

Original Research Article

<https://doi.org/10.20546/ijcmas.2017.611.003>

Relative Salt Tolerance of Different Grape Rootstocks to Different Chloride Salts

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ABSTRACT

A Pot culture experiment was conducted at Grape Research Station, Rajendranagar, Hyderabad to study the variability in salt tolerance of grape rootstocks (viz., Dogridge, Salt Creek, RS-19, SO4 and 1613-C) to different chloride salts viz., NaCl, KCl, MgCl₂ and CaCl₂ salts). The experiment was laid out in a FCRBD with three replications. The relative salt tolerance was assessed based on growth parameters, dry weight of root to shoot ratio and also on the ability of rootstocks to limit uptake of Na and Cl ions. The Cl salts associated with divalent cations MgCl₂ and CaCl₂ treatments recorded the higher number of average roots, leaves, length of longest root, dry weight of roots per plant and also dry weight of root to shoot ratio when compared to those associated with monovalent cations KCl and NaCl. Among the rootstocks tested significantly highest root growth parameters measured in terms of root number (59.79), length (42.9cm) and dry weight (24.51g) and also dry weight of root to shoot ratio (0.6) was recorded in Dogridge. There was significant difference among rootstocks in their cationic composition with application of different Cl salts. Concentration of Na⁺ was lower (0.06%) in 1613-C and SO4 where as higher Na⁺ content in leaf was observed in Salt Creek (0.10%) which was on par with Dogridge (0.09%) and RS-19 (0.08%). The highest K content in leaf was recorded with RS-19 (1.84%) which was on par with Dogridge (1.69%) and Salt Creek (1.69%). The SO4 (1.95%) recorded highest Ca content in leaf which was on par with 1613-C (1.81%) and RS-19 (1.79%). With regards to Mg content there was no significant difference among rootstocks. High chloride exclusion ability represents the salt tolerance. Significantly lowest chloride content was recorded with Dogridge (0.87%) rootstock whereas the highest chloride content was recorded with Salt Creek (1.14%) and was on par with other rootstocks. The application of CaCl₂, MgCl₂ and KCl salts did not have significant influence the uptake of Na⁺ ion. The Cl accumulation in leaf was significantly higher when applied in the form of NaCl followed by KCl and it was significantly lower when applied in the form of CaCl₂ and MgCl₂ salt. The order of tolerance to chloride salts by grape rootstocks was in of the order CaCl₂ > MgCl₂ > KCl > NaCl salts. Therefore based on low Cl content in leaves, high dry weight of root shoot ratio and high vigour Dogridge is more tolerant to salinity than other rootstocks studied.

Keywords

Salt tolerance,
Root to shoot ratio,
Ion toxicity.

Article Info

Accepted:
04 September 2017
Available Online:
10 November 2017

Introduction

Grape (*Vitis* spp) is one of the most commercially grown fruit crops in the world.

Grapes are cultivated in an area of 111.4 thousand hectare with a total production

1,234.9 thousand tons in India (Shinde, 2016). Salinity is a serious concern in grape production, owing to moderates tolerant to saline environment. Salts are a natural component in soils and water. The ions responsible for salination are: Na^+ , K^+ , Ca^{2+} , Mg^{2+} and Cl^- . Among the strategies adopted for sustaining growth and productivity of vine cultivars under salinity use of tolerant rootstocks is widely accepted (Singh *et al.*, 1993). Susceptibility or tolerance of rootstocks to high salinity is a coordinated action of multiple factors. The salinity tolerance induced by rootstock is attributed to root system restricting the movement and or limiting absorption and accumulation of toxic ions from saline soils (Hepaksoyetal, 2006; walker *et al.*, 2002). Plants generally vary in response to soil salinity and grapevine in particular has been defined as moderately sensitive to salinity (Downton, 1977; Mass, 1990). Physiological effects of exposure to salinity in grapevine include reduced stomatal conductance and photosynthesis (Ben-Asher *et al.*, 2006; Downton, 1977) systemic disturbances can lead to reduced growth and vegetative biomass (Shani and Ben-Gal, 2005) and yield (Walker *et al.*, 2002, 2004).

