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Effect of soil moisture stress on physiological response in grape (*Vitis vinifera* L.) varieties

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ABSTRACT

Four varieties of grape namely Flame Seedless, Thompson Seedless, Sharad Seedless and Tas-A-Ganesh were subjected to different levels of moisture stress to study their physiological response. Stress was imposed for 14 days by withholding irrigation. Observations on relative water content, leaf water potential, leaf osmotic potential and gas exchange parameters like photosynthetic rate, transpiration rate, stomatal conductance and water use efficiency (WUE) were recorded. None of the varieties could survive for 14 days without irrigation (100% stress). Flame Seedless and Thompson Seedless at 50% moisture stress maintained higher turgidity as indicated by lesser reduction in relative water content and water potential attributed to better osmotic adjustment. Marginal reduction in photosynthesis and greater reduction in transpiration rate in the variety Flame Seedless may have resulted in higher WUE under moisture stress. Higher photosynthetic rate, lower transpiration rate, higher water relation parameters and high WUE in Flame Seedless under soil moisture stress indicated its better tolerance to drought.

Key words: Grape varieties, soil moisture stress, water potential, water use efficiency

INTRODUCTION

Grape is an important fruit crop in India, cultivated in an area of about 60, 000 ha across the country. Major grape growing areas are concentrated in Maharashtra, Andhra Pradesh, and Karnataka regions. The major constraints in these dry regions are water scarcity and soil salinity. Severe drought results in plant water deficit that reduces cell turgor causing stomatal closure and reduction in cell enlargement, thus, reducing both leaf surface and photosynthesis per unit area. Among the several adaptive strategies, increasing the efficiency of water use for biomass production is perhaps the most relevant mechanism in drought tolerance (Lincoln and Eduardo, 2002). Though the use of rootstocks to combat adverse effects of soil and water salinity is a common practice in major grape growing regions of the country, raising vineyards their on own roots in commercial varieties, where assured source of irrigation water and excellent soil condition exist, is in practice in some regions. Hence, it was considered appropriate to screen grape genotypes for drought tolerance taking into account physiological aspects like photosynthesis rate, transpiration rate, water use efficiency (WUE), stomatal conductance, relative water content (RWC), etc. at different levels of soil moisture stress.

MATERIAL AND METHODS

Experiments were conducted at the experimental plots of Indian Institute of Horticultural Research, Bangalore, under open conditions. Rooted cuttings of four grape genotypes, viz., Flame Seedless, Thompson Seedless, Sharad Seedless (selection from Kishmish chernyi) and Tas-A-Ganesh (selection from Thompson Seedless) were transplanted into pots of 14" diameter filled with standard potting mixture consisting of farm yard manure (FYM), red earth and sand (1:2:1). The potting mixture was porous with water holding capacity of 30%. Plants were subjected to uniform cultural practices like irrigation, fertilizer application, weeding and plant protection measures for six months. At six months, the plants were irrigated to field capacity before imposing soil moisture stress. In order to calculate field capacity, pots filled with a known volume of potting mixture were placed in large plastic buckets and irrigated with a known quantity of water and left to stand for six hours to attain field capacity. At six hours, the volume of water drained into the plastic bucket was measured and subtracted from the total amount of water applied. The difference in volume was treated as the quantum of irrigation water needed to be applied to attain field capacity

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Table 1. Influence of moisture stress on relative water content (RWC, %) in grape varieties

Variety (V)	Days after initiation of stress cycle at different levels of stress (S)								
	4th day			9th day			14th day		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
Flame Seedless	90.96	82.54	76.73	90.27	81.27	*	87.36	71.94	*
Thompson Seedless	88.74	83.74	76.87	88.26	81.27	*	87.39	71.17	*
Sharad Seedless	87.01	75.70	62.97	87.59	71.63	*	81.98	67.04	*
Tas-A-Ganesh	79.86	70.74	55.24	78.61	65.97	*	80.25	61.64	*
	V	S	VxS	V	S	VxS	V	S	VxS
S Em ±	1.293	1.113	2.231	0.956	0.676	1.356	1.681	5.041	6.954
C.D *(P=0.05)*	3.772	3.267	6.532	5.867	2.027	4.054	5.041	3.564	NS

