr	50.67s	8.33	85.33ef	2.66	20.33hi	22.59no	0.528i-l
G_7T_1	21.33o-q	127.70cd	9.33	80.67i	3.00	13.67n-q	49.19ef	0.703ab
G_7T_2	21.33o-q	127.70cd	8.33	80.67i	2.66	16.00k-n	34.59ij	0.522i-l
G_7T_3	25.00i-k	104.00g-i	8.33	86.00e	2.66	24.33g	14.74r-t	0.346qr
G_8T_1	21.67n-q	147.00b	10.00	85.33ef	2.66	15.67l-o	41.74g	0.698ab
G_8T_2	23.67j-m	124.00c-e	9.66	82.33h	1.66	16.33k-n	33.82i-k	0.584e-h
G_8T_3	21.67n-q	104.00g-i	9.33	79.33ij	1.66	16.67k-n	21.66op	0.341q-s
G_9T_1	28.67g	67.67pq	8.33	79.33ij	2.66	15.33l-o	36.60hi	0.589d-g
G_9T_2	20.67p-r	128.30cd	8.00	78.67jk	3.33	17.00j-m	18.74pq	0.435mn
G_9T_3	34.67e	69.67n-q	7.66	86.00e	2.33	20.33hi	6.49z	0.186v
$G_{10}T_1$	24.33j-l	120.70de	9.33	72.00n	6.66	49.67b	10.42v-y	0.529i-l
$G_{10}T_2$	23.33k-n	109.30fg	8.66	74.67m	6.00	48.00bc	6.82z	0.416no
$G_{10}T_3$	21.00pq	106.00g-i	7.66	77.33kl	5.00	39.33e	5.67z	0.257tu
$G_{11}T_1$	40.00bc	75.67l-p	8.33	94.67c	2.66	12.67o-q	42.38g	0.616de
$G_{11}T_2$	38.00d	87.00j	7.33	94.33c	2.33	11.67p-r	38.26h	0.505j-l
$G_{11}T_3$	38.00d	56.67rs	6.00	99.00a	2.00	9.33r-t	34.19i-k	0.369o-r
$G_{12}T_1$	41.67ab	78.33k-m	6.66	84.00fg	4.33	11.33p-s	63.38a	0.713ab
$G_{12}T_2$	31.00f	75.00l-p	5.66	85.33ef	2.66	10.67q-t	61.30a	0.677bc
$G_{12}T_3$	38.00d	68.67o-q	5.66	90.67d	2.66	8.33s-u	30.06lm	0.340q-s
$G_{13}T_1$	35.00e	100.7hi	4.66	94.67c	3.00	8.33s-u	62.42a	0.557f-i
$G_{13}T_2$	34.67e	116.00ef	3.66	98.67a	2.33	7.33u	52.08de	0.387n-q
$G_{13}T_3$	38.33cd	82.67j-l	3.66	90.67d	2.33	6.33u	53.80cd	0.391n-q
$G_{14}T_1$	21.00pq	62.67qr	7.66	84.00fg	2.66	10.67q-t	55.00bc	0.622de
$G_{14}T_2$	23.33k-n	77.67k-n	5.66	86.00e	2.33	11.33p-s	47.77f	0.546g-j
$G_{14}T_3$	20.00qr	79.00j-m	5.66	90.00d	2.00	8.33s-u	47.35f	0.512i-l
$G_{15}T_1$	21.67n-q	85.00jk	6.66	83.33gh	2.66	11.33p-s	57.29b	0.623de
$G_{15}T_2$	26.67hi	72.00m-p	6.00	95.00c	2.33	11.67p-r	31.66kl	0.370o-r
$G_{15}T_3$	19.33r	73.33m-p	4.66	80.00ij	2.33	7.66tu	21.15op	0.241u
CV%	1.09	18.52	9.66	1.09	18.54	9.70	6.16	7.34
$LSD_{(0.05)}$	1.94	8.66	----	1.51	----	3.33	2.91	0.051

Note: Values with same letter are not significantly different

Interaction effects of tomato genotypes and drought treatments were not significant on the number of cluster per plant (Table 2). The maximum number of cluster per plant (16.67/plant) were obtained from G1T1 and G1T2 whereas the minimum number of cluster per plant (3.66 /plant) were found in G13T2 and G13T3 (Table 5).

