

Original Research Article

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## Relative Salt Tolerance of Different Grape Rootstocks to NaCl

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### ABSTRACT

An experiment was conducted at Grape Research Station, Rajendranagar, Hyderabad to study the relative salt tolerance of grape rootstocks at different levels of sodium chloride. The treatments consisted of five rootstocks viz., Dogridge, Salt Creek, RS-19, SO4 and 1613-C and five levels of sodium chloride 4, 8, 16 and 32 meq of Cl/l in irrigation water including control (normal irrigation water). The experiment was laid out in a FCRBD with three replications. The relative salt tolerance was judged based on growth parameters, dry weight of root to shoot ratio, symptoms of toxicity, chloride content K/Na ratio in leaf and days taken for appearance of toxicity symptoms. The dry weight of root to shoot ratio was significantly higher in Dogridge (0.6) and RS-19 when compared to others. The K/Na ratio in 1613-C (14.1) SO4 (13.4) and RS-19 (10.3) was significantly higher than Dogridge (8.8) and Salt Creek (7.4). Dogridge was the best chloride excluder based on lowest concentrations of accumulated Cl<sup>-</sup> in laminae (0.8%). The scorching symptoms due to salt toxicity were observed earlier in RS 19 followed by Salt Creek, Dogridge, 1613 C and later in SO4. High innate vigour (high dry weight of root to shoot ratio and growth parameters) of Dogridge combined with high chloride exclusion ability represents the best combination for salt tolerance which however, could not be supported by low K/Na ratio. In case of 1613 C and SO4, the high K/Na ratio and late appearance of salt toxicity symptoms supported salt tolerance but less vigour and chloride exclusion were not in support relative to Dogridge. In all the rootstocks there was progressive decline in the growth parameters, K/Na ratio, root to shoot ratio and increase in chloride content with the increase in concentration of NaCl over control. Such information further supported by field studies could assist in assessment of rootstocks for areas of high salinity.

### Keywords

Salt tolerance,  
root to shoot ratio,  
K/Na ratio,  
scorching injury.

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## Introduction

Grapevine is used for table, juice, wine and dried grape production, is an economically important fruit crop that is moderately sensitive to salinity. In Telangana State grape production has become the most coveted farming enterprise because of the

suitable climate, soil and high returns. Dogridge (*Vitis champini*) is the most common rootstock used by grape growers for grafting Thompson Seedless, the popular commercial variety of this region. It is mainly grown in Rangareddy, Medak and

Mahaboobnagar districts of Telangana State. Salinity is an increasing threat for horticulture and is a major factor in reducing plant productivity (Bohnert *et al.*, 1995). In this region the chloride levels in irrigation water were reported to be more than the threshold limit of 4meq/l in nearly 60% of the vineyards (GRS Annual report, 2008-2009). In grapevine salt stress symptoms include leaf burn, reduced vigour and reduced yield with a strong positive correlation between the two (Downton WJS, 1977). There is a strong influence of rootstock on scion production upon salt stress. Hence, the effect of excess salts can be avoided by using salt tolerant grape rootstocks. Rootstocks obtained from wild *Vitis* species differ widely in their capability to tolerate salinity. Downton and Hawker (1980) reported that root growth was more adversely affected than shoot growth under salinity environment studies therefore the ratio of root to shoot is more important in salt tolerance. Walker *et al.*, 2002a concluded that a high innate vigour of a rootstock combined with moderate to high chloride and sodium exclusion ability represents the best combination for salt tolerance. Increased evidence shows that it is not the absolute quantity of Na<sup>+</sup> per se that influences salt resistance, but rather the cytosolic K<sup>+</sup>/Na<sup>+</sup> ratio that determines plant salt tolerance (Shabala and Pottosin, 2010). The very fact that there are marked differences of relative salt tolerance among the rootstocks emphasizes the importance of this study. Very limited information is available with respect to the response of rootstocks to salinity. Hence, the present study was aimed to screen grape rootstocks for their relative salt tolerance to NaCl salinity based on growth parameters, dry weight of root to shoot ratio, symptoms of toxicity, chloride content, K/Na ratio in leaf and days taken for appearance of toxicity symptoms.

