J. Hort. Sci.
Vol. 1 (1): 19-23, 2006

Response of grape rootstocks to soil moisture stress

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ABSTRACT

Studies on root and shoot morphology, endogenous hormones and water use efficiency in five grape rootstocks namely Dogridge, 1613 C, Salt Creek, St. George and *Vitis champinii* clone (VC Clone) at three levels of moisture stress viz., no stress (100% irrigation), 50% stress (50% irrigation) and 100% stress (without irrigation) for 14 days revealed that Dogridge and Salt Creek rootstocks maintained the highest ratios of root to shoot length and root to shoot dry weight as compared to other rootstocks. Water use efficiency increased with increased soil moisture stress and was the highest in Dogridge and Salt Creek. The abscisic acid content in the leaves of Dogridge was maximum at 50% stress followed by that of Salt Creek. Similarly the cytokinin content (both t-ZR and DHZR) was minimum in Dogridge and Salt Creek at 50% stress while it was maximum in 1613 C and St.George. The root to shoot length ratio was positively correlated with ABA content under moisture stress conditions. The higher levels of abscisic acid content in Dogridge and Salt Creek under soil moisture stress suggested their better drought tolerance capacity through a reduction of stomatal conductance and increased water use efficiency.

Key words: ABA, cytokinins, grape rootstocks, root to shoot length ratio, root to shoot dry weight ratio, water use efficiency

INTRODUCTION

In India, use of rootstocks in viticulture is gaining importance as grape is cultivated predominantly under arid and semi arid regions. Rootstocks are known for their deep root system to exploit water from deeper layers of soil and also have selective absorption capacity of mineral elements to restrict toxic elements in saline soils. Among the several adaptive strategies, improving water use efficiency is perhaps the most relevant mechanism in drought tolerance (Lincoln and Eduardo, 2002). Another important adaptation to moisture stress is that root growth is generally less inhibited than shoot growth. This characteristic is thought to be adaptive, wherein roots continue to explore soil for water while inhibition of shoot growth together with stomatal closure restricts transpiration. Abscisic acid (ABA) is mostly synthesized in root system and translocated into leaves during moisture stress to close stomata and maintain relative water content in the plant system. The ability to synthesize ABA is specific to variety. Rootstocks are known to influence the physiological and biochemical processes of scions after budding or grafting (Hartmann and Kester, 1976). This investigation aims to study the levels of endogenous ABA and cytokinin levels in the leaves of commonly employed rootstocks, their root and shoot growth patterns under varying levels of soil moisture stress with the ultimate objective of identifying the drought tolerant rootstocks in terms of increased water use efficiency by production of more ABA and increased root growth.

MATERIAL AND METHODS

Experiments were conducted at the research farm of Indian Institute of Horticultural Research, Hessaraghatta, Bangalore, India during October-May, 2002-03. The experimental site is situated at 14^0N latitude and 77^0E latitude. It is in the elevated plain at an altitude of 863 m above the mean sea level. The climate is mild and slightly humid. maximum and minimum temperatures were between 30-34.5 ^{0}C and 18-21 ^{0}C respectively; the relative humidity was 65-70% in the morning hour (8 A.M) and 30-35% during afternoon (1 P.M), while the evaporation rate ranged between 6.25 to 8.3 mm during the experimental period.

Rooted cuttings of five grape rootstocks namely; Dogridge, 1613 C, Salt Creek, St. George and V C clone from the nursery beds were transplanted to 14" cement pots containing 20 kg potting mixture of red sandy loam soil, farm yard manure and sand (2:1:1). The water holding

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capacity of the potting mixture was 30%. The plants, when attained the age of six months, were subjected to two levels of moisture stress *viz.*, 50% stress and 100% stress and a check was maintained with 100% irrigation (no stress). The period of stress was 14 days. Plants were irrigated manually with 1.5 l of water for control (no stress), 0.75 l for 50% stress and 100% stress treatment received no irrigation of water. The experiment was designed in factorial randomized design with three replications consisting of two factors *viz.*, irrigation levels and grape rootstocks. Each replication consisted of 10 vines.

