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Influence of rootstocks on salinity tolerance of Thompson Seedless grapevines

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Abstract

Salinity is one of the most important abiotic stresses affecting the productivity of the grapes in India. The response of vines differs under such conditions. Dogridge rootstock though introduced in the country to deal with salinity and moisture stress, tolerance was found lacking under such conditions. A study was conducted to evaluate the salinity tolerance of Thompson Seedless vines raised on different rootstocks and on own root at two salinity levels *viz.,* 2 and 4 dSm^{-1}. The rootstocks included were 110R and 1103P from *Vitis berlandieri* x *Vitis rupestris* parentage, Dogridge (*Vitis champinii*) and St. George (Rupestris *du* Lot). The irrigation water salinity was manipulated using sodium chloride. Thompson Seedless vines raised on 110R and 1103P rootstocks did not show marginal necrosis and leaf blackening symptoms at both salinity levels whereas other rootstocks showed mild to severe symptoms. All stock-scion combinations recorded significantly higher bunch weight than own rooted vines. Highest yield was recorded in the 1103P rootstock at both the salinity levels which was on par with 110R rootstock. Significant differences existed between rootstocks and own root at both the salinity levels with the lowest mean petiole Na values recorded in case of vines raised on 110R. High content of Na in vine tissues (>1.0%) grafted on Dogridge rootstock suggest that this rootstock could not exclude Na under saline irrigation. Though below the threshold levels, at 4 dSm^{-1} level, Dogridge rootstock recorded significantly higher chloride in petioles than other rootstocks. The sodium –potassium ratios in leaf blade and petiole were least in case of 110R and 1103P rootstocks whereas higher values were recorded in case of other stock-scion combinations and on own roots. Highest accumulation of sodium in vegetative parts was recorded in vines grafted on Dogridge whereas the rootstocks 110R and 1103P, accumulated highest K, Mg, Ca and P.

Key words: Rootstocks, Thompson Seedless, salinity tolerance, grapes, sodium, chloride, nutrients, saline irrigation

Introduction

Majority of the grape growing regions comprising states of Maharashtra and North Karnataka in India is concentrated in the agro-ecological region of Deccan Plateau, hot semi-arid eco-region (K4Dd3). The mean annual precipitation, ranging between 600 and 1000 mm, covers about 40 per cent of annual potential evapotranspiration demand. This results in gross annual deficit of 800 to 1000 mm of water. The moisture availability mostly remains as sub marginal (Gajbhiye and Mandal, 2006). Growers in this region, use different sources of irrigation water having varying water quality due to low availability from single source (canal, open well, bore well, river). In the event of failure of rains/ low precipitation, the growers depend mainly on ground water for irrigation, which is generally saline. Bhargava *et al.* (2006) reported that more than 50% of bore well water samples (used for irrigating vineyards) tested, had EC more than 1.0 dSm^{-1}, where growth is restricted due to salinity and hence, it is inevitable to raise vineyards on tolerant rootstocks. Forty five per cent of the water samples analysed had more than 3 $meql^{-1}$ chloride content, making them unsafe for growing grapes even on rootstocks. Further, these samples contained Na content between 0.20 to 70.74 $meql^{-1}$ during 1999 - 2004. Thus, salinity has become a serious menace, affecting the agricultural productivity of India.

Dogridge was introduced during 1980s in India to cope up with the problems of salinity and moisture stress. Study carried out by Satisha and Prakash (2005) showed that Thompson Seedless variety grafted on Dogridge rootstock performed well at 50 % water stress as compared to other rootstocks, which was confirmed by carbon isotope discrimination. Deshmukh *et al.* (2008) showed through short term studies with ungrafted rootstocks that Dogridge could tolerate up to 6.5 dSm^{-1} NaCl salinity. However, the toxic effects of salinity are cumulative, with tissue concentrations of NaCl generally increasing with duration of exposure (Prior *et al.,* 1992). *In situ* observations in commercial vineyards in Israel (Shani and Ben-Gal unpublished data 1996-2002) and in Texas (McEachern, 1995) indicated a slowly materializing increase in vine mortality correlated with conditions of relatively moderate salinity. Dogridge rootstock is not able to tolerate sodicity as leaf blackening and necrosis have been observed in many Indian vineyards planted on calcareous soils (Sharma *et al.,* 2010; 2011). These inferences were drawn from the field where the symptoms had already occurred and no systematic study was done.