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. The very fact that there are marked differences of relative salt tolerance among the rootstocks but also there are differences in absorption of Cl ion when associated with different cations emphasizes the importance of this study. Hence, this study is aimed to determine the effects of different Cl salts (NaCl , KCl , CaCl_2 and MgCl_2) on the tolerance of grape rootstock measured in terms of growth parameters, dry weight of root to shoot ratio, sodium and chloride content in leaf.

Materials and Methods

The present pot culture study was conducted at Grape Research Station, Rajendhranagar, 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 $17^{\circ} 20' \text{ N}$ and longitude of $78^{\circ} 25' \text{ E}$. The treatments consisted of 20 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 four chloride viz., NaCl , KCl , CaCl_2 and MgCl_2 salts applied at 4meq, 8, 16 and 32 meq/lit concentrations. In the present study the mean of different concentration of salts was presented to study the effect of different cations accompanying the Cl anion on different rootstocks. 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 red soil and well decomposed FYM mixed well in 3:1 proportion. The irrigation water (control) was neutral (pH 7.5), slightly saline (0.85 dSm^{-1}) with chloride (2 meq l^{-1}) and sodium (0.5 meq l^{-1}) levels below the threshold limit. It was safe with respect to residual sodium carbonate and sodium adsorption ratio. After the initial establishment, the rootstocks were irrigated with saline water prepared by mixing four different chloride salts (NaCl , KCl , CaCl_2 and MgCl_2) at different concentrations (4meq, 8, 16 and 32 meq/lit) in irrigation water for three months. The plants were irrigated with uniform volume of water below the field capacity. 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^{-1}) and phosphorus (9.5 kg ha^{-1}), medium in potassium (154 kg/ha). The soil

was neutral in reaction (pH 7.1) and non saline (EC 0.32 dSm⁻¹). Standard procedures were followed for analysis of soil (Jackson 1973) and water (Jackson 1973). 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 root volume (cc) was measured by water displacement method. The leaves were collected from each replication and were washed and oven dried at 60⁰C temperature. Sodium and calcium content in leaves was determined using flame photometer. Magnesium and chlorides was determined by titration (Richard, 1968).

Results and Discussion

Growth parameters

The effect of different chloride salts on the growth parameters like leaf number, shoot length and dry weight of shoot of grape rootstocks are shown in Table 1. Among the different Cl salts significantly highest number of leaves was recorded with MgCl₂ treatment (80.0) on par with CaCl₂ (77.0) and the lowest was recorded with NaCl application (72.0). Among rootstocks highest with Dogridge (87.00) which was on par with 1613-C (85.00) and lowest number of leaves was recorded in Salt Creek (60.0). With respect to shoot length the rootstocks recorded highest with MgCl₂ (73.2cm), followed by CaCl₂ (69.5 cm) and KCl (69.2cm) which were on par with each other, and significantly lowest in NaCl (67.3 cm). The shoot length was maximum in SO₄ (74.3cm) but was on par with RS-19 (72.7cm) and Salt Creek (70.3cm). While the least shoot length was recorded in Dogridge (63.2 cm) which was on par with 1613-C (67.6cm). The interaction effect between rootstock and salts were found to be significant, the highest shoot length was recorded with NaCl and KCl applied to SO₄

and lowest was recorded with NaCl and KCl applied to Dogridge. The rootstocks did not vary significantly with respect to dry weight of shoots. 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. Askri *et al.*, (2012) observed that salinity significantly reduced vine shoot length, whole plant size, leaves, stems and roots in wild grapevine accessions. It is known that plant growth reduction due to salinity can be attributed to the osmotic effects of salts.

