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EFFECT OF DIFFERENT WATER REGIMES ON BIOMETRIC TRAITS OF SOME TOLERANT AND SENSITIVE TOMATO GENOTYPES

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ABSTRACT

Eleven local/exotic tomato genotypes were examined thoroughly to estimate the reduction in crop growth and yield at different water regimes *i.e.,* at 80% of field capacity (optimum watered) 60% and 40% of field capacity (water deficit) conditions. Among all the genotypes, genotype *L. pennelli* out yielded followed by CLN1767 and *L. chilense* in terms of dry biomass and fruits as compared to rest of the genotypes.Lower water stress regimes(60 and 40% field capacities) further reduced significantly leaf area index. Whereas, CLN1767 and Lyallpur-1 were intermediate in total number of fruits. Lowest number of fruits but amazingly greater single fruit weight was recorded in Roma and Ratan at even 40% moisture regime. In view of these results, it could thus be concluded that considerable genetic variation exists in tomato and water stress tolerance that is associated with better adaption to water stress and can be used in breeding for stress tolerance.

Keywords: Tomato, Dry matter, Water stress regimes, Fruit size, Total soluble solids.

INTRODUCTION

Although substantial research work have been reported to enhance water stress tolerance of plant species but it still needs considerable efforts because stress tolerance mechanisms in plants remained enigmatic (Tester and Langridge, 2010; Ashraf, 2010). It has been reviewed many times that moisture stress tolerance of various crops mainly depend on their ability to access and efficient use of soil water (Richards *et al*., 2010) but this mainly depends on type of crop species, type of cultivar, time and duration of water availability and type of agricultural conditions (Munns *et al*., 2010; Richards *et al*., 2010). Thus it is essential to evaluate the inclusive water stress tolerance mechanism of plant species for farmer's viewpoint. Sound documentation now available that increasing stress reduced tomato yield by decreasing fruit size, but improved fruit quality (based on Brix and taste panel results) (Nichols *et al*., 1995; Nahar and Gretzmacher, 2002; Nahar and Ullha, 2011). Soluble solids and pH of the product is determined by both the acid and sugar concentrations of the ripen fruit. High water stress leads to decreased yield, maximum accumulation of soluble solids and reduced viscosity. Transitional water stress although reduce crop yield but results in enhanced soluble solids along with good viscosity (May, 1993; May and Gonzales, 1999). Results from the studies in which water stress imposed as number of irrigation at different plant developmental stages suggested that less number of irrigation at flowering stage resulted in greater yield losses as compared to other plant growth stages indicating that flowering stage is critical growth stages (Plaut, 1995). Hence, the most critical time for moisture is at flowering, fruit set, and development. The main objective of the study was to explore genetic potential of the crop under water stress condition. Therefore, we investigated yield and quality of tomato fruits in the present study under water deficit conditions.

MATERIALS AND METHODS

The work was carried out at National Agriculture Research Center (NARC), Islamabad, Pakistan (33.40º N and 73.07º E; 683 meter above sea level) under plastic tunnel/screen house. Seeds of 11 selected tomato genotypes (including drought tolerant, intermediate and sensitive) were obtained from NARC, Islamabad, Pakistan. The experiment was planned according to randomized complete block design (RCBD) following three water stress treatments and three replications. Plastic pots (25 cm × 17 cm × 25 cm) were filled with 6 kg normal potting mixture (sand, well rotten farmyard manure and soil in 1:2:3 ratio). Soil moisture content from composite sample was determined by using ThetaProbe soil moisture sensor (Delta T Devices, UK). Nursery of eleven selected tomato genotypes was raised in plastic multipots tray, containing 1:1 ratio of soil and well rotten farmyard manure under polythene tunnel (8 m width × 20 m length × 3 m height). Three water regimes; 80% field capacity and irrigation at 60%, and 40% field capacities were started five weeks after seed germination. Field capacities were maintained throughout the growth period of tomato till maturity (Mahmood-ul-Hassan, 2001). Three randomly selected replicates were harvested after three week of water stress. At maturity, number of fruits was counted per plant and their weight was recorded. Data for each recorded variable were analyzed statistically through analysis of variance using STATISTICA version 7 software (StatSoft, Inc, OK, USA). Comparison of mean values was undertaken through least significance difference (*LSD*) test as described by Snedecor and Cochran (1980).

RESULTS

Soil water stress reduced significantly all the yield and yield attributed parameters of all the tomato genotypes. However, the tomato genotypes also differed for these attributes under soil water stress conditions. Since the interaction term genotype × water stress was also significant, it is necessary to compare mean data of these attributes for each genotype at each level of water stress (Table 1).

