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Variability in biophysical parameters and pollen viability in response to stress in tomato genotypes

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ABSTRACT

Tomato (*Solanum lycopersicon* L.), is one of the most popular vegetable crop widely grown which ranks next to potato. In tropical Asia, it is an important cash-earning crop for small farmers. It is a challenge to technology, processes and resources of horticultural production to produce vegetables several times more to meet the needs, but irrigation has become a constraint semi-arid regions. Therefore, an attempt was made to investigate variability of biophysical parameters and pollen viability in response to stress in tomato genotypes at KRC College of Horticulture, Arabhavi, Karnataka. Drought was imposed 15 days after transplanting to all the genotypes in both the IW/CPE ratio of 0.40 and 1.20 treatments. Irrigation was given when the pan evaporation reaches 41.66 mm (1.20 IW/CPE ratio) and 125 mm (0.40 IW/CPE ratio) and pollen were given heat stress at 25, 30 and 35^{0}C. Significantly maximum pollen viability was found in 1.2 IW/CPE ratio when compared to 0.4 IW/CPE ratio. The genotypes, L-30, IIHR 2274 and L-40-3 were recorded significantly maximum pollen viability and it was least in L- 17 and L-28. Photosynthetic rate was found comparably higher in the genotypes L-30, IIHR 2274 and L-40-3 compared to genotypes L-17 and L-28. Due to higher photosynthetic rate and heat tolerance the genotypes L-30, IIHR 2274 and L-40-3 able to tolerate drought and produce more yield per plant compared to the genotype L-17 and L-28.

Key words: *Solanum lycopersicon* L, photosynthetic rate, pollen viability, stomatal conductance, transpiration.

INTRODUCTION

Tomato (*Solanum lycopersicon* L.), which belongs to the family solanaceae, is one of the most popular and widely grown vegetables in the world. Tomatoes are the important source of lycopene, ascorbic acid and b-carotene and valued for its colour and flavour. Tomato is also rich in medicinal value. Drought is the major inevitable and recurring feature of semi-arid tropics and despite our improved ability to predict its onset, duration and impact, crop scientists are still concerned about it as it remains the single most important factor affecting the yield potentials of crop species. On an average, water use efficiency in the existing irrigation project in India is only about 40 per cent. This needs an immediate attention towards the judicious application of water. This is possible only by following scientific water management practices. Amongst several practices, scheduling of irrigation plays an important role in efficient water management.

In view of this, the present investigation was planned to identify variability in different drought adoptive mechanisms among different tomato genotypes with the objective to study the effect of temperature stress on pollen viability and its relationship with drought tolerance.

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MATERIALS AND METHODS

Field experiment was conducted at K. R. C. College of Horticulture, Arabhavi, Belgaum district, Karnataka, India during 2004 on medium black soil. The experiment was conducted with 11 genotypes (Arka Meghali (local check), GK-3, IIHR 2274, L-10 (P), L-17, L-28, L-30, L-38-1, L-40-3, Punjab Chhauhara and S-22). Water stress was imposed on 15th day onwards after transplanting. Irrigation was scheduled based on the evaporimeter reading. Open pan evaporation was recorded in 'mm' per day. Cumulative pan evaporation (CPE) was calculated and quantity of water to be irrigated through furrow was measured with the help of V-notch installed at plot head. Accordingly the measured quantity of water was applied to the plots as per the irrigation schedules. It was applied based on IW/CPE ratio, where in depth of irrigation (IW) was maintained constantly at 50 mm. Soon after reaching the particular ratio based on the cumulative pan evaporation, irrigation was scheduled to particular treatment. In 0.40 IW/CPE ratio treatment crop was irrigated for every 125 mm of CPE where as in 1.20 IW/CPE ratio irrigation was given for every 41.66 mm of CPE. The experiment was laid out in factorial randomised block design with two replication. Five plants were tagged and used for recording the observations such as stomatal conductance, leaf transpiration rate and photosynthesis were made on the adaxial surface of the fully expanded top leaf at 45 days after transplanting (DAT) using the steady state porometer (LC pro+ Portable Photosynthetic System, ADC Bioscientific Ltd. England). These measurements were taken under clear sunny day between 10.00 am to 12.00 noon. Pollen viability test carried out by colleting the flowers which were water stressed from the field in the morning hours and given the heat treatment of 25°C, 30°C and 35°C for 15 minutes and tested for pollen viability using the acetocarmine method. In this method a drop of acetocarmine was placed on a clean slide then preheated stressed pollens were added. Pollens were teased with needle and covered with covering slip. Then the slide was heated gently with a alcohol lamp. Pressure was applied to the cover slip to flatten the material and edge of the cover slip were sealed with wax and examined under microscope. The pollen which are fertile appear red and sterile were unstained. Fisher's method of analysis of variance was applied for the analysis and interpretation of the experimental data as given by Panse and Sukhatme (10). Plants were applied with fertilizers and other cultivation operations including plant protection measures were carried out as per recommended package of practices of University of Agricultural Sciences, Dharwad (Anon, 1).