S1: Control (100% irrigation); S2: 50% stress (50% irrigation); S3: 100% stress (no irrigation)

(100% irrigation). Half the amount of this was considered as 50% irrigation. One set of plants was maintained without irrigation (0% irrigation i.e.,, 100% moisture stem). The above treatments were applied for 14 days and periodic observations recorded for various physiological parameters on the 4th, 9th and 14th day of the stress cycle. Irrigation was done manually.

Relative water content was determined as per the procedure of Barrs and Weatherly (1962), leaf water potential was measured using water potential system CR-7, Campbell Scientific Inc, USA, and leaf osmotic potential was measured using vapor pressure osmometer model 5100 C, Wescor. Gas exchange parameters, namely, photosynthetic rate (Pn), transpiration rate (E) and stomatal conductance (gs) were measured using portable, open photosynthesis system (Model LCA-3, ADC, UK). Water use efficiency at the single leaf level (A/E) was calculated using photosynthesis and transpiration rate values. Data were computed for statistical analysis taking three replications for each measurement.

RESULTS AND DISCUSSION

Relative water content (RWC) of leaves under controlled conditions (100% irrigation) varied from 90.96 to 79.86% among the varieties on 4th day of stress cycle, while under 50% and 100% moisture stress, it ranged from 83.74 to 79.74% and 76.87 to 52.24%, respectively. Considerable reduction in RWC was observed among the varieties at 50% stress. ‘Flame Seedless’ and ‘Thompson Seedless’ maintained a higher RWC of 71% at the end of the stress cycle at 50% moisture stress (Table 1). Water potential varied significantly among the varieties (Table 2). At 50% moisture stress, the water potential ranged from –1.66 to –1.99 Mpa on the 4th day of stress cycle. As the moisture stress progressed, there was a pronounced decrease

Table 2. Influence of moisture stress on leaf water potential (-MPa) and leaf osmotic potential (-MPa) in grape varieties

Variety (V)	Days after initiation of stress cycle at different levels of stress (S)								
	4th day			9th day			14th day		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
	Leaf water potential (-MPa)								
Flame Seedless	1.20	1.30	1.66	1.21	1.32	*	1.15	1.31	*
Thompson Seedless	1.34	1.45	1.99	1.38	1.51	*	1.21	1.48	*
Sharad Seedless	1.45	1.51	1.81	1.21	1.29	*	1.28	1.51	*
Tas-A-Ganesh	1.21	1.66	1.85	1.30	1.67	*	1.23	1.64	*
	V	S	VxS	V	S	VxS	V	S	VxS
S Em ±	0.009	0.008	0.166	0.221	0.106	0.323	0.240	0.169	0.332
C.D *(P=0.05)*	NS	0.203	NS	NS	NS	NS	NS	NS	NS
	Leaf osmotic potential (-Mpa)								
Flame Seedless	1.16	1.23	1.66	0.97	1.30	*	1.48	1.38	*
Thompson Seedless	1.30	1.23	1.67	1.47	1.35	*	1.76	1.48	*
Sharad Seedless	1.06	1.29	1.53	1.19	1.49	*	1.38	1.81	*
Tas-A-Ganesh	1.13	1.46	1.75	1.31	1.59	*	1.25	1.90	*
	V	S	VxS	V	S	VxS	V	S	VxS
S Em ±	0.209	0.002	0.005	0.005	0.003	0.007	0.007	0.050	0.103
C.D *(P=0.05)*	0.008	0.075	0.450	0.163	0.115	0.230	0.218	0.514	NS

S1: Control (100% irrigation); S2: 50% stress (50% irrigation); S3: 100% stress (no irrigation)
Plants died and observations were not recorded