## Materials and Methods

The present pot culture study was conducted at Grape Research Station, Andhra Pradesh Horticultural University, Rajendranagar, Hyderabad during the year 2008-09. It is situated at an altitude of 530.38 meters above M S L and geographically lies at a latitude of 17° 20' N and longitude of 78° 25' E . The treatments consisted of 25 treatment combinations with an objective to screen five rootstocks viz., Dogridge (*Vitis champini*), Salt Creek (*Vitis champini*), RS-19(Ramsey (*V. candicans* x *V. rupestris*) and Schwarzmann (*V. riparia* x *V. rupestris*)), SO4 (*Vitis berlandieri* x *Vitis riparia*) and 1613-C (*Vitis solonis* x *Othello*) against five levels of sodium chloride concentrations viz., control (normal irrigation water ), 4, 8, 16 and 32 meq Cl/l<sup>t</sup> in irrigation water. The experiment was laid out in a FCRB with three replications and three rootstocks in each replication. Six months old rooted cuttings of rootstocks were planted in earthen pots filled with soil collected from Grape Research Station, Rajendranagar and rotten FYM mixed well in 3:1 proportion. After the initial establishment, the rootstocks were irrigated with saline water prepared by mixing sodium chloride (control, 4, 8, 16 and 32 meq Cl/l<sup>t</sup> ) in irrigation water for three months. The plants were irrigated with uniform volume of water below the field capacity. The irrigation water (control) was neutral (pH 7.5), slightly saline (0.85 dSm<sup>-1</sup>) with chloride (2 meq l<sup>-1</sup>) and sodium (0.5 meq l<sup>-1</sup>) levels below the threshold limit. It was safe with respect to residual sodium carbonate and sodium adsorption ratio. The soil used for pot filling was sandy clay loam in texture, low in organic carbon (0.35%), low in available nitrogen (225 kg ha<sup>-1</sup>) and phosphorus (9.5 kg ha<sup>-1</sup>), medium in potassium (154 kg/ha ).The soil was neutral in reaction (pH 7.1) and non saline (EC

0.32 dSm<sup>-1</sup>). Standard procedures were followed for analysis of soil and water. Leaf toxicity (scorching) in grape rootstocks were recorded at different intervals. Based on the percentage of scorching the leaves were classified into S1 (initiation of scorching), S2 (< 25%), S3 (26 to 50 %), S4 (51 to 75 %) and S5 (> 75%). Biometric observations per plant viz., number of roots (cm), root volume (cc), shoot length (cm), number of leaves, dry weight of root (g) and dry weight shoot (g) were recorded at the end of the experiment. The percent reduction in growth parameters at highest NaCl concentrations over control, dry weight of root to shoot ratio, K/Na ratio was computed. The root volume was measured by water displacement method. The leaves were collected from each replication and were washed and oven dried at 70°C temperature. Sodium content in leaves was determined using Flame photometer. Chlorides was determined by Argentometric titration (Richard, 1968)

## Results and Discussion

Growth parameters Significant genotypic variation in growth parameters when exposed to added salt concentrations was evident from Table 1 and 2. Among the rootstocks the leaf number per plant was significantly highest in Dogridge which was on par with 1613 C followed by SO4, RS19 and lowest in Salt Creek. This could be attributed to percent reduction over control.

However, highest shoot length was recorded in SO4 (80.3cm) while it was lowest in Dogridge (60.2cm) and 1613-C (61.3cm). In terms of percent reduction in shoot length maximum was recorded in Dogridge (33.5%) and minimum in SO4 (18.1%) (Table 4). The rootstocks did not vary significantly with respect to dry weight of shoots (Table 1).

Differences in root growth parameters of the rootstock were apparent with addition of NaCl salt. Of the rootstocks tested significantly highest root growth parameters reflected in terms of root number, volume and dry weight were recorded in Dogridge (55.2 , 92cc and 21.2g respectively) and lowest in Salt Creek (42.7,82cc and 17.4g respectively) in Table 2. Percent reduction in root growth parameters of most rootstocks was in the following order RS 19> Dogridge > SaltCreek > 1613 C > SO4 (Table 5). Similar reduction of dry matter weight under salt stress was previously reported by (Shani and Ben-Gal, 2005).