RESULTS AND DISCUSSION

The photosynthetic rate of leaves under a given environmental condition is a function of various biophysical and biochemical processes involved during diffusion of CO_2 from atmosphere into chloroplast and the subsequent enzyme reactions. Maximum photosynthetic rate, transpiration rate and stomatal conductance was observed in 1.2 IW/CPE ratio (Table 1). These biophysical characters were significantly reduced to the extent of 24.93, 42.42 and 20.77 per cent as the stress level increased from 1.2 IW/CPE ratio to 0.4 IW/CPE ratio. Performance of genotypes across the irrigation levels for photosynthesis was found significantly

Table 1. Photosynthesis, transpiration rate and stomatal conductance of tomato genotypes as influenced by irrigation levels at 45 DAT.

Genotypes		Photosynthesis ($mmolCO_2$ $m^{-2}.s^{-1}$)			Transpiration rate (mmol $H_2O.m^{-2}.s^{-1}$) IW/CPE ratio			Stomatal conductance (mmol $m^{-2}s^{-1}$)		
		1.2	0.4	Mean	1.2	0.4	Mean	1.2	0.4	Mean
Arka Meghali		26.28	18.30	22.29	9.64	6.16	7.90	1.27	0.45	0.86
GK-3		28.75	24.25	26.50	8.44	7.11	7.78	0.45	0.38	0.41
IIHR 2274		30.53	13.75	22.14	9.09	8.07	8.58	0.47	0.41	0.44
L-10 (P)		27.55	25.05	26.30	7.22	7.01	7.11	0.27	0.21	0.24
L-17		19.47	11.97	15.72	8.23	7.46	7.85	0.64	0.15	0.39
L-28		25.74	22.20	23.97	10.75	9.79	10.27	0.57	0.54	0.55
L-30		26.26	19.08	22.67	8.40	8.30	8.35	0.68	0.22	0.45
L-38-1		25.89	16.13	21.01	8.85	6.03	7.44	0.41	0.40	0.40
L40-3		26.55	20.42	23.48	10.55	9.61	10.08	0.72	0.57	0.65
Panjab Chhauhara		29.05	24.82	26.93	8.06	6.90	7.48	0.71	0.37	0.54
S-22		29.68	26.08	27.88	10.68	7.53	9.11	1.11	0.48	0.80
Mean		26.88	20.18	23.53	9.08	7.63	8.36	0.66	0.38	0.52
Range	Minimum	19.47	11.97	15.72	7.22	6.03	7.11	0.27	0.15	0.24
	Maximum	30.53	26.08	27.88	10.75	9.79	10.27	1.27	0.57	0.86
			CD at 5%			CD at 5%			CD at 5%	
Irrigation (I)			2.12			1.23			0.11	
Genotypes (G)			4.97			NS			0.26	
Interaction (I x G)			NS			NS			0.37	

