BRIEF COMMUNICATION

Tolerance to water stress in tomato cultivars

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Abstract

The effects of plant water stress imposed at vegetative, flowering, and fruiting stages of four cultivars of tomato (*Lycopersicon esculentum* Mill.) on net photosynthetic rate (P_N), stomatal conductance (g_s), transpiration rate (E), osmotic adjustment, and crop water stress index (CWSI) were investigated. Osmotic adjustment was the highest in cv. Arka Meghali, followed by cv. RFS-1. CWSI was lowest in cv. Arka Meghali and highest in cv. Pusa Ruby. Significant reduction in g_s, E, and P_N was observed in all the cultivars. The maximum reduction in E was observed in cv. Arka Saurabh during the fruiting stage (62.4 %) and maximum reduction in P_N at the flowering stage in Pusa Ruby (53.1 %). Maximum P_N was.observed in Arka Meghali under water stress. The values of internal CO_2 concentration (C_i) did not follow the decrease in g_s which might be taken as an indication of mesophyll (non-stomatal) limitation to P_N. Magnitude of P_N decrease accompanying g_s reductions varied in the four cultivars. Arka Meghali which had highest rate of gas exchange efficiency (P_N/g_s) under water deficits can be recommended for rainfed cultivation.

Plant water deficits result in low g_s, P_N, and E of leaves. Osmotic adjustment helps to maintain pressure potential in the cells and this allows leaf extension and photosynthesis to continue under stress (Morgan 1984). Continued growth through osmotic adjustment may be advantageous, particularly during intermittent drought in which there is a high probability of rainfall breaking the drought (Ludlow and Muchow 1990). Tomato production as compared to other vegetables has always been associated with abundance of water. Tomato is very sensitive to water stress (Waister and Hudson 1970), the most sensitive being the stages of flowering and fruit enlargement (Huang 1978). Srinivasa Rao and Bhatt (1992) have reported genotypic differences in osmotic adjustment among tomato cultivars. The objective of our study was to investigate the effects of plant water stress at different growth stages on P_N, g_s, osmotic adjustment, and crop water stress index in four tomato cultivars.

Seedlings of *Lycopersicon esculentum* (L.) Mill. cultivars Pusa Ruby, Arka Saurabh, Rainfed Selection-1 (RFS-1), and Arka Meghali were raised in a nursery and four-week-old seedlings were transplanted in the field in a split plot design with four replications during the winter seasons of 1995 and 1996. Water stress treatments were given at vegetative (plant age 30 d), flowering (50 d), and fruiting (65 d) stages for four weeks by withholding irrigation. Osmotic potential (ψ_s) was recorded with a *Wescor 5100C* Vapour Pressure Osmometer at 10:00. Osmotic adjustment was calculated as the difference in ψ_s at full pressure potential between stress and control treatments (Blum 1989). The g_s, E, C_i, and P_N were measured using *LCA-3* portable photosynthetic system (*Analytical Development Corporation*, UK). The irradiance varied from 900 to 1650 μmol m^{-2} s^{-1} (PAR) and CO_2 concentration was 350 cm^3 m^{-3} under natural environmental conditions. Crop canopy air temperature difference (CCATD) was recorded using hand-held *Instatherm* infra-red thermometer. Crop water stress index (CWSI) was recorded directly using *A G Multimeter* (*Everest*, U.S.A.) model *510B* calculated from CCATD and vapour pressure difference (VPD) values. These observations were recorded between 10:00 and 12:00. As the results of both the years were similar, average values were taken and compared for significance at both 0.05 and 0.01 levels of probability. Linear correlation analyses were performed to determine relationship between different parameters recorded.

Osmotic potential (ψ_s) was more negative in cv. Arka Meghali at the end of four-week water stress at all the growth stages than in other cultivars and the lowest

Received 6 January 2000, *accepted* 19 April 2000.
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Contribution No.107/99 of I.I.H.R. Bangalore.
Acknowledgments: The authors are grateful to Mr. A.D.D.V. Nageshwara Rao and Mr. C. Muniraju for technical help.