Thambe (1999) and Deshmukh *et al.*, 2008 also recorded similar result with regard to these growth parameters in Dogridge when compared to 1616-C, Salt Creek and 1613-C rootstocks. The variation in growth parameters among various rootstocks might be due to high vigour, inherent genetic differences and their variations in adaptability to salinity environments (Shikhamany, 1999). According to Munns (2003), the decrease in plant biomass due to salinity may be related to low external water potential, ion toxicity, indirect effect on nutrients uptake and ion imbalance.

It was observed that in all the rootstocks there was a progressive decline in the growth parameters with the increase in the concentration of NaCl over control. However, the interaction effect of rootstocks and concentration was significant only for shoot length, average number of roots.). Sinel nikova *et al.*, (1972) stated that increase in salinity levels caused decrease in plant hormone content (Auxin and Gibberellin) and increase in inhibitors level which restricted the growth and subsequent rooting.

### **Dry weight of root to shoot ratio, K/Na ratio and Cl content**

The responses of rootstocks obtained from wild *Vitis* species to increasing concentrations of sodium chloride were examined in a pot culture experiment where changes in dry weight of root to shoot ratio, K/Na ratio and Cl content could be related to salt tolerance (Table 3).

Of the rootstocks tested, higher dry weight of root to shoot ratio which is an indicator for salt tolerance was registered in Dogridge (0.6) and RS-19 (0.6) while in all other rootstocks an uniform ratio of 0.5 was recorded. Downton and Hawker (1980) reported that root growth was more adversely affected than shoot growth under salinity environment. Samra (1986) pointed out that root and shoot biomass production of grape was adversely affected as ESP increased.

Salinity tolerance was also associated with their ability to exclude Na<sup>+</sup> and/or Cl<sup>-</sup> or with K/Na ratio. The K/Na ratio has been considered to be a good indicator for salt stress (Devitt *et al.*, 1981, Aslam *et al.*, 1988). As per Levitt (1974) higher the K/Na in leaves more is the salt tolerance. There was significant variation in leaf K/Na ratio a good indicator for salt stress.

Among the rootstock studied 1613-C maintained highest ratio (14.1) indicating salt tolerance and was statistically on par with SO4 (13.4) and RS-19 (10.3) while Salt Creek (7.4) recorded lowest ratio on par with Dogridge (8.8). Samra (1986) stated that tolerance seems to be related to K/Na ratio in the leaf and not with absolute contents of sodium. The salt tolerant varieties maintained higher K levels than the sensitive ones (Troncoso' *et al.*, 1999). The K/Na ratio in leaf decreased significantly with increasing concentration of NaCl. The least K/Na in leaf was recorded with 32 meq

of Cl/lit i.w. (5.13). The interaction between rootstocks x concentrations was found to be non significant with regards to K/Na ratio in leaf.

High chloride exclusion ability also represents the salt tolerance (Walker *et al.*, 2003) because salt-induced limitations in photosynthesis and stomatal conductance of grapevines are related to high Cl and not to Na contents in the leaves (Prior *et al.*, 1992).

In the presence of salt, there was some variation among the rootstocks in the Cl-concentrations. It is evident from the Table 3 that among the rootstocks Dogridge maintained lowest Cl- content (0.88%) representing better salt tolerance than other rootstocks. Whereas, the other rootstocks under study did not show any significant difference among themselves. Significantly highest Cl- content in leaf (1.78%) was recorded with 32 meq of Cl/lit i.w. This was followed by progressive increase in Cl- content in leaf with increase in concentration of Cl- salts. The lowest Cl- content in leaf was recorded with control (0.51%). The interactions effect between rootstocks x concentrations was found to be non significant.

### **Days Taken for Manifestation of Scorching Injury**

In results presented in the Table 6 revealed that the chloride toxicity symptoms on leaves were noticed earlier in RS-19 followed by Salt Creek and Dogridge rootstock where as manifestation of symptoms was late in 1613-C and SO4. Chloride accumulation causes burning on the leaf blades in high chloride treatment. (Ehlig, 1960 and Kupier, 1968). This could be because of high levels of chloride were observed in petiole and leaf lamina at abscission (Downton, 1977).