3.4 Days to Maturity

Statistically, significant variation was found on days to first fruit harvest with different tomato genotypes (Table 2). Longest period (96.0 days) was required for harvesting in G11 whereas shortest period (74.67 days) was required for G10 (Table 3). Days to fruit harvest were significantly affected by drought treatments (Table 2). Early harvesting was performed in treatment T3 (for 45 days) (87.60 days) treated tomato genotypes and delayed in T1 (control) (84.64 days) which was statistically identical with T2 (30 days) (84.87) (Table 4). Maturity time decreases with the increasing drought levels in tomato plants. Similar results were reported by Sibomana and Aguyoh [15]. Interaction of tomato genotypes and drought treatments affects significantly on days taken to fruit harvest (Table 2).

In this case, earlier harvesting period (72.00 days) was observed in G10T1 whereas delayed in G11T3 (99.00 days) which was statistically identical with G13T2 (98.67) (Table 5).

3.5 Number of Fruits per Cluster

The number of fruits per cluster was significantly varied statistically among different tomato genotypes (Table 2). The maximum number of fruits per cluster (5.88/plant) was obtained from G10 whereas minimum (2.00/plant) was found on G8 which was statistically identical with G11 and G14 (2.33/plant) (Table 3). The number of fruits per cluster was significantly varied statistically by drought treatments (Table 2). Highest fruits per cluster (3.33/plant) was found in T1 (control) whereas T3 (45 days) provided the lowest number of fruits per cluster (2.66/plant) (Table 4). Reduction in fruit number per cluster due to the increase of drought levels was found by Sibomana and Aguyoh [15]. Water stress can accelerate the abscission process, leading in some cases to the premature dropping of fruits [16]. Interaction of tomato genotypes and drought treatments was not significant on fruit number per cluster (Table 2). Maximum numbers of fruits (6.66/plant) were obtained from G10T1 whereas minimum numbers of fruits per cluster (1.66/plant) were found in G8T2 and G8T3 (Table 5).

3.6 Number of Fruits per Plant

The maximum number of fruits (54.33 / plant) was found from G1 whereas minimum (7.333 / plant) was found in G13 (Table 3). The number of fruits per plant was significantly varied statistically by drought treatments (Table 2). The highest fruit number (22.16 / plant) was found in T1 (control) whereas T3 (45 days) provide the lowest number of fruits (19.67 / plant) (Table 4). The number of tomato fruits per plant depends on the number of trusses/plant, the number of flowers/truss and the fruit set index (number of fruits/number of flowers) at each truss. Srivastava et al. [17]; also found that drought-induced high temperature also causes flower drop up to 22.5 and immature fruits drop in the tomato. The number of fruits reduction in the plants, when they experienced drought stress during the early fruiting stage, would have been due to reduced fruit size and fruit number. The fruits of a plant treated at this stage were smaller than those of the control. The reduction in the fruit number was due to dropping of immature fruits. During the period of fruit enlargement, considerable amounts of carbohydrates and water are transported to the fruits. Therefore, the size of the fruit largely depends on this phase [16]. Interaction of tomato genotypes and drought treatments significantly affects the number of fruits per plant (Table 2). The maximum number of fruits (57.670/plant) were obtained from G1T1 which was statistically identical with G1T2 (55.330/plant) whereas the minimum number of fruits (6.333/plant) was found in G13T3 statistically identical with G13T2 (7.333/plant), G15T3 (7.667) and G12T3, G13T1, G14T3 (8.333) (Table 5). The number of fruits per plant increased maximum in genotype G6 because the reduction percentage at 30 days was minimum (-17.53%) and also increased in genotype G7 at severe drought stress (45 days) (-77.98% reduction percentage) (Fig. 1).