A number of rootstocks are available albeit in smaller quantities with the grape growers with some having the potential to replace Dogridge under saline conditions. However, there are variations in the preferential nutrient absorption by rootstocks. Keller *et al.* (2001) showed that generally the more vigorous rootstocks result in higher N levels on the grafted variety. Nikolaou *et al.* (2000) reported higher vigour index measured in terms of pruning weights in Thompson Seedless vines grafted on '99R' and '110R' compared to other rootstocks. Grant and Matthews (1996) investigated the effects of P on four different rootstocks *viz.,* Freedom, Aramon Rupestris Ganzin no.1(AxR#1), Rupestris St George, 110 Richter (110R). The rootstock, 110R produced the lowest growth in the P treatment but it was least affected by a lack of P. It is argued that the difference may be related to it's *V. berlandieri* parentage, given that the metabolism of this American native species is better adapted for P absorption.

Keeping the above in view, two salinity treatments (EC levels- 2 and 4 dSm^{-1}) were given after 30 days of pruning during foundation pruning season upto next fruit pruning and after bunch emergence (30 days after fruit pruning) till berry growth to Thompson Seedless vines raised on different rootstocks own root to study their influence on yield and yield related traits; petiole and leaf blade nutrient content at harvest in 2008.

Materials and methods

The plant materials for this study were located in the vineyards of the National Research Centre for Grapes, Pune in India. The vineyard was planted in 2001 with Thompson Seedless vines raised on its own roots and on different rootstocks *viz.*, Dogridge, 110R, 1103P and St. George. Two salinity treatments *viz.*, 2 dSm^{-1} and 4 dSm^{-1} were imposed after 30 days of pruning during foundation pruning season upto next fruit pruning and from 30 days after fruit pruning till berry growth. The EC of the irrigation water was manipulated using sodium chloride. Vines were irrigated with water having EC=2.0 dSm^{-1}; pH=7.78; Ca^{2+} =29.4 ppm; Mg^{2+} = 91 ppm; Na^{+} =179.4 ppm; K^{+}=0.95 ppm; Cl^{-} =259.15 ppm; HCO_3^{2-} = 488 ppm, SO_4^{--} = 125.14 ppm and 37.0 ppm nitrate-N. The average minimum and maximum temperatures during the study period were 8.6 and 35.89 °C, respectively. Total rainfall received was 512 mm whereas total pan evaporation was 1302 mm. The vineyard was fertilized at the rate of 160 kg N, 50 kg P_2O_5 and 160 kg K_2O on per hectare basis during the fruiting season. The soils of the vineyard were calcareous, alkaline in reaction exhibiting swelling and shrinkage behaviour. The soil samples were collected from the root zone up to 30 cm depth at the time of leaf sampling at harvest. The exchangeable Na content in soil ranged between 880 to 1258 ppm at 4 dSm^{-1} level and 633 to 695 ppm at 2 dSm^{-1} level whereas, the chloride content ranged between 621 to 692 ppm at 4 dSm^{-1} level and 151 to 261 ppm at 2 dSm^{-1} level. The exchangeable K content ranged between 465 to 685 ppm in the experimental vineyards.