**Table.1** Effect of Varying Levels of Sodium Chloride Salt on Shoot Growth Parameters in Different Grape Rootstocks

Rootstocks	Number of Leaves						Shoot length(cm)						Dry wt of shoot(g)						
	Concentrations (meq of Cl/l <i>t</i> i.w.)						Concentrations (meq of Cl/l <i>t</i> i.w.)						Concentrations (meq of Cl/l <i>t</i> i.w.)						
	Control	4meq	8meq	16 meq	32 meq	Mean	Control	4meq	8meq	16 meq	32 meq	Mean	Control	4meq	8meq	16 meq	32 meq	Mean	
<b>Dogridge</b>	95.0	93.0	88.0	79.0	71.0	<b>85.2</b>	90.5	80.3	62.0	43.0	25.0	<b>60.2</b>	43.2	40.8	37.4	35.0	29.2	<b>37.1</b>	
<b>Salt Creek</b>	68.0	60.0	55.0	42.0	32.0	<b>51.4</b>	89.8	71.9	71.7	61.8	37.4	<b>66.5</b>	42.6	39.1	36.3	33.4	28.6	<b>36.0</b>	
<b>RS-19</b>	80.0	76.0	69.0	58.0	45.0	<b>65.6</b>	96.1	72.7	64.0	59.7	50.3	<b>68.6</b>	42.0	39.6	37.7	34.4	29.9	<b>36.7</b>	
<b>SO4</b>	90.0	86.0	74.0	63.0	54.0	<b>73.4</b>	98.0	85.9	78.0	74.3	65.1	<b>80.3</b>	42.8	40.6	35.8	33.4	30.3	<b>36.6</b>	
<b>1613-C</b>	95.0	91.0	86.0	76.0	69.0	<b>83.4</b>	84.5	70.5	54.2	51.5	45.8	<b>61.3</b>	42.0	40.6	37.7	34.5	30.5	<b>37.1</b>	
<b>Mean</b>	<b>85.6</b>	<b>81.2</b>	<b>74.4</b>	<b>63.6</b>			<b>91.8</b>	<b>76.3</b>	<b>66.0</b>	<b>58.1</b>	<b>44.7</b>		<b>42.5</b>	<b>40.1</b>	<b>37.0</b>	<b>34.1</b>	<b>29.7</b>		
		<b>SEm±</b>	<b>CD</b>					<b>SEm±</b>	<b>CD</b>					<b>SEm±</b>	<b>CD</b>				
<b>R</b>		1.05	(0.05p) 3.2					1.50	4.6					2.0	NS				
<b>C</b>		1.05	3.2					1.50	4.6					1.27	3.9				
<b>RxC</b>		3.5	NS					3.37	10.3					4.5	NS				