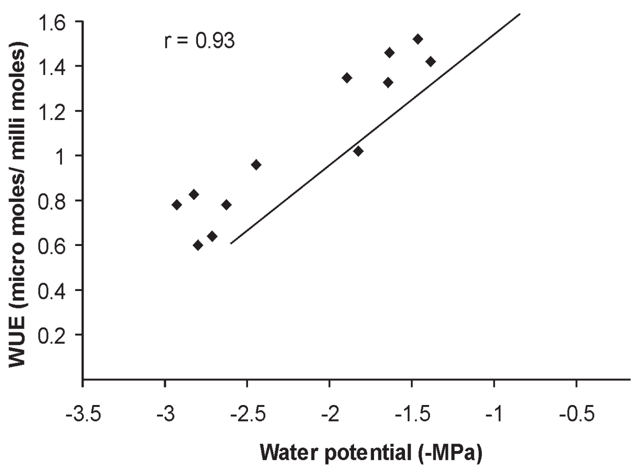

Fig 1. Relation between water potential (-MPa) and WUE (µ mole / m mole) in grape varieties under 50% moisture stress

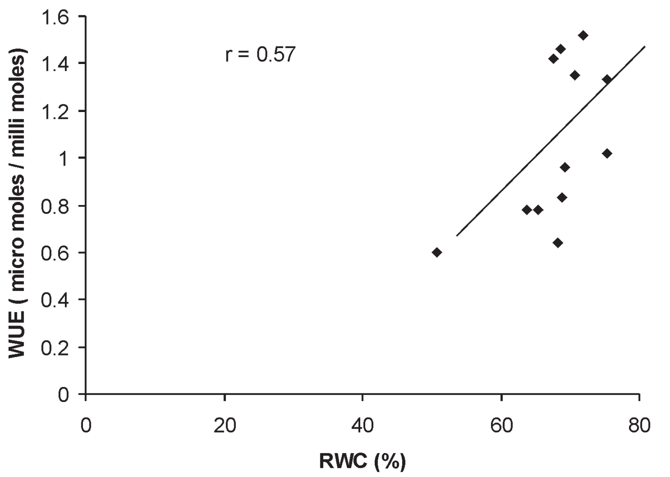

Fig 2. Relation between WUE (µ mole / m mole) and RWC (%) in grape varieties under 50% moisture stress

in water potential among the varieties. 'Flame Seedless' recorded maximum leaf water potential of –1.31 Mpa at the end of the stress cycle at 50% moisture stress, while, in Tas-A-Ganesh recorded the least (-1.64 Mpa). Similarly, considerable reduction in leaf osmotic potential was also such among the varieties as stress progressed. On the 4th day of stress cycle, at no stress, osmotic potential ranged from –1.06 to –1.30 Mpa, while, at 50% stress it ranged from –1.53 to –1.75 Mpa. On both the 9th and 14th day of stress cycle, 'Flame Seedless' and 'Thompson Seedless' recorded maximum osmotic potential at 50% moisture stress (Table 2).

None of the varieties survived 14 days without irrigation (100% stress). The RWC data for all the varieties indicated that varieties Flame Seedless and Thompson Seedless maintained higher RWC at 50% moisture stress until the 14th day. This indicated their capacity to maintain turgidity even under stress. Lowering of leaf osmotic potential in response to soil moistures stress may help maintain the required water relations (During, 1985). In the present study, strong positive correlation was observed between water potential and water use efficiency (r = 0.93) under 50% moisture stress on the 14th day of stress cycle (Fig 1). This relationship suggests that water potential of the tissue during stress period a better indicator of its water

Table 3. Photosynthetic rate and transpiration rate of grape varieties at different levels of moisture stress