The number of bunches emerging after fruit pruning were retained as such on each vine. The bunch number, average bunch weight and total yield per vine were recorded at the time of harvest. The ion accumulation in vine tissues on different stock-scion combinations was studied in the vegetative growth at the time of harvest. Twenty representative shoots were selected from each replication from four representative vines and oven dry weight was recorded for each tissue (blade, petioles and canes). All the leaves on a cane were collected and leaf blade and petiole samples separated and analysed for their nutrient content. The nutrient content was determined after washing, oven drying at 70°C and grinding in Cyclotec sample mill (Foss Tecator make). Nitrogen in the tissues was estimated by Kjeldahl method using Gerhardt semi automatic distillation apparatus (VAPODEST 30) after digesting in H_2SO_4: $HClO_4$ mixture. Another portion of tissue samples was digested in block digestor in H_2SO_4: H_2O_2 mixture for estimation of P, K, Ca, Mg and Na. Phosphorus was estimated colorimetrically by Vanadomolybdate method. An atomic absorption spectrophotometer (Perkin Elmer Analyst 100) was used to estimate K and Na in emission mode and Ca and Mg in absorption mode. The chloride in the tissue extract was determined by using flow injection system (Skalar make San system). The data was statistically analysed using SigmaStat ver. 10 using Factorial RBD block design with two factors (rootstocks and salinity) with three replications.

Results and discussion

Yield and yield related parameters: Thompson Seedless vines raised on 110R and 1103P rootstocks did not show marginal necrosis and leaf blackening symptoms at both 2 dSm^{-1} as well as 4 dSm^{-1} level, whereas vines on other rootstocks and own rooted vines showed mild to severe symptoms at both the salinity levels (Fig.1). This development of the leaf blackening and necrosis might have led to reduced bunch weight, thereby affecting the productivity of the vines (Table 1). Similar results have also been reported earlier by Sharma *et al.* (2010 and 2011). Black leaf symptom development was associated with loss of chlorophyll and reduced photosynthetic ability, suggesting damage to the photosynthetic system (Smithyman *et al.,* 2001). The perusal of Table 1 also showed direct impact of salinity treatment and rootstocks on yield and bunch weight. Increasing salinity levels led to significant decline in bunch weight and yield of all the stock-scion combinations. Highest bunch weight was recorded in Thompson Seedless vines grafted on Dogridge rootstock at 2 EC level which was significantly higher than all the other stock-scion combinations and on own roots. But at 4 EC level, even though Dogridge recorded highest bunch weight, it was not significantly superior over other stock-scion combinations. However, all stock-scion combinations recorded significantly higher bunch weight than own rooted vines under both the levels of salinity. No significant differences were observed between the salinity treatments of the individual stock-scion combination with regard to bunch number. Whatever, the number of bunches emerged after fruit pruning were retained on the vines and as such could not actually reflect the yield values. But nevertheless, the yield decline between the salinity levels for each individual stock-

Table 1. Yield, bunch number, bunch weight and pruning weight of Thompson Seedless vines as affected by rootstocks and salinity levels at harvest stage

Rootstock	Yield/ vine (kg)		Bunch number		Bunch weight (g)		Pruning weight (g)	
	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}
Own Root	8.34	6.26	43.67	38.67	192.67	162.67	1152.9	936.8
Dogridge	9.61	7.43	36.33	33.67	264.00	221.00	1700.4	1787.1
110R	10.61	9.04	44.00	41.67	240.67	217.33	1884.4	1888.6
St. George	7.98	7.29	33.00	33.33	240.33	218.67	1523.8	1525.3
1103P	10.89	9.19	45.00	43.67	242.00	210.67	1899.4	1649.9
Salinity (mean values)	9.49	7.84	40.40	38.20	235.93	206.07	1632.2	1557.5
CD Salinity (P=0.05)	0.72		NS		7.92		72.0	
CD Rootstock (P=0.05)	1.13		4.38		12.52		113.8	
CD Interaction (P=0.05)	NS		NS		NS		160.9	

Fig.1. Leaf blackening and necrosis symptoms in Thompson Seedless vine

scion combination was highest in case of own root followed by Dogridge. Highest yield was recorded in the 1103P rootstock at both the salinity levels which was on par with 110R rootstock. With regard to the pruning weights, significant differences were observed between the salinity treatments.