Observations were recorded on gas exchange parameters using portable photosynthesis system (Model 6200, LiCor, USA). Water use efficiency (WUE) was derived from photosynthesis rate and transpiration rate. Fully developed immature leaves were collected in icebox and washed in distilled water; 10 g leaf tissue was ground in 80% methanol and filtered using Whatman filter paper. Residue was incubated overnight with 80% methanol, filtered, filtrates were pooled and dried using rotary flash evaporator at 35 ^{0}C under vacuum and the residue was dissolved in distilled water. The water extract was partitioned thrice against di-ethyl ether after adjusting pH to 3.0 with 0.1 N HCl. The ether fraction was dried in the flash evaporator at 35 ^{0}C and the residue was dissolved in 5ml tris buffer (20 mM, pH 7.4) for ABA estimation. Aqueous phase was partitioned with water saturated n-butanol at pH of 8.0. The butanol fraction was dried under reduced pressure at 35 ^{0}C in the flash evaporator and the residue was dissolved in 5ml tris buffer (20 mM, pH 7.4) for estimation of cytokinins like, zeatin riboside (ZR) and dihydro zeatin riboside (DHZR). ELISA technique was used to quantify ABA (Weiler, 1982) and Cytokinins (Barthe and Stewart, 1985) employing laboratory raised polyclonal antibodies. The quantity of hormones was expressed as ng/g fresh weight of the tissue.

Statistical analysis was performed following Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Gas exchange parameters

Photosynthetic rate in all the rootstocks reduced from fully irrigated control to 50 % stress. None of the rootstocks could survive for 14 days without irrigation (100% stress). Dogridge rootstock maintained higher photosynthesis on 14th day of stress at 50 % stress. Drastic reduction in transpiration rate was recorded on 14th day of stress cycle in all the rootstocks. Dogridge and Salt Creek maintained lower transpiration rate among the rootstocks. Water use efficiency increased from control to 50% stress in all the rootstocks, highest being in Dogridge. Similar results were also reported by Allweldt and Ruht (1982) in grapevines with marginal reduction in photosynthesis and greater reduction in transpiration under moisture stress conditions. Prakash *et al* (2001) also observed reduction in photosynthesis and transpiration rate of grape rootstocks with increased soil moisture stress. Maintenance of high photosynthetic rate and decreased transpiration rate under 50% moisture stress could have contributed for the increased WUE in the rootstocks, Dogridge and Salt Creek.

Endogenous Hormones

Significant differences in hormonal content of rootstocks at all stress levels were observed. ABA content of all the rootstocks increased with increased soil moisture stress. At 50% moisture stress, Dogridge recorded maximum ABA content followed by Salt Creek, while it was least in 1613 C and St. George. Simultaneously, there was a reduction in t-ZR content in all the rootstocks with increased moisture stress. But DHAR content decreased in all the rootstocks except in Dogridge and St. George. Among the rootstocks, 1613 C had the highest cytokinin content at 50% stress, while it was least in Dogridge and Salt Creek. Reynolds and Naylor (1994) and Schultz (1998) also reported such increases in ABA: cytokinin ratio and decreased stomatal conductance when grape vine Pinot Noir and Reisling were subjected to moisture stress. The variation in ABA levels among the rootstocks may be a varietal behaviour as suggested by Regina and Carbonneau, (1997). In spite of the high ABA content in Dogridge leaves, there was higher photosynthesis and lower transpiration rate, which might be due to relatively higher stomatal conductance in this rootstock under moistures stress revealing its drought tolerance.

Morphological parameters

As the soil moisture stress increased, root length increased among grape rootstocks with a concurrent reduction in total shoot length. The total root length was maximum in Dogridge followed by Salt Creek and both recorded lowest shoot length. The root to shoot length ratio was maximum in Dogridge (3.50) and was minimum in St. George (1.37). Similarly, there was an increase in total root dry matter and decrease in shoot dry mass with increased soil moisture stress. The root to shoot dry weight ratio was maximum in Dogridge (2.01) followed by Salt Creek (1.38) and was least in St. George (1.10). Increase in ABA content of drying roots combined with availability of water drawn

Table 1. Influence of moisture stress on gas exchange parameters in grape rootstocks