Data in Table 2depicts that at 40% field capacity, genotype *L. pennellii* produced the maximum shoot dry weight (60.1 g) followed by CLN1767 and *L. chilense* as compared to rest of the genotypes. In contrast, Avinash-2 had consistently lower shoot dry biomass under all level of water stress conditions. At all water regimes, *L. chilense* produced the highest root dry weight than all other tomato genotypes, while Avinash-2 and Ratan were the lowest in root dry weight, while, all remaining genotypes were intermediated in their root dry weights.

At 80% field capacity highest leaf areas were recorded for the tomato genotypes Ailsa Craig and Pusa Ruby whereas, the reverse was true for Ratan and *L. pennellii*. Maximum reduction in leaf area index of all tomato genotypes observed at 40% field capacity. But maximum reduction as compared to control was calculated for the genotypes Roma and Avinash-2 (26% and 36%) respectively. Moderately water stress tolerant genotype10584/G followed by water stress sensitive Avinash-2 attained maximum plant height while *L. pennellii*, *L. chilense* and CLN1767 produced minimum plant height (32.2, 30.4 and 29.0 cm) respectively, under 40% field capacity (Table 2).

Data in Table 3 show that among all the genotypes, Roma, Avinash-2 and Ratan respectively had consistently lowest total number of fruits (49, 36 and 33 %) than the other genotypes at all moisture regimes. Tolerant genotype Lyallpur-1was the highest in total number of fruits under 60% and 40% field capacity (88%) after *L. pennellii* (74%). Generally water stress sensitive and moderately water stress sensitive tomato genotypes produced greater single fruit weight than the water stress tolerant genotypes under both well watered as well as water stress conditions. Water stress sensitive Roma followed by P. Chuhara had highest single fruit weight than the other genotypes under normal conditions (80% field capacity), whereas water stress sensitive Ratan out yielded at water stress level (40% field capacity) closely followed by Roma and Pusa Ruby. And CLN1767 and *L. chilense* were the lowest and statistically at par (Table 4).

The results in Table 5 reveal that under normal irrigation (80%), the genotype 10584/G followed by Ailsa Craig produced maximum total fruit weight, whereas under water stress conditions water stress tolerant genotypes CLN1767 and Lyallpur-1, and moderately water stress tolerant 10584/G had maximum total weight of fruits than the other genotypes (Table 3). More reduction in total fruit weight as compared to control was recorded for P. Chuhara (58%) and minimum was for Lyallpur-1 (101%). It is interesting to note that Ailsa Craig and *L. chilense* closely followed by *L. pennelli* were intermediate in producing total fruit weight at the highest moisture stress (40%).

Total soluble solids in tomato fruits were significantly enhanced at different levels of water regimes in all genotypes of tomato, except in Roma and P. Chuhara where it decreased significantly at the highest water stress level (Table 5). Though maximum increase (7.02) in total soluble solids in tomato fruit was found in water stress sensitive genotype Ratan but greater increase in total soluble solids in tomato fruit was calculated in water stress tolerant genotypes (Lyallpur-1 closely followed by *L. chilense* and *L. pennelli*) as compared to those of water stress sensitive genotypes at the highest soil water stress levels (40% field capacity).

DISCUSSION

The production of higher dry biomass in both absolute and relative terms by *L. pennellii* followed by CLN1767, and their higher shoot water content, clearly confirm their high tolerance to drought against other genotypes examined in this study. Contrarily, lower dry biomass and smaller leaf area of Ratan, Roma and Avinash-2 indicated their sensitivity to continued water stress. Other genotypes did not show consistent relationships for various different growth variables in response to increasing drought stress. Lawlor (2002) and Dubey (2005) also affirmed such decrease in growth of tomato genotypes under simulated drought may be due to reduction in photo synthetically active leaf area. Reduction in growth rate of leaf under water deficit surroundings is an early phenomenon. As plant height is a manifestation of inherited biological and environmental aspects. Hence, under soil drying conditions roots tend to produce signal like ABA, which is transmitted to the leaves by the xylem thus influencing growth rate of the plant (Chao *et al*., 2011). In the present study, water stress tolerant *L. pennellii* was the highest in leaf area index, whereas water stress sensitive genotypes Roma and Ratan were the lowest in this growth variable. However, it is noteworthy that *L. chilense* had the highest leaf area index under water stress condition but it had relatively lower dry biomass. Relatively lower shoot dry biomass with highest leaf area index in *L. chilense* might have been due to its more carbohydrate investment in roots. In addition, water stress sensitive tomato genotypes Roma, Ratan and Avinash-2 were the lowest in root dry biomass and leaf area index. Keeping in view the findings of certain studies, it has been found that biomass allocation to root, quantity and length of functional roots increases water stress tolerance in crops (Kage *et al*., 2003). From the farmer's viewpoint tomato fruit yield is a very significant determinant in assessing crop production under stressful environs. In the present study, water stress tolerant genotypes of tomato produced greater total fruit yield than those of water stress sensitive one. These results can be elucidated in light of some previous studies that drought caused reduction in many crops yields depending on both intensity and duration of stress period, type of species and type of cultivar of the same species (Farooq *et al*., 2008; Ashraf, 2010). Similar results had also been reported by Bhatti *et al*. (2000) who recorded a substantial decrease in yield of four tomato varieties under different levels of moisture stress. Genotypic differences in tomato fruit yield might have been due to differences in total number of fruits or single fruit weight. It is suggested that water stress-induced reduction in tomato yield was due to reduction in flower development and this adverse effect was more in water stress sensitive genotypes. However, due to more reduction in number of flowers and fruits, the size of fruit more increased in water stress sensitive plants than that in water stress tolerant plants. There was a significant increase in total soluble solids of all tomatoes due to water deficit conditions (40% of field capacity) which is in close conformity to earlier report of Mitchell *et al.* (1991).