Variety (V)	Days after initiation of stress cycle at different levels of stress (S)								
	4th day			9th day			14th day		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
	Photosynthetic rate (m moles/m^2/sec)								
Flame Seedless	9.26	8.16	1.00	8.90	7.60	*	10.00	9.10	*
Thompson Seedless	8.86	8.23	1.13	9.33	8.20	*	9.63	8.00	*
Sharad Seedless	9.20	7.56	*	7.86	7.53	*	7.50	7.06	*
Tas-A-Ganesh	7.63	5.70	*	7.80	6.66	*	7.83	5.73	*
	V	S	VxS	V	S	VxS	V	S	VxS
S Em ±	0.365	0.316	0.632	0.238	0.696	0.943	0.348	0.302	0.604
C.D *(P=0.05)*	1.060	0.923	NS	0.696	0.602	NS	1.080	1.380	NS
	Transpiration rate (m moles /m^2/sec)								
Flame Seedless	9.60	8.06	7.23	10.40	7.73	*	10.50	6.90	*
Thompson Seedless	9.60	8.63	7.16	10.16	8.23	*	10.40	7.80	*
Sharad Seedless	11.80	10.00	*	10.06	9.03	*	10.33	8.90	*
Tas-A-Ganesh	12.26	9.63	*	11.10	9.59	*	10.76	9.50	*
	V	S	VxS	V	S	VxS	V	S	VxS
S Em ±	0.162	0.140	0.281	0.128	0.111	0.223	0.123	0.110	0.220
C.D *(P=0.05)*	0.474	0.410	0.821	0.376	0.325	0.651	0.371	0.321	0.643

S1: Control (100% irrigation); S2: 50% stress (50% irrigation); S3: 100% stress (no irrigation)
Plants died and observations were not recorded

Table 4. Stomatal conductance and instantaneous water use efficiency of grape varieties at different levels of moisture stress

Variety (V)	Days after initiation of stress cycle at different levels of stress (S)								
	4th day			9th day			14th day		
	S1	S2	S3	S1	S2	S3	S1	S2	S3
Stomatal conductance (ì moles/m²/sec)									
Flame Seedless	0.59	0.37	0.19	0.54	0.34	*	0.57	0.41	*
Thompson Seedless	0.50	0.42	0.19	0.50	0.42	*	0.52	0.40	*
Sharad Seedless	0.62	0.46	*	0.53	0.47	*	0.42	0.39	*
Tas-A-Ganesh	0.55	0.41	*	0.43	0.39	*	0.43	0.36	*
	V	S	VxS	V	S	VxS	V	S	VxS
S Em ±	0.003	0.002	0.052	0.013	0.018	0.023	0.014	0.012	0.025
C.D *(P=0.05)*	NS	0.076	0.014	0.013	0.034	0.069	0.042	0.037	0.074
Instantaneous water use efficiency (ì mole / m mole)									
Flame Seedless	0.96	1.01	0.13	0.84	0.98	*	0.96	1.33	*
Thompson Seedless	0.92	0.97	0.15	0.91	0.99	*	0.91	1.02	*
Sharad Seedless	0.77	0.75	*	0.77	0.52	*	0.72	0.78	*
Tas-A-Ganesh	0.61	0.59	*	0.70	0.69	*	0.72	0.60	*
	V	S	VxS	V	S	VxS	V	S	VxS
S Em ±	0.003	0.030	0.060	0.042	0.036	0.072	0.046	0.039	0.079
C.D *(P=0.05)*	0.108	0.008	NS	0.121	0.105	0.210	0.134	0.116	0.232

S1: Control (100% irrigation); S2: 50% stress (50% irrigation); S3: 100% stress (no irrigation)
Plants died and observations were not recorded

status than RWC, as, the correlation coefficient of RWC and WUE is 0.58 even though the relation between the two parameters is of a positive nature (Fig 2). The reduction in osmotic potential indicates osmotic adjustment and the varies from variety to variety. Zhang and Archbold (1993) also reported maintenance of higher turgor potential and lower osmotic potential in stressed plants of *Fragaria chiloensis* than in non-stressed plants, but no such reduction was reported in *F. verginiana,* suggesting cultivar difference in osmotic adjustment. Osmotic adjustment was better in 'Flame Seedless' and 'Thompson Seedless' than in 'Sharad Seedless' and 'Tas-A-Ganesh' as indicated by leaf water potential. Increased osmotic adjustment has been attributed to increased sugar and other compatible solutes (Rodrigues *et al,* 1993). In the present investigation, it was observed that the increased osmotic adjustment in 'Flame Seedless' could be due to a high potassium content in this variety (data not shown) as it is an effective inorganic osmolyte. Morgan *et al* (1977) also reported that the spectrum and relative contribution of different solutes to osmotic adjustment varied with plant species and leaf age. Turgid leaves with high moisture could have helped in normal functioning of 'Flame Seedless' and 'Thompson Seedless' under moisture stress.