Rootstock	Rate of photosynthesis (μ mol CO_2 / m^2 /sec)				Transpiration rate (μ mol H_2O / m^2 /sec)				Stomatal Conductance (μ mol CO_2 / m^2 /sec)				Water use efficiency (μ mol CO_2 / m mol H_2O)			
	0 day	14th day			0 day	14th day			0 day	14th day			0 day	14th day		
		S1	S2	S3		S1	S2	S3		S1	S2	S3		S1	S2	S3
Dogridge	13.70	8.30	9.36	*	9.06	9.76	7.06	*	0.82	0.53	0.35	*	1.50	0.84	1.31	*
1613 C	8.33	5.70	4.83	*	7.80	9.46	8.33	*	0.38	0.44	0.36	*	1.05	0.60	0.58	*
Salt Creek	11.20	6.80	9.23	*	9.33	9.76	7.63	*	0.62	0.58	0.39	*	1.19	0.69	1.21	*
St. George	11.10	10.60	7.20	*	9.43	10.33	9.40	*	0.62	0.52	0.38	*	1.16	1.02	0.76	*
VC clone	12.03	7.03	8.40	*	9.56	10.06	7.93	*	0.72	0.44	0.39	*	1.25	0.69	1.06	*
		R	S	R×S		R	S	R×S		R	S	R× S		R	S	R ×S
SEM ±	1.184	0.324	0.251	0.262	0.420	0.113	0.087	0.196	0.099	0.016	0.013	0.029	0.09	0.040	0.031	0.070
CD at 5 %	NS	0.937	0.726	1.624	NS	0.327	0.253	0.567	NS	NS	0.037	NS	NS	0.118	0.091	0.204

Table 2. Influence of soil moisture stress on endogenous hormonal content in grape rootstocks

Rootstock	Abscisic acid) (ng /g tissue))				Zeatin riboside (ng / g tissue)				Dihydrozeatin riboside (ng / g tissue)			
	0 day	14th day			0 day	14th day			0 day	14th day		
		S1	S2	S3		S1	S2	S3		S1	S2	S3
Dogridge	73.80	66.37	163.8	*	41.24	43.41	32.85	*	30.22	33.56	26.60	*
1613 C	17.37	19.35	25.92	*	63.74	63.49	47.12	*	40.98	41.92	44.42	*
Salt Creek	33.41	32.46	78.05	*	51.28	52.18	34.32	*	27.04	27.85	29.70	*
St. George	22.20	12.17	31.38	*	52.98	71.16	30.92	*	31.81	52.97	30.25	*
VC clone	13.68	22.46	34.42	*	75.21	53.43	35.16	*	51.50	31.61	39.62	*
		R	S	R×S		R	S	R×S		R	S	R×S
SEM±	1.908	2.005	1.268	2.835	1.361	1.096	0.693	1.551	1.294	1.176	14.975	33.488
CD at 5 %	6.01	5.914	3.740	8.363	4.288	3.235	2.046	4.575	4.079	3.469	2.193	4.905

Table 3. Influence of soil moisture stress on plant morphological characters on 14th day of stress cycle in grape genotypes

Rootstock	Total Root Length (cm)			Total Shoot Length (cm)			Root to shoot length ratio		
	S 1	S 2	S 3	S 1	S 2	S 3	S1	S2	S3
Dogridge	356.33	647.66	*	330.00	183.66	*	1.09	3.50	*
1613 C	189.00	190.00	*	170.66	125	*	1.17	1.52	*
Salt Creek	252.66	420.00	*	277.00	191.00	*	0.91	2.19	*
St. George	277.66	322.66	*	325.00	235.33	*	0.85	1.37	*
VC clone	201.66	323.33	*	266.66	162.66	*	0.75	1.99	*
	V	S	V×S	V	S	V×S	V	S	V×S
SEm ±	23.68	69.84	95.52	8.600	25.366	34.596	0.130	0.082	0.184
CD at 5%	14.976	44.175	60.248	5.439	16.043	21.880	0.384	0.243	0.543

Table 4. Influence of soil moisture stress on plant morphological characters on 14th day of stress cycle in grape genotypes

Rootstock	Total root dry weight (g)			Total shoot dry weight (g)			Root to shoot dry weight ratio		
	S 1	S 2	S 3	S 1	S 2	S 3	S1	S2	S3
Dogridge	26.75	47.89	*	38.64	24.19	*	0.69	2.01	*
1613 C	28.45	33.12	*	28.92	28.59	*	0.74	1.21	*
Salt Creek	22.91	40.03	*	31.38	29.15	*	0.79	1.38	*
St. George	25.31	27.91	*	28.00	25.13	*	0.98	1.10	*
VC clone	32.20	30.85	*	29.93	25.34	*	1.09	1.22	*
	R	S	R×S	R	S	R×S	V	S	V×S
SEm ±	2.528	1.599	3.576	1.469	0.946	2.116	0.129	0.081	0.183
CD at 5%	NS	4.717	10.548	4.415	2.792	6.244	0.382	0.241	0.540