3.7 Average Fruit Weight per Plant

G13 tomato genotype provides the maximum average fruit weight (56.10g/plant) while minimum (7.64 g/plant) was obtained from G10 tomato genotype which was statistically identical with G1 (8.776 g/plant) (Table 3). Average fruit weight per plant showed statistically significant variation with different drought treatments (Table 2). Maximum average fruit weight (36.45 g/plant) was obtained from T1 (control) whereas minimum average fruit weight (21.40 g/plant) was found in T3 (45 days) (Table 4). Nyabundi and Hsiao [18]; reported that when tomato plants are subjected to different levels of drought stress under field conditions, vegetative growth is inhibited. Less water flows in the fruit cause

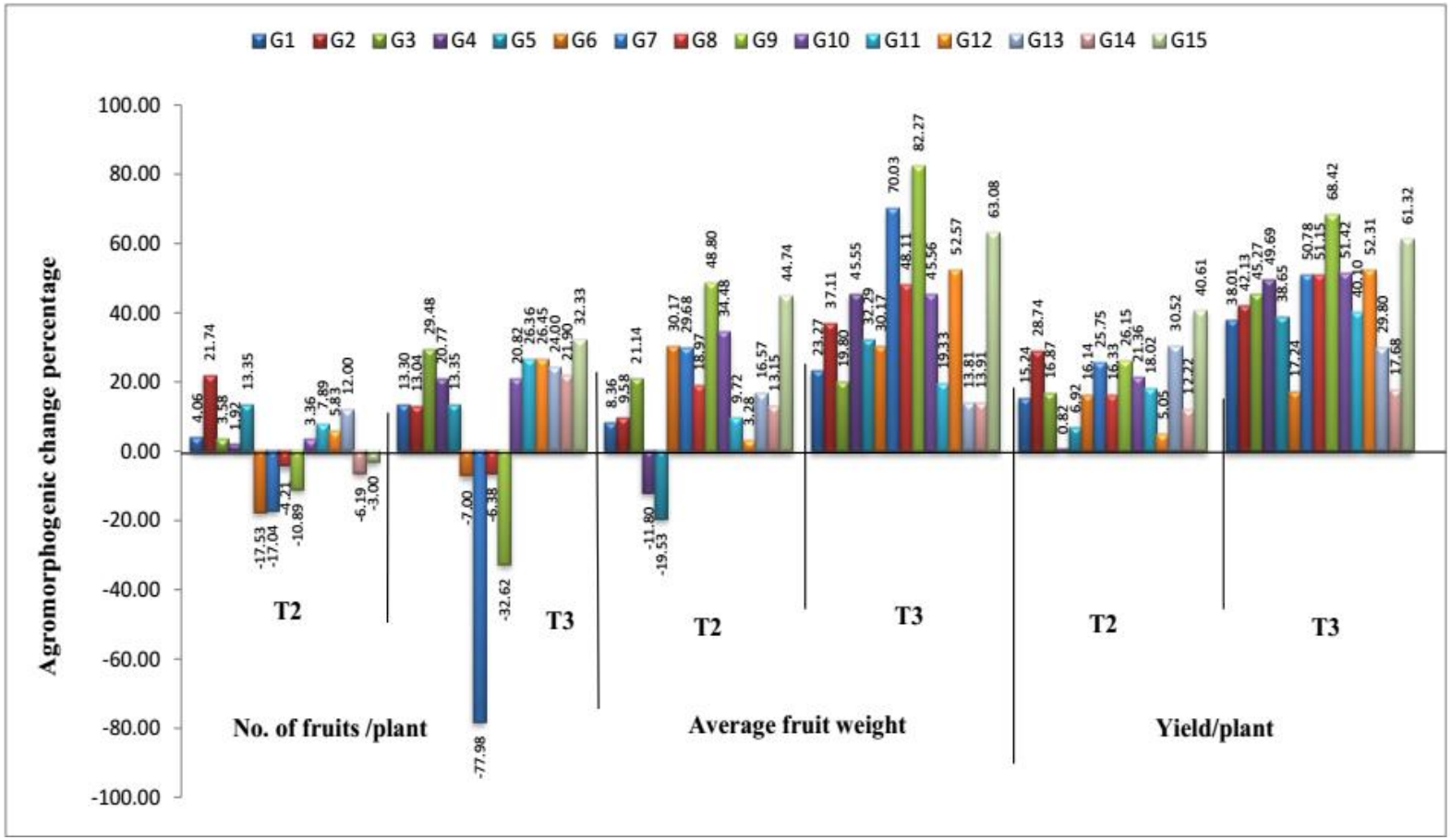

Fig. 1. Reduction percentage in no. of fruits/plant, average fruit weight/plant and yield/plant under increasing drought