Table 1. Effect of water stress on net photosynthetic rate (P_N) [μmol(CO_2) m^{-2} s^{-1}], transpiration rate (E) [mol(H_2O) m^{-2} s^{-1}], stomatal conductance (g_s) [mol m^{-2} s^{-1}], osmotic potential (ψ_s) [-MPa], internal CO_2 concentration (C_i) [μmol mol^{-1}], and crop water stress index (*CWSI*) of tomato cultivars at different stages of growth after 4 weeks of stress. Mean values ($n = 8$) in a row followed by a different letter for each cultivar are significantly different ($p = 0.05$) according to Duncan's multiple range (DMR) test. cv = cultivars, tr = treatment, s = stages, int = interaction.

	Cv.	Growth stages Vegetative Stress	 Irrigated	 Flowering Stress	 Irrigated	 Fruting Stress	 Irrigated		SE	CD 5 %	CD 1 %
P_N	Arka Saurabh	8.5^{b}	11.7^{b}	5.7^{b}	9.7^{b}	6.3^{b}	9.9^{b}	cv	0.17	0.48	0.63
	Pusa Ruby	6.7^{b}	11.0^{b}	4.6^{b}	9.8^{b}	6.3^{b}	11.4^{b}	tr	0.12	0.34	0.45
	RFS – 1	10.6^{c}	15.0^{c}	8.0^{c}	11.2^{b}	9.5^{b}	12.3^{c}	s	0.15	0.42	0.55
	Arka Meghali	14.9^{d}	17.2^{d}	11.2^{d}	14.1^{c}	12.0^{c}	15.2^{d}	int	0.42	1.18	1.54
E	Arka Saurabh	6.2^{b}	10.7^{b}	4.3^{b}	9.2^{b}	3.2^{b}	8.5^{b}	cv	0.17	0.49	0.65
	Pusa Ruby	6.8^{b}	9.8^{b}	6.4^{b}	11.9^{b}	6.25^{b}	12.2^{b}	tr	0.15	0.43	0.56
	RFS – 1	11.8^{d}	14.0^{c}	7.2^{c}	11.3^{b}	8.5^{c}	14.8^{d}	s	0.12	0.35	0.46
	Arka Meghali	9.2^{c}	14.0^{c}	8.4^{d}	11.5^{b}	8.6^{c}	13.3^{c}	int	0.43	1.21	1.58
g_s	Arka Saurabh	0.51^{b}	0.89^{b}	0.35^{b}	0.76^{b}	0.11^{b}	0.74^{b}	cv	0.02	0.07	0.09
	Pusa Ruby	0.65^{b}	1.68^{b}	0.19^{b}	0.78^{b}	0.13^{b}	0.89^{b}	tr	0.02	0.06	0.08
	RFS – 1	1.10^{c}	1.61^{c}	0.56^{c}	1.28^{b}	0.58^{b}	1.15^{c}	s	0.02	0.05	0.06
	Arka Meghali	1.02^{d}	1.56^{c}	0.85^{d}	1.30^{b}	0.72^{c}	1.37^{d}	int	0.06	0.17	0.22
ψ_s	Arka Saurabh	1.04^{b}	0.93^{b}	1.26^{b}	0.96^{b}	1.49^{b}	1.21^{b}	cv	0.03	0.07	0.10
	Pusa Ruby	0.89^{b}	0.87^{b}	1.16^{a}	1.12^{b}	1.31^{b}	1.15^{b}	tr	0.02	0.06	0.08
	RFS – 1	1.14^{c}	1.02^{b}	1.65^{c}	1.13^{c}	1.54^{c}	1.06^{b}	s	0.02	0.05	0.07
	Arka Meghali	1.45^{d}	1.06^{b}	2.15^{d}	1.09^{c}	1.59^{c}	1.09^{b}	int	0.06	0.18	0.24
C_i	Arka Saurabh	264^{a}	292^{c}	276^{b}	291^{c}	265^{b}	293^{c}	cv	2.48	7.01	9.18
	Pusa Ruby	270^{a}	269^{b}	278^{b}	283^{b}	270^{b}	284^{b}	tr	1.75	4.95	6.49
	RFS – 1	267^{a}	257^{a}	254^{a}	268^{a}	255^{a}	261^{a}	s	2.14	6.07	7.95
	Arka Meghali	268^{a}	251^{a}	258^{a}	263^{a}	260^{a}	261^{a}	int	6.08	17.16	22.49
CWSI	Arka Saurabh	0.842^{b}	0.584^{c}	0.831^{c}	0.598^{c}	0.814^{b}	0.603^{c}	cv	0.008	0.022	0.029
	Pusa Ruby	0.912^{d}	0.596^{d}	0.878^{d}	0.616^{d}	0.930^{d}	0.628^{d}	tr	0.007	0.015	0.021
	RFS – 1	0.885^{c}	0.421^{b}	0.824^{b}	0.396^{b}	0.862^{c}	0.414^{b}	s	0.006	0.019	0.025
	Arka Meghali	0.785^{a}	0.162^{a}	0.766^{a}	0.249^{a}	0.762^{a}	0.306^{a}	int	0.019	0.054	0.072