Table 1: Mean squares from analysis of variance (ANOVA) of the data of shoot dry weight, root dry weight, leaf area index, plant height and relative water number of fruits/plant, single fruit weight, total fruit weight and total soluble solids of tomato genotypes grown under varying levels of soil moisture stress at adult stage

Source of variation	df	Shoot dry weight	Root dry weight	Leaf area index	Plant height	No. of fruits per plant	Single fruit weight	Total fruit weight	Total soluble solids
Main Effects									
Water stress (W)	2	3042.2 ***	54.2 ***	34.41 ***	6088.4 ***	1077.5 ***	800.9 ***	0.55 ***	8.2***
Genotypes (G)	10	325.5 ***	10.4 ***	0.95 ***	3064.8 ***	942.0 ***	457.3 ***	0.10 ***	0.43 ***
Interaction									
W × G	20	41.7 ***	0.8 ***	0.54 ***	155.1 ***	33.15 ***	52.4 ***	0.016 ***	1.56 ***
Error	66	7.1	0.2	0.002	6.8	0.18	0.96	0.001	0.075

ns, *, **, *** = non-significant, Significant at 0.05, 0.01, and 0.001 levels respectively.

Table 2: Shoot and root dry weight of 40 days old plants of 11 selected tomato genotypes at levels of stress

Genotypes	Shoot dry weight			Root dry weight		
	Moisture stress (Fraction Field Capacity)					
	80%	**60%**	**40%**	**80%**	**60%**	**40%**
	G			g		
L. pennellii	68.3 a	66.5 a	60.1 a	10.09 bc	9.23 b	7.14 bc
L. chilense	70.0a	60.3 bcd	47.3 bc	11.00 a	10.83 a	11.03a
Lyallpur-1	67.7a	63.8 ab	45.6 cd	10.72 ab	8.73 bc	7.54 b
CLN1767	67.4 ab	60.9 bcd	51.4 b	10.28 ab	9.13 b	7.78 b
10584/G	57.7 d	61.5 bc	41.4 de	9.10 de	9.03 b	6.79 cd
P. Chuhara	63.3bc	60.7 bcd	41.2 e	9.32 d	7.95 de	6.29 de
Ailsa Craig	62.1b	56.6 d	41.2 e	10.13 b	8.23 cd	6.39 de
Pusa Ruby	60.7 cd	63.6ab	38.2 e	9.17 de	8.08 cde	6.34 de
Roma	52.1 e	51.9 e	40.1 e	9.38 cd	8.28 cd	6.74 cd
Avinash-2	48.1e	43.7 f	37.2 e	8.14 f	7.38 ef	5.89 e
Ratan	60.7 cd	57.8 cd	38.2 e	8.47 ef	7.05 f	5.69 e
	LSD 5% = 4.3			LSD 5% = 0.729		

Means in each column with similar letters (a-g) did not differ significantly at P< 0.05 level

Table 3: Leaf area index and plant height of 40 days old plants of 11 selected tomato genotypes at levels of stress