NS = Non-significant; DAT = Days after transplanting higher in the genotype S-22 and minimum was noticed in the L-17. Among the different irrigation levels, higher photosynthetic rate was observed in the genotype IIHR-2274, S-22 and GK-3 under irrigation schedule of 1.2 IW/CPE and minimum was noticed in the genotype L-17 whereas under sever stress of 0.4 IW/CPE, genotype S-22 and L-10 (P). These results are in conformity with findings of Janoudi and Widders (6) in cucumber, Narender *et al.* (9) in chickpea, Chowdhury and Varma (2) in sweet potato, Pirjo *et al.* (11) in tomato and turnip, Silk and Fock, (14) in tomato, Vyas *et al.* (17) in cluster bean also by Garg *et al.* (4) in moth bean. They reported that, as the stress increased, plants photosynthesis and stomatal conductance also decreased. Under the sever stress, S-22 and L-10 (P) has maintained higher photosynthetic rate due to maintaince of moderately higher RWC (Table 3). Genotypes S-22 maintained higher RWC across the irrigation levels and also at the stress level of 1.2 and 0.4 IW/CPE and minimum was noticed in the genotype L-28. Those genotypes showed better maintenance of higher RWC ensuring better hydration and more favourable internal water relations of tissue with a possibly higher pressure potential and showed better drought tolerance capacity. Similar results were reported earlier by Srinivas and Bhatt (15) in tomato. They stated that tomato plant water potential decreased with the onset of drought, however, some species which maintained higher RWC found to be drought resistance than those with low RWC. Accumulation of polyamines which has association for the better maintenance of turgidity and cell membrane stability by increased levels of spermine as evident from lesser change in RWC under stress. Spermine has been shown to counter the stress induced change in RWC in plant, since spermine enhances ABA levels in stressed plants. Present investigation is also in accordance with earlier findings of Devendra and Minhas (3) in potato, Narender *et al*. (9) in chickpea, Halil *et al*. (5) in eggplant and Upreti and Murti (16) in french bean.

Soil water content either directly or indirectly influence plant growth as well as transpiration rate, since they are mainly trugor depended processes. At the onset of stress extension growth and leaf expansion are first affected, followed by decrease in rate of transpiration due to partial stomatal closer potentially (Halil *et al*. 5). In the present investigation it found that transpiration rate was significantly differed only for irrigation levels (Table 1). Significantly higher transpiration was noticed

Table 2. Effect of temperature on pollen viability of tomato genotypes as influenced by irrigation levels.

Genotypes		Pollen viability (%)								
		Temperature (^oC)								
		25			30			35		
		IW/CPE ratio								
		1.2	0.4	Mean	1.2	0.4	Mean	1.2	0.4	Mean
Arka Meghali		83.20	75.45	79.33	65.50	51.75	58.63	46.95	48.30	47.63
GK-3		64.17	46.70	55.43	81.05	77.30	79.18	50.05	46.55	48.30
IIHR 2274		80.65	67.30	73.98	87.65	76.36	82.01	70.90	40.95	55.93
L-10 (P)		83.25	65.35	74.30	61.15	59.45	60.30	60.35	49.55	54.95
L-17		58.13	48.15	53.14	56.30	41.00	48.65	48.20	40.27	44.23
L-28		60.18	48.10	54.14	55.90	41.50	48.70	43.70	39.50	41.60
L-30		88.90	85.15	87.03	78.95	75.30	77.13	63.50	47.78	55.64
L-38-1		83.90	76.45	80.18	87.65	75.35	81.50	67.30	45.05	56.18
L40-3		76.40	48.30	62.35	66.00	62.90	64.45	64.30	48.28	56.29
Panjab Chhauhara		82.75	76.45	79.60	74.50	72.25	73.38	66.80	44.45	55.63
S-22		90.10	76.85	83.48	67.30	74.20	70.75	57.10	49.61	53.35
Mean		77.42	64.93	71.18	71.09	64.31	67.70	58.10	45.48	51.79
Range	Minimum	58.13	46.70	53.14	55.90	41.00	48.65	43.70	39.50	41.60
	Maximum	90.10	85.15	87.03	87.65	77.30	82.01	70.90	49.61	56.29
			CD at 5%			CD at 5%			CD at 5%	
Irrigation (I)			5.83			5.48			2.86	
Genotypes (G)			13.67			12.86			6.71	
Interaction (I x G)			NS			NS			9.49	