**Table.2** Effect of Varying Levels of Sodium Chloride Salt on Root Growth Parameters in Different Grape Root

Rootstocks	Number of Roots Concentrations (meq of Cl/l <i>t</i> i.w.)						Average Length of Root (cm) Concentrations (meq of Cl/l <i>t</i> i.w.)					
	Control	4meq	8meq	16 meq	32 meq	Mean	Control	4meq	8meq	16 meq	32 meq	Mean
<b>Dogridge</b>	82.1	78.6	61.7	38.7	15.1	<b>55.2</b>	61.2	54.7	43.7	34.9	15.7	<b>42.0</b>
<b>Salt Creek</b>	64.8	56.9	44.3	33.4	14.2	<b>42.7</b>	60.8	53.4	43.9	26.7	11.5	<b>39.3</b>
<b>RS-19</b>	67.5	59.5	43.3	32.1	23.2	<b>45.1</b>	59.7	44.1	36.2	24.3	12.5	<b>35.4</b>
<b>SO4</b>	68.4	60.3	48.5	35.5	23.9	<b>47.3</b>	58.7	46.7	38.8	29.6	14.4	<b>37.6</b>
<b>1613-C</b>	69.5	60.9	52.5	31.8	21.6	<b>47.3</b>	59.5	46.5	35.2	21.2	13.7	<b>35.2</b>
<b>Mean</b>	<b>70.5</b>	<b>63.2</b>	<b>50.1</b>	<b>34.3</b>	<b>19.6</b>		<b>60.0</b>	<b>49.1</b>	<b>39.6</b>	<b>27.3</b>	<b>13.6</b>	
	<b>SEm±</b>		<b>CD</b> <b>(0.05p)</b>				<b>SEm±</b>		<b>CD</b> <b>(0.05p)</b>			
<b>R</b>	0.65		2.0				0.85		2.6			
<b>C</b>	0.65		2.0				0.85		2.6			
<b>RxC</b>	1.44		4.4				3.0		NS			
Rootstocks	Dry Weight of Roots (g) Concentrations (meq of Cl/l <i>t</i> i.w.)						Root volume (cc) Concentrations (meq of Cl/l <i>t</i> i.w.)					
	Control	4meq	8meq	16 meq	32 meq	Mean	Control	4meq	8meq	16 meq	32 meq	Mean
<b>Dogridge</b>	36.1	23.5	20.3	18.3	7.5	<b>21.2</b>	150	120	90	70	30	<b>92</b>
<b>Salt Creek</b>	27.2	23.6	15.8	13.4	6.8	<b>17.4</b>	130	100	90	70	20	<b>82</b>
<b>RS-19</b>	33.5	22.5	17.5	12.7	5.3	<b>18.2</b>	150	120	70	50	30	<b>84</b>
<b>SO4</b>	31.5	26.8	19.5	16.8	9.8	<b>20.9</b>	130	110	90	70	50	<b>90</b>
<b>1613-C</b>	25.2	21.2	18.2	14.4	8.6	<b>17.5</b>	130	110	90	60	20	<b>84</b>
<b>Mean</b>	<b>30.7</b>	<b>23.4</b>	<b>18.3</b>	<b>15.1</b>	<b>7.6</b>		<b>138</b>	<b>112</b>	<b>86</b>	<b>64</b>	<b>32</b>	
	<b>SEm±</b>		<b>CD</b> <b>(0.05p)</b>				<b>SEm±</b>		<b>CD</b> <b>(0.05p)</b>			
<b>R</b>	0.78		2.4				0.85		2.6			
<b>C</b>	0.78		2.4				0.85		2.6			
<b>RxC</b>	2.7		NS				3.0		NS			

**Table.3** Effect of Varying Levels of Sodium Chloride Salt on Root to Shoot Ratio, K/Na Ratio and Chloride Content in Different Grape Rootstocks

Rootstocks	Root to Shoot Ratio						K/Na ratio					Chloride content(%)					
	Concentrations (meq of Cl/l i.w.)						Concentrations (meq of Cl/l i.w.)					Concentrations (meq of Cl/l i.w.)					
	Control	4meq	8meq	16 meq	32 meq	Mean	4meq	8meq	16 meq	32 meq	Mean	Control	4meq	8meq	16 meq	32 meq	Mean
<b>Dogridge</b>	0.83	0.58	0.55	0.51	0.25	<b>0.60</b>	14.21	8.87	7.06	4.92	<b>8.76</b>	0.47	0.67	0.85	1.1	1.28	<b>0.88</b>
<b>Salt Creek</b>	0.63	0.60	0.43	0.39	0.23	<b>0.50</b>	12.77	7.65	5.32	3.79	<b>7.38</b>	0.64	0.89	1.2	1.38	2.41	<b>1.31</b>
<b>RS-19</b>	0.81	0.58	0.47	0.37	0.17	<b>0.60</b>	19.3	10.99	7.16	3.92	<b>10.34</b>	0.42	0.54	1.06	1.42	1.85	<b>1.06</b>
<b>SO4</b>	0.76	0.66	0.53	0.49	0.31	<b>0.50</b>	26.06	13.01	10.01	4.67	<b>13.44</b>	0.57	0.89	1.07	1.33	1.49	<b>1.07</b>
<b>1613-C</b>	0.60	0.51	0.49	0.41	0.26	<b>0.50</b>	20.03	17.56	10.22	8.37	<b>14.05</b>	0.46	0.78	0.92	1.14	1.88	<b>1.04</b>
<b>Mean</b>	<b>0.73</b>	<b>0.59</b>	<b>0.49</b>	<b>0.43</b>	<b>0.24</b>		<b>18.5</b>	<b>11.62</b>	<b>7.95</b>	<b>5.13</b>		<b>0.51</b>	<b>0.75</b>	<b>1.02</b>	<b>1.27</b>	<b>1.78</b>	
		<b>SEm</b>	<b>CD</b>					<b>SEm±</b>	<b>CD</b>			<b>SEm±</b>	<b>CD</b>				
		±	(0.05 p)						(0.05p)								
<b>R</b>		0.009	0.03					1.36	4.17			0.03	0.1				
<b>C</b>		0.009	0.03					1.21	3.73			0.03	0.1				
<b>RxC</b>		0.02	0.07					2.91	N.S.			0.1	NS				