Nutrient content in petiole and leaf blade: Data on variations in the nutrient contents of petiole and leaf blade are given in Table 2 and 3. Except for nitrogen, salinity-rootstock interaction was prominent with respect to the sodium (Na), potassium (K), chloride (Cl) and phosphorus (P) contents in both the petiole and leaf blade.

Significant differences existed for Na between rootstocks and own root at both the EC level with the lowest mean petiole Na values recorded in case of vines raised on 110R. There was an increase in the Na concentration from 0.623% at 2 dSm^{-1} to 1.023% at 4 dSm^{-1} in leaf blade of Thompson Seedless vines grafted on Dogridge rootstock, which clearly implies that Dogridge rootstock cannot be used in situations, where Na content is high in irrigation water. This is in confirmation with the finding of Sharma *et al.* (2005), who demonstrated greater affinity of Dogridge rootstock to Na through DRIS indices. In contrast, significantly lowest accumulation of Na was recorded in leaf blades of vines grafted on 110R rootstock at both the salinity levels, indicating preference of 110R over Dogridge in situations where irrigation water contains higher Na levels. Similar results have been reported by Sharma *et al.* (2011) and Sharma and Upadhyay (2008), wherein, B-2/56 of similar parentage as 110R and 1103P rootstocks showed relatively lower accumulation of sodium as compared to Dogridge rootstock. As stated earlier vines raised on Dogridge, St. George and on its own root showed leaf blackening symptoms at both the salinity levels. According to Khanduja *et al.* (1980), leaf Na^+ content associated with injury symptom was 0.55% in Thompson Seedless vines whereas Nagarajah (1992) found 0.5% sodium content to be toxic on Sultana vines. This study clearly shows leaf blade injury with Na^+ concentration exceeding 0.54%.

In case of Cl content in both leaf blade and petiole, all the rootstocks proved to be better excluders in comparison to the own rooted vines. The Cl values in the petiole and leaf blade, for all the rootstocks ranged from 0.767-0.871 and 0.15-0.20 % at 2 dSm^{-1} to 0.927-1.338 and 0.26-0.41 % at 4 dSm^{-1} level, respectively, whereas, in case of own rooted vines, it increased from 1.626 and 0.696 % at 2 dSm^{-1} to 2.07 and 1.49 % at 4 dSm^{-1}, respectively. Levels above 1.2 % in leaf lamina are considered to be toxic (Ehlig,1960) whereas levels above 1.5 % in petioles are considered to be excessive (Reuter and Robinson,1997). Amongst the rootstocks, at 4 dSm^{-1} level, Dogridge rootstock recorded significantly higher accumulation of chloride in petioles than other rootstocks, however, these were below the threshold levels. Nevertheless, it can be argued that there is a possibility of this rootstock succumbing to increasing chloride accumulation as compared to other rootstocks in saline environment.

Higher K values (>1 %) in the petiole was recorded in vines raised on 110R at both the salinity levels whereas it declined from 0.772 % in vines raised on Dogridge at 2 dSm^{-1} to 0.433 % at 4 dSm^{-1} level. Infact at 4 dSm^{-1}, no significant differences was observed in vines raised on St. George, own root and Dogridge. Sharma *et al.* (2010) reported that under saline irrigation, vines grafted on Dogridge rootstock has shown the tendency to accumulate sodium in excess leading to K deficiency, reduced fruitfulness and death of vines. The vines raised on 110R and 1103P, maintained higher K levels at both the salinity levels in leaf blade. The sodium –potassium ratios in leaf blade and petiole were least in case of 110R and 1103P rootstocks whereas higher values were recorded in case of other stock-scion combinations and on own roots. Lower sodium –potassium ratios in the vines showed salinity tolerance (Samra, 1985). Likewise, maintenance of a high cytosolic K^+/Na^+ concentration ratio is a key requirement for plant growth in soils with a high NaCl concentration (Upadhyay *et al.*, 2012). This showed that rootstocks 110R and 1103P could cope up in soils with high sodium chloride salinity.