values were at the flowering stage (Table 1). Osmotic adjustment was the highest (1.06 MPa) in Arka Meghali during the flowering stage, followed by RFS-1 (0.52 MPa). Much lower osmotic adjustment of 0.13 MPa was observed by Torrecillas *et al.* (1995) in tomato subjected to water stress for only 7 d. Our results support the observations of Morgan (1984) that water stress induced osmotic adjustment differences among the cultivars may be an important attribute of drought resistance in tomato.

CCATD values were negative during the flowering and fruiting stages after 9 d of water stress in Arka Meghali and after 15 d in RFS-1 indicating that plants of these cultivars are cooler under water stress than those of other cultivars. CWSI was low in Arka Meghali at all the growth stages and highest in Pusa Ruby (Table 1). Plant canopy temperature is an indicator of crop water stress. Monitoring canopy temperature by infra-red thermometry provides valuable information in the periods during which plants are stressed for water.

Significant reduction in E due to water stress was observed at all growth stages in all the cultivars (Table 1). Maximum reduction in E was observed in Arka Saurabh during the fruiting stage (62.4 %). E was comparatively higher in the stressed plants of Arka Meghali at the flowering and fruiting stages, compared to other cultivars, which might be the reason for negative values of CCATD. Values of g_s were also higher in Arka Meghali than in other cultivars under water stress at all the growth stages (Table 1).

There was a decrease in P_N following the decrease in soil water availability in all the cultivars (Table 1). Maximum P_N was observed in Arka Meghali under water stress. The reduction in P_N was only 13.4, 20.6, and 21.1 % at the vegetative, flowering, and fruiting stages, respectively. Reduction at the flowering stage in Pusa Ruby was maximum (53.1 %) compared to other cultivars. Positive correlations between g_s and P_N or E were found. Correlations between E and P_N, ψ_s and P_N, and g_s and ψ_s were non-significant. This confirmed the relationship between P_N and g_s under drought. Srinivasa Rao and Bhatt (1998) have showed genotypic variation in the P_N per unit g_s for tomato. Krieg (1983) and Radin *et* *al.* (1988) have proposed this as a screening tool for gas exchange efficiency. Magnitude of P_N decrease accompanying g_s reductions varied in the four cultivars. Cv. Arka Meghali, which had higher rate of P_N without much reduction in g_s, had higher gas exchange efficiency under water deficits and thus can be recommended for rainfed cultivation.

The values of C_i did not follow the decrease in g_s. With the increase in water stress C_i increased. The occurrence of high C_i at low stomatal aperture under water stress indicates mesophyll (non-stomatal) limitation to P_N (Ephrath *et al.* 1990). However, non-uniform stomatal closure under short-term water stress could affect C_i calculation (Mansfield *et al.* 1990, Cornic and Briantais 1991, Luo 1991) supporting mesophyll limitation to photosynthesis.

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