S 1: Control (100% irrigation) S 2: 50% stress (50% irrigation) S 3: 100% stress (0% irrigation); *: Plants died and the observations were not recorded from the wetter roots have an impact on root growth as revealed by Dry *et al* (2000), where partial root drying treatment recorded higher root length than fully irrigated treatment. Sharp (1996) also suggested that ABA can maintain root growth under conditions of low soil moisture which results in inhibition of shoot growth. The increased root elongation in Dogridge and Salt Creek under moisture stress may be due to ABA mediated regulation of osmotic adjustment in root tips, wall loosening enzymes and restriction of ethylene biosynthesis as hypothesized by Sharp *et al* (1994). The reduction in shoot length of rootstocks at 50% moisture stress may be due to reduced cytokinin available from the roots, suggesting its important role in stomatal conductance. This was confirmed by Stoll *et al* (2000) where, spraying grapevines exposed to water deficit, with cytokinin restored stomatal conductance to values close to that of fully irrigated vines. Though ABA content of 1613 C and St. George increased marginally, there was a reduction in stomatal conductance. This might be due to accumulation of compounds similar to that of ABA that could not be detected by assay system used for ABA. Parry *et al* (1988) reported increased accumulation of t-xanthoxin in water stress mutants of tomato at a similar rate as ABA in wild mutants of tomato. Similarly Netting *et al* (1997) observed an increased accumulation of precursors of ABA biosynthesis pathway in ABA deficient mutant of tomato.

The ABA content was positively correlated (r = 0.89) with root to shoot length ratio (Fig. 1) and negatively correlated (r = -0.69) with transpiration rate (Fig. 2).

The increased WUE, high root to shoot length ratio and root to shoot dry weight ratio in response to increased ABA content and reduced cytokinin content under soil moisture stress conditions in Dogridge and Salt Creek rootstocks suggests their better drought tolerance capacity than 1613 C and St. George rootstocks.

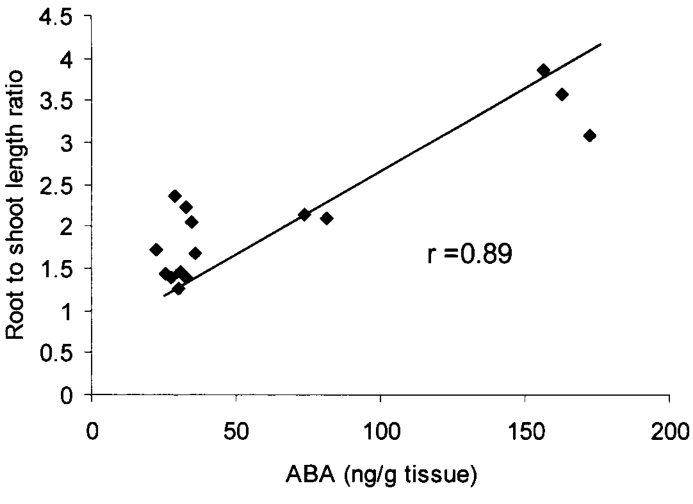

Fig 1. Relationship between ABA and root to shoot length ratio

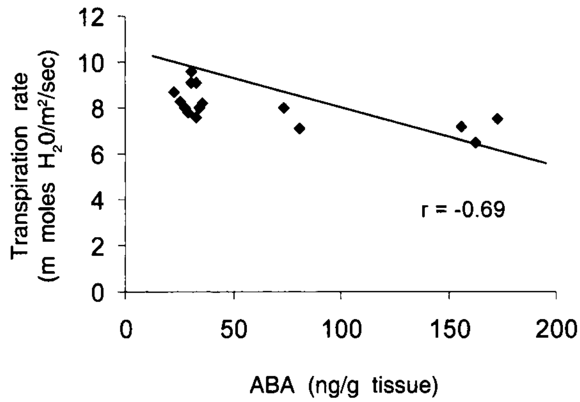

Fig 2. Relationship between ABA and transpiration rate

ACKNOWLEDGEMENTS

The authors are thankful to Mr. Jayaram and Mr. Nageshwara Rao for their technical assistance during this investigation.

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(MS Received 29 June, 2006 Revised 14 July, 2006)