**Table.4** Percent Reduction in Growth Parameters of Different Grape Rootstocks due to NaCl

NaCl							
Dogridge	Salt Creek	RS-19	SO4	1613-C	MEAN		
leaf number per vine	10		24.4	18.0	18.4	12.2	<b>16.6</b>
Shoot length	33.5		25.9	28.7	18.1	27.6	<b>26.8</b>
Dry weight of shoot per vine	14.1		15.5	12.6	14.5	11.7	<b>13.7</b>
<b>MEAN</b>	<b>19.1</b>		<b>21.95</b>	<b>19.78</b>	<b>17.0</b>	<b>17.15</b>	<b>19.0</b>

of Different Grape Rootstocks Due to NaCl

NaCl							
Dogridge	Salt Creek	RS-19	SO4	1613-C	MEAN		
Number of roots per vine		32.8	34.1	33.2	30.8	31.9	<b>32.6</b>
Average length of roots per vine		31.2	35.4	40.9	35.9	40.8	<b>36.8</b>
Root volume per vine		38.7	36.9	44.0	30.8	35.4	<b>37.1</b>
Dry weight of roots per vine		40.2	36.0	45.7	33.4	30.6	<b>37.2</b>
<b>Mean Reduction</b>		<b>35.73</b>	<b>35.60</b>	<b>40.95</b>	<b>32.73</b>	<b>34.68</b>	<b>35.93</b>



**Table.6** Days for Manifestation of Injury Due to Varying Level of NaCl Salinity in Grape Rootstocks

NaCl										
Levels meq of Cl/lit	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
<b>Dogridge</b>					<b>Salt Creek</b>					
Control	-	-	-	-	-	-	-	-	-	-
4meq	69	78	91			65	74	86		
8meq	59	67	75	85		59	67	76	82	
16meq	48	54	66	74	80	44	56	64	70	76
32meq	43	46	53	66	73	38	47	56	64	70
<b>RS-19</b>					<b>SO<sub>4</sub></b>					
Control	-	-	-	-	-	-	-	-	-	-
4meq	63	71	83			98	112	119		
8meq	57	63	70	78		88	99	106	116	
16meq	41	48	53	59	67	79	86	103	109	113
32meq	35	41	47	52	59	66	78	89	97	109
<b>1613-C</b>										
Control	-	-	-	-	-					
4meq	68	80	92							
8meq	60	71	83	90						
16meq	54	62	69	77	85					
32meq	49	57	66	72	78					

The highest rate of scorching S5 (> 75% scorching), symptoms was observed at 32 and 16 meq of Cl/lit iw., concentration in all rootstocks,. Downton and Millhouse, 1983 reported that adding salt to the plants excessively causes salt injury and premature senescence in older leaves. Salt injury is more likely related to chloride, since Cl- absorbs more quickly than sodium.

Putting together the combination of all the parameters for salt tolerance the high innate vigour (high dry weight of root to shoot ratio and growth parameters) of Dogridge combined with high chloride exclusion ability represents the best combination for salt tolerance which could not be supported by low K/Na ratio. In all the rootstocks there was progressive decline in the growth parameters, K/Na ratio, root to shoot ratio and increase in chloride content with the

increase in concentration of NaCl over control. Such information further supported by field studies could assist in assessment of rootstocks for areas of high salinity.

In conclusion, the potential to provide a relative assessment of salt tolerance has been demonstrated in this study. High dry weight of root to shoot ratio, growth parameters combined with high chloride exclusion ability represented the best combination for salt tolerance in case Dogridge however, the K/Na ratio was in less support of salt tolerance. In case of 1613 C, the high K/Na ratio and late manifestation of salt toxicity symptoms supported salt tolerance however low root to shoot ratio and high chloride exclusion relative to Dogridge did not.

Therefore the potential of both Dogridge and 1613 C for salt tolerance as concluded from

this pot culture experiment when further supported by field studies could assist in assessment of rootstocks for areas of high salinity.

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