Photosynthetic rate, stomatal conductance, transpiration rate and instantaneous WUE recorded significant difference among the varieties and in stress levels on all days of the stress cycle (Table 3 and 4). Both 'Sharad Seedless' and 'Tas-A-Ganesh' did not show any photosynthetic activity on the 4th day of stress cycle at 100 % stress. On the 14th day of stress cycle, maximum reduction in photosynthesis was recorded in 'Tas-A-Ganesh' from non-stress to stress conditions. Among the varieties, Flame Seedless recorded maximum photosynthesis of 9.10 mmole / m²/sec at 50% moisture stress. Considerable reduction in transpiration rate was recorded on the 14th day of stress cycle from non-stress to 100% stress conditions. On the 14th day of stress cycle, reduction in transpiration rate was higher in 'Flame Seedless' and 'Thompson Seedless' and was least in 'Tas-A-Ganesh'. Though there was considerable reduction in stomatal conductance with increased soil moisture stress among varieties, 'Flame Seedless' maintained the highest stomatal conductance of 0.41 mmole / m²/sec at 50% moisture stress on the 14th day and it was least in 'Tas-A-Ganesh' (0.36 mmole / m²/sec).

Water use efficiency increased with increased soil moisture stress on 9th and 14th day of the stress cycle in all the varieties. But, on 4th day of the stress cycle, there was reduction in WUE at 100% stress compared to 50% stress. 'Flame Seedless' recorded maximum WUE on 9th and 14th day of the stress cycle at 50% stress, while, it was least in 'Tas-A- Ganesh'.

The marginal reduction recorded in photosynthesis and greater reduction in transpiration rate may be due to reduced stomatal conductance under moisture stress conditions. Lakso (1985) also reported marginal reduction in photosynthesis and maximum reduction in transpiration in stressed grapevines. Maintenance of high WUE under moisture stress in 'Flame Seedless' and 'Thompson Seedless' indicated higher reduction in transpiration and maintenance of photosynthesis even under moisture stress. Studies on photosynthesis under drought conditions in field-grown grapes by Flexas *et al* (1998) revealed no photo-inhibition even when stomatal conductance was reduced. The increased WUE in these two varieties may be due to larger reduction in transpiration rate and marginal reduction in photosynthesis. This also confirms the findings of Allweldt and Ruhl (1982) who observed 33-48% reduction in photosynthesis and 45-57% reduction in transpiration rate under stress conditions. Similar increase in WUE at decreased water potential was reported by Behaboudian *et al (*1986) in pistachio varieties. The increased photosynthetic rate in Flame Seedless at 50% moisture stress may be due also to increased chlorophyll content (data not shown) in this variety which might have absorbed large spectrum of sunlight to carry out photosynthesis. Maintenance of marginal reduction in photosynthesis, lower transpiration rate, better water relations and increased WUE suggests the distinction and differential sensitivity levels among varieties under moisture stress.

Finally, it is concluded that a slight reduction in photosynthetic rate, lower transpiration rate and better water relation in terms of water potential and osmotic adjustment under mild water stress in the varieties Flame Seedless and Thompson Seedless suggests their uniqueness and differential sensitivity to soil moisture stress. The other two varieties, viz., Sharad Seedless and Tas-A-Ganesh, both being clonal selections (mutants) from 'Kishmish chernyi' and 'Thompson Seedless' respectively did not respond positively under moisture stress conditions.

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