NS= Non- significant.

at 1.2 IW/CPE compared to 0.4 IW/CPE. Irrespective of irrigation levels, genotype L-28 recorded maximum transpiration rate and least was noticed in L-10(P). Genotypes which maintained higher transpiration rate under 0.4 IW/CPE ratio might have less leaf temperature. This may be due to cooling of the leaf surface on account of excessive loss of water through transpiration leading to lesser leaf temperature which helps the plants to tolerate the excessive heat load. Present investigation is in confirmation with the findings of Pirjo *et al*. (11) in tomato and turnip, Halil *et al*. (5) in eggplant and Meenakumari *et al*. (7) in maize

The stomatal conductance decreased drastically under stress. Stomatal conductance was found to be more sensitive to water deficit than the process of water loss and CO_2 exchange themselves, which are regulated by it. Under the stress conditions, photosynthetic rate could be limited by stomatal conductance as well as mesophyll related non stomatal factors in sweet potato (Chowdhury and Varma, 2). In the present investigation it found that, among the genotypes, Arka Meghali maintained higher stomatal conductance. Among the interaction effect of genotypes and irrigation levels, Arka Meghali showed significantly higher stomatal conductance at 1.2 IW/CPE ratio and minimum was observed in L-17 at 0.4 IW/CPE ratio. Under drought stress, stomata are partially closed resulting in limited water loss and photosynthetic rate with restricted diffusion of CO_2 into the leaf, which leads to lower internal CO_2 level and CO_2 deficiency at the reaction site of RuBisCo which might not be the only reason for decline in the photosynthesis. Direct inhibition of biochemical processes by altered ionic or osmotic conditions, which affect ATP synthesis and RuBisCo activity, might be another reason for decrease in photosynthetic rate under drought stress. Present investigation is in conformity with earlier works of Janoudi and Widders (6) in cucumber, Chowdhury and Varm (2) in sweet potato, Pirjo *et al.* (11), Silk and Fock (14) in tomato, Yadav *et al.* (18) in potato and turnip also by Yadav *et al.* (19) in sorghum.

Under the high temperature stress it has two major effects on pollen grains. First it reduced the total number of grains and secondly it leads to a marked reduction in germination and more moderate reduction in pollen viability of the pollen grains (Pressman *et al*., 12). In present study also it indicated at higher temperature stress reduces the pollen viability. Pollen viability studies found significant differences among the genotypes and irrigation levels at temperature treatment of 25, 30 and 35°C, there was significance for interaction only at 35°C

Table 3. Relative water content (per cent RWC) at 75 DAT and yield of tomato genotypes as influenced by irrigation levels.