Own rooted vines recorded the highest P content in both the petioles and leaf blade followed by vines raised on 110R and 1103P. St. George rootstock recorded highest decline in P content of petiole at 4 dSm^{-1} level compared to other rootstocks. In the case of P content in leaf blades, significantly high P content was recorded in own rooted vines and vines raised on 110R and 1103P. Decline in P content values in both petioles as well as leaf blade could be due to increase in Cl content with increasing salinity level.

Significant differences in Mg content of both petioles and leaf blades were observed between the stock-scion combinations, nevertheless the values were sufficient not to lead to any

Table 2. Petiole nutrient content (%) of Thompson Seedless vines as affected by rootstocks and salinity levels at harvest stage

Rootstock	K		Na		Cl		Ca		P		Mg		N		K/Na	
	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}
Own Root	1.28	0.43	1.29	1.39	1.63	2.07	1.98	1.92	0.29	0.26	0.85	0.92	0.55	0.56	0.99	0.32
Dogridge	0.77	0.43	1.26	1.49	0.81	1.34	1.64	1.98	0.11	0.11	0.91	0.84	0.52	0.54	0.62	0.29
110R	1.05	1.02	0.89	1.04	0.77	1.07	1.50	1.63	0.20	0.21	1.10	0.99	0.51	0.53	1.19	0.98
St. George	0.98	0.39	1.12	1.24	0.87	0.93	1.38	1.64	0.16	0.09	0.91	1.00	0.58	0.59	0.88	0.32
1103P	1.19	0.72	0.86	1.04	0.83	1.04	1.51	1.60	0.20	0.19	1.05	1.03	0.57	0.60	1.37	0.64
Salinity (mean values)	1.05	0.60	1.08	1.24	0.98	1.29	1.60	1.75	0.19	0.17	0.96	0.96	0.55	0.56	1.01	0.51
CD Salinity (P=0.05)	0.01		0.01		0.04		0.05		0.01		NS		NS		0.01	
CD Rootstock (P=0.05)	0.02		0.02		0.06		0.08		0.016		0.04		NS		0.02	
CD Interaction (P=0.05)	0.03		0.03		0.09		0.11		0.02		0.06		NS		0.03	

Table 3. Leaf blade nutrient content (%) of Thompson Seedless vines as affected by rootstocks and salinity levels at harvest stage

Rootstock	K		Na		Cl		Ca		P		Mg		N		K/Na	
	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}
Own Root	0.77	0.48	0.54	0.77	0.70	1.49	3.11	2.86	0.27	0.23	0.54	0.58	1.47	1.51	1.41	0.62
Dogridge	0.50	0.48	0.62	1.02	0.17	0.40	2.83	2.89	0.17	0.15	0.63	0.63	1.42	1.46	0.81	0.47
110R	0.66	0.68	0.19	0.32	0.15	0.41	2.70	2.90	0.27	0.23	0.72	0.68	1.48	1.70	3.44	2.11
St. George	0.82	0.45	0.46	0.62	0.20	0.33	2.77	2.93	0.24	0.18	0.68	0.68	1.65	1.67	1.80	0.73
1103P	0.69	0.79	0.27	0.41	0.17	0.26	2.66	2.86	0.25	0.22	0.65	0.73	1.60	1.55	2.57	1.95
Salinity (mean values)	0.69	0.58	0.42	0.63	0.28	0.58	2.81	2.89	0.24	0.20	0.64	0.66	1.52	1.58	2.01	1.18
CD Salinity (P=0.05)	0.01		0.01		0.02		NS		0.01		NS		NS		0.08	
CD Rootstock (P=0.05)	0.02		0.21		0.03		NS		0.01		0.05		0.06		0.13	
CD Interaction (P=0.05)	0.03		0.03		0.05		NS		NS		NS		NS		0.18	