reduction in fruit size and thus reduces the fruit weight. Tuberosa and Salvi [19]; reported that tomato growth parameters and yield were higher at a high irrigation rate and decreased significantly at drought stress. Interaction of tomato genotypes and drought treatments significantly affects the average fruit weight (Table 2). The highest average fruit weight (63.38 g/plant) was obtained from G12T1 which was statistically identical with G12T2 (61.3 g/plant) and G13T1 (62.42 g/plant) while the lowest average fruit weight (5.673 g/plant) was found in G10T3 which was statistically identical with G10T2 (6.827 g/plant) and G9T3 (6.490 g/plant) (Table 5). Average fruit weight per plant increased in genotype G5 at moderate drought stress (30 days) (reduction percentage -19.53%) and the minimum reduction was found in genotype G13 at severe drought stress (45 days) (13.81%) (Fig. 1).

3.8 Yield per Plant

Maximum yield (0.578 kg/plant) was found in G3 which was statistically identical with G12 (0.577 kg/plant) and G14 (0.560 kg/plant) whereas minimum yield (0.388 kg/plant) was obtained from G2 which was statistically identical with G10 (0.4000 kg/plant) and G4, G9 (0.403 kg /plant) (Table 3). The yield per plant was significantly influenced statistically by drought treatments (Table 2). The yield per plant was maximum (0.608 kg/plant) in T1 (Control) whereas minimum (0.342 kg/plant) in T3 (45days) (Table 4). Drought stress at a flowering stage not only reduces flower formation but also increases flower shedding. Mahendran and Bandara [20]; observed that when plants were exposed to moisture stress at the flowering stage, a severe drop in flowering occurred. Reduction in flower number reduces the amount of final yield. Hence, moisture stress during the flowering stage may have resulted in the highest reduction in yield. The plants which were exposed to moisture stress during the vegetative stage showed the next highest yield reduction. The yield reduction in the plants when treated at the vegetative stage was due to reduced development of leaves, twigs and branches [21]. Drought stress reduces the yield per plant [22] assessed comparative yield responses of greenhouse-grown tomato to full and deficit irrigation. They reported that marketable tomato yield was lowest under conventional deficit irrigation treatments. Interaction of tomato genotypes and drought treatments significantly affects the yield per plant of tomato (Table 2). Maximum yield (0.729 kg/plant) was obtained from G3T1 which was statistically identical with G12T1 (0.713 kg/plant), G7T1 (0.703 kg/plant) and G8T1 (0.698 kg/plant) while minimum yield (0.186 kg/plant) from G9T3 (Table 5). The minimum reduction was found in genotype G4 at moderate drought stress (30 days) (0.82%) and in genotype G6 (17.24%) at severe drought stress (45 days) (Fig. 1).

4. CONCLUSION

Large amounts of land in the northern region of Bangladesh remain uncultivable due to high level of drought. The affected areas of Bangladesh are increasing rapidly. To overcome the drought problem, drought soils can be used to grow drought-tolerant plants. Thus the development of drought-tolerant crops is a key global agricultural goal. Drought stress adversely affects the physiology of tomato at all stages of growth and development. Observation of agro-morphogenic characters played an important role in the selection of suitable genotype for future breeding purpose. Analyzing the data of this study it can be concluded for agro-morphogenic traits as fruits per plant increased in genotype G6 at moderate drought stress and in genotype G7 at severe drought stress. The average fruit weight per plant increased in genotype G5 at moderate drought stress and the minimum reduction was found in genotype G13 at severe drought stress. Yield per plant reduced minimum in genotype G4 at moderate drought stress and in genotype G6 at severe drought stress. Considering the yielding character, genotype G4, G5 and G6 could be recommended to the farmers for cultivation in the northern region of Bangladesh for moderate drought stress and genotype G6, G7 and G13 could be recommended for prolonged and severe drought stress.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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