Genotypes	Yield (kg/plant)			RWC (%)		
	IW/CPE ratio			IW/CPE ratio		
	1.2	0.4	Mean	1.2	0.4	Mean
Arka Meghali	1.24	0.88	1.06	68.17	59.21	63.69
GK-3	1.74	0.98	1.36	58.46	52.44	55.45
IIHR 2274	2.21	1.10	1.65	66.68	42.36	54.52
L-10 (P)	2.04	1.18	1.61	70.31	64.80	67.56
L-17	1.46	0.87	1.17	61.53	54.77	58.15
L-28	0.97	1.01	0.99	51.65	41.75	46.70
L-30	2.13	0.98	1.56	64.65	59.44	62.04
L-38-1	1.26	1.10	1.18	66.64	61.37	64.01
L-40-3	1.45	1.13	1.29	68.09	65.56	66.83
Punjab Chhauhara	1.74	0.59	1.17	55.88	52.97	54.42
S-22	2.09	1.31	1.70	74.45	62.84	68.65
Mean	1.67	1.01	1.34	64.23	56.14	60.18
Range	0.97	0.59	0.99	51.65	41.75	46.70
	2.21	1.31	1.70	74.45	65.56	68.65
		CD at 5%			CD at 5%	
Irrigation (I)		0.10			0.53	
Genotypes (G)		0.23			1.25	
Interaction (I x G)		0.32			1.75	

DAT = Days after transplanting.

(Table 2). Significantly maximum pollen viability was found at 1.2 IW/CPE compare to 0.4 IW/CPE ratio at different temperature regime of 25, 30 and 35^{0}C. As the stress levels increased from 1.2 IW/CPE to 0.4 IW/CPE the pollen viability was reduced to 16.13, 9.54 and 21.74 per cent at 25, 30 and 35^{0}C, respectively. The genotypes, L-30, IIHR 2274 and L-40-3 recorded significantly maximum pollen viability (87.03, 82.01 and 56.29% at 25, 30 and 35^{o}C, respectively) and least pollen viability was recorded in the genotype L-17 (53.14 and 48.65% at 25 and 30^{o}C, respectively) and L-28 at 35^{o}C (41.65%). The present study in conformity with of Ram *et al.* (13), Muthuvel *et al.* (8) and Pressman *et al.* (12) in tomato. They also stated that reduction in viability of pollen grain was associated with variation in carbohydrate status at letter stages of development of the anther and to an even greater extent of pollen grains.

Reduced pollen viability and higher transpiration reduced the yield of tomato per plant (Muthuvel *et al*., 8). In the present investigation it was found that the genotypes L-30, IIHR 2274 and L-40-3 maintained comparable low transpiration rate compared to genotypes L-17 and L-28. Photosynthetic rate of genotype L-30, IIHR 2274 and L-40-3 was maximum (22.67, 22.14 and 23.48 mmole CO_2 m^{-2} s^{-1}, respectively) compared to genotype L-17 and L-28 (17.42 and 21.27 mmole CO_2 m^{-2} s^{-1}, respectively). Due to higher photosynthetic rate, optimum transpiration rate and higher heat tolerance and better water utilization these genotypes L-30, IIHR 2274 and L-40-3 were able to tolerate drought and produce more yield per plant compared to the genotypes L-17 and L-28 (Table 3). Through the correlation study, it also confirmed that there was positive association between the pollen viability under different temperature regimes and yield at water stress of 1.2 IW/CPE and there was positive correlation of pollen viability and higher temperature regime of 30 and 35^{o}C with yield under the sever stress of 0.4 IW/CPE (Table 4).

Table 4. Correlation of yield with pollen viability in various temperature regimes

Temperature (^{o} C)	Correlation co-efficient (r) at different IW/CPE ratio	
	1.2	0.4
25	0.528	-0.037
30	0.385	0.183
35	0.547	0.352

*indicates correlation co-efficient (r) significant at 5 % (0.602) and **indicates correlation co-efficient (r) significant at 1 % (0.735); n=9, Sample size = 11

Hence, considering all the parameters such as pollen viability, biophysical and yield it can be inferred that genotypes GK3, IIHR 2274, L-10 (P), L-30, L-38-1, L-40-3 and S-22 performed better under drought conditions and could be catagorised as drought tolerant genotypes and these genotypes could be grown under rainfed condition compared to genotypes L-17 and L-28 which can be catagorised as drought susceptible ones.

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