Genotypes	Leaf area index			Plant height		
	Moisture stress (fraction of field capacity)					
	80%	60%	40%	80%	60%	40%
	Cm			cm		
L. pennellii	2.94 h	2.51 d	2.38 a	46.7 g	40.8 ef	32.2 ef
L. chilense	3.54 e	2.81 b	2.38 a	46.1 g	39.0 f	30.4 f
Lyallpur-1	3.94 d	2.81 b	1.78 bc	54.3 f	43.8 de	35.2 de
CLN1767	4.04 c	2.51d	1.81 b	55.5 f	37.6 fg	29.0 f
10584/G	3.15 g	2.31 e	1.31 e	109.7 a	96.8 a	86.2 a
P. Chuhara	3.24 f	2.61c	1.71 c	62.6 e	47.9 d	39.3 d
Ailsa Craig	4.24	3.01a	1.51 d	54.8 f	44.5 de	35.9 de
Pusa Ruby	4.24 c	2.61 c	1.31 e	76.8 d	54.2 c	45.6 c
Roma	3.94 d	1.81g	1.01 g	44.1 g	34.6 g	20.3 g
Avinash-2	4.14 b	1.91f	1.51 d	96.7 b	62.2 b	53.6 b
Ratan	2.65 i	1.61 h	1.21 f	84.2 c	37.9fg	29.3f
	LSD 5% = 0.072			LSD 5% = 4.3		

Means in each column with similar letters (a-g) did not differ significantly at P< 0.05 level

Table 4: Total number of fruits and single fruit weight of 40 days old plants of 11 selected tomato genotypes at levels of stress

Genotypes	Total number of fruits			Single fruit weight		
	Moisture stress (fraction of field capacity)					
	80%	60%	40%	80%	60%	40%
	Kg			g		
L. pennellii	37.17 b	35.17 a	32.63 a	31.06 g	31.16 cd	27.71 d
L. chilense	34.17 c	29.67 bc	26.83 b	22.93 i	24.30 f	22.30 f
Lyallpur-1	34.7 c	31.17 b	25.73 bc	25.73 h	23.21 f	26.10 e
CLN1767	41.7 a	36.64 a	24.03 c	35.78 e	26.26 e	22.49 f
10584/G	34.17 c	31.17 b	14.63d	35.67 e	29.71 d	24.59 e
P. Chuhara	21.17 e	17.17 e	10.63 f	50.33 b	31.06 cd	29.06 cd
Ailsa Craig	35.17 c	29.27 c	12.53 e	45.13 c	35.28 b	29.96 c
Pusa Ruby	24.17 d	21.17 e	11.53 ef	43.79 c	31.52 c	38.28 b
Roma	11.17 g	8.17 g	5.43 g	56.09 a	42.06 a	40.06 a
Avinash-2	13.17 f	10.17f	4.73 g	33.21 f	26.59 e	20.13 g
Ratan	12.17 fg	9.67 fg	4.00 g	40.13 d	40.78a	38.78 ab
	LSD 5% = 1.34			LSD 5% = 1.59		

Means in each column with similar letters (a-g) did not differ significantly at P< 0.05 level

Table 5: Total weight of fruits and total soluble solids of 40 days old plants of 11 selected tomato genotypes at levels of stress.

Genotypes	Total weight of fruits			Total soluble solids		
	Moisture stress (fraction of field capacity)					
	80%	60%	40%	80%	60%	40%
	Kg			Brix		
L. pennellii	0.603 g	0.607 de	0.520 bc	4.82 c	5.40 bc	6.14 b
L. chilense	0.633 fg	0.567 e	0.490 c	4.35 d	5.92 a	6.68 a
Lyallpur-1	0.713de	0.697 c	0.580 a	5.98 a	4.50 f	5.24 f
CLN1767	0.813 c	0.827 b	0.593 a	4.30 d	5.99 a	6.60 a
10584/G	1.013a	0.928 a	0.580 a	4.32 d	5.82 ab	6.67 a
P. Chuhara	0.713 de	0.623 d	0.560 ab	5.97 a	4.78 def	5.50 def
Ailsa Craig	0.913 b	0.713 c	0.480 c	5.40 b	5.20 cd	5.95 bc
Pusa Ruby	0.183 h	0.680 c	0.420 d	4.97 bc	5.17 cd	5.92 bcd
Roma	0.613 fg	0.480 f	0.400 d	6.29 a	4.70 ef	5.44 ef
Avinash-2	0.733 d	0.567 e	0.410 d	5.15 bc	4.95 de	5.69 cde
Ratan	0.663 ef	0.440 f	0.370 d	4.86 c	6.20 a	7.02 a
	LSD 5% = 0.05			LSD 5% = 0.45		

Means in each column with similar letters (a-g) did not differ significantly at P< 0.05 level

Conclusion: From the observations it can be concluded that 60% moisture of the field capacity was adequate moisture supply for the investigated tomato genotypes and could be recommended for higher fruit yield and better fruit size. This result also shows that the tolerant genotypes; CLN1767 and Lyallpur-1 might be directly sown in arid and/or semi-arid regions through suitable management because soil compaction might have some role. Further, these genotypes due to its better adaptability have potential as a source of drought responsive genes for crop improvement.

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