Table 4. Total nutrient uptake (cane + petiole + leaf blade) in Thompson Seedless vines as affected by rootstocks and salinity levels at harvest stage (g/vine)

Rootstock	Na		K		Cl		Mg		Ca		P	
	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}	2 dSm-1	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}	2 dSm^{-1}	4 dSm^{-1}
Own Root	527.8	602.1	759.6	374.2	598.7	1010.9	464.6	413.0	1946.9	1543.6	272.6	191.4
Dogridge	821.7	1415.2	831.3	724.9	309.0	730.3	762.1	789.8	2672.5	2866.8	292.9	239.4
110R	394.4	590.0	1185.4	1158.0	338.3	679.2	900.3	868.2	2814.2	2968.1	419.9	339.9
St. George	541.4	848.5	1000.4	660.7	312.6	448.3	668.3	705.7	2228.7	2365.6	305.4	232.4
1103P	470.9	564.9	1198.5	1071.1	348.6	469.5	846.9	788.9	2792.3	2508.9	414.6	301.3
Salinity (mean values)	551.2	804.1	995.0	797.7	381.4	667.6	728.4	713.1	2490.9	2450.6	341.1	260.9
CD Salinity (P=0.05)	32.6		40.5		20.5		32.2		110.8		13.7	
CD Rootstock (P=0.05)	51.5		64.1		32.4		51.0		175.3		21.6	
CD Interaction (P=0.05)	72.8		90.6		45.8		72.1		247.9		30.6	

deficiency in the vines. Higher Mg content in both petioles and leaf blades was recorded in 110R, St. George and 1103P at both the salinity levels. Calcium content in leaf blades was not significantly affected by the stock-scion combinations. Even where significant differences were observed in the petiole Ca content, the values were more in sufficient range. Salinity levels did not significantly affect the total N content of both petioles and leaf blades in the vines.

Nutrient accumulation in the vegetative matter (cane + leaf blade + petiole): The total nutrient accumulation is given in Table 4. The variation in accumulation is dependent on the weight of the vegetative parts recorded and the nutrient content of the vine parts. Amongst the vegetative parts analysed, highest accumulation of sodium and chloride was recorded in the leaf in all the rootstocks irrespective of salinity level in the current season growth. The salinity–rootstock interaction was significant for all the nutrients under study. Significantly highest accumulation of Na^+ was recorded in vines grafted on Dogridge followed by St. George and then on its own root at both the salinity levels. Rootstocks significantly accumulated Na^+ at both the EC levels, suggesting that increasing salinity in the irrigation water could lead to more salt accumulation and thereby could affect the total productive life of the vines. This affect could be much faster in Dogridge and least in case of 110R and 1103P rootstocks. Regarding chloride, significantly highest accumulation was recorded in Thompson Seedless on its own roots followed by vines raised on Dogridge rootstock. This could also lead to Dogridge rootstock succumbing to chloride toxicity over a period of time as compared to other rootstocks. Other important nutrients like K, Mg, Ca and P accumulation was significantly high in 110R and 1103P rootstocks.

The results of this study showed that Dogridge introduced in the country as salinity and moisture stress tolerant rootstock could not prevent the accumulation of sodium in the Thompson Seedless vines. Infact, rootstocks from *Vitis berlandieri* x *V. rupestris* parentage *viz.,* 110R and 1103P could prevent the accumulation of sodium even at 4 dSm^{-1} level. Even though, chloride accumulation in all the stock-scion combinations was below the threshold limit in both leaf blade and petioles, nevertheless Dogridge accumulated significantly more chloride than other rootstocks in the Thompson seedless vines. There is a possibility of this rootstock succumbing to increasing chloride accumulation as compared to other rootstocks in saline environment. Decline in K levels with increasing Na accumulation at 4 dSm^{-1} level was observed in all the stock-scion combination except 110R which could maintain sufficient K levels in the tissues. Long term studies need to be continued in different soil types and salinity levels to study the salt accumulation in tolerant rootstock over period of time.

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