Root parameters

Differences in root growth parameters of the rootstock were apparent with addition of Cl salts. There was no significant effect of interaction between different chloride salts and root parameters of rootstocks. The grape rootstocks recorded highest average number of roots, length and dry weight of roots per plant with MgCl₂ and CaCl₂ treatments when compared to KCl and NaCl treatments. Among sources of chloride salts MgCl₂ application recorded significantly highest root volume (125.6 cc) but was on par with CaCl₂ (108.4cc) and KCl (105.6 cc) application. The minimum root volume was recorded with NaCl treatment (86.4 cc). The results clearly depict that effect of accompanying cation on Cl absorption. Chlorides when associated with Na had an adverse effect on root growth when compared to K⁺, Ca⁺² and Mg⁺². This could be because of the toxic effect of Cl as well as the accompanying cation Na. Similar results were reported by Kishore *et al.*, (1985) where Cl when associated with cations Na⁺ and K⁺ were more toxic than Ca⁺² and Mg⁺². Araya *et al.*, (1993) reported that the effect on

decreased growth and survival shown by sodium when accompanying chloride in the salts applied through irrigation was much greater than that of calcium as the accompanying element (Table 2).

Among the rootstocks tested significantly highest root growth parameters reflected in terms of root number, length and dry weight was recorded in Dogridge (59.79, 42.9cm and 24.51g respectively). The highest root volume was recorded with RS-19 (114 cc) but was on par with SO₄ (112.5 cc) and Salt Creek (105cc). The lowest root volume was recorded by Dogridge (100.5 cc) and 1613-C (100.5 cc). Salt influences plant metabolism and the most important effect is halting plant growth and development (Levitt, 1980). Impeded plant growth due to salt could be due to physiological drought caused by low water potential in soil solution, low relative turgidity and osmotic regulations that occurs as a result of increasing cell ionic concentration (Schwarz, 1995).

The effect of different Cl salts on dry weight of root to shoot ratio of different rootstocks, chemical composition of rootstock leaf (Na⁺, K⁺, Ca⁺² and Mg⁺²) and Cl content was reported in Table 3.

Dry weight of root to shoot ratio

The plants with higher dry weight of root to shoot ratio exhibit relative salt tolerance. Divalent cations accompanying chloride anion CaCl₂ (0.6) and MgCl₂ (0.6) recorded higher dry weight of root to shoot ratio when compared to Cl salts with monovalent NaCl (0.5) and KCl (0.5). This could be because the Ca⁺² and Mg⁺² ion had less negative effect on roots than NaCl and KCl (Table 3). Downton and Hawker (1980) reported that root growth was more adversely affected than shoot growth under salinity environment. This might also be because of higher absorption of Cl⁻ associated with Na⁺ and K⁺ when

compared to Ca⁺² and Mg⁺² (Table 3). Similar findings were reported by (Kishore *et al.*, 1985). Hence it can be inferred that tolerance of rootstocks to Cl was more when the accompanying cation was divalent (Ca and Mg) than when the accompanying cation was monovalent. The highest Dry weight of Root to Shoot ratio was recorded with Dogridge (0.6) on par with RS19 (0.6).

Cation composition in leaf (Na⁺, K⁺, Ca⁺² and Mg⁺²)

There was significant difference among rootstocks in their cationic composition with application of different Cl salts (Table 3 and 4). Concentration of Na⁺ was lower in 1613-C and SO₄ when compared to other rootstocks. Similar results were obtained by Shikhamany (1999) with the rootstocks Teleki, 5-A, St. George and 1613-C as compared to Dogridge, Tambe (1999) with Salt Creek as compared to Dogridge and 1616-C and Jagdev Sharma & Upadhyay (2008) with Dogridge as compared to B2-56 in reducing the Na⁺ concentration in the petioles. Fisarakis *et al.*, (2001) reported lowest Na⁺ content recorded when sultana vines grafted on 110R and SO₄ rootstocks especially in roots as compared to 41-B, 1103P and 140 Ru rootstocks. Lal *et al.*, (2007) reported that as general rule salt concentration of leaves increases more quickly in salt sensitive varieties than salt tolerant varieties.

With regard to K⁺ content in leaf, 1613-C recorded lowest K⁺ content while other rootstocks were on par with each other. Tambe (1999) reported that highest K⁺ content was recorded in petioles of Salt Creek as compared to Dogridge and 1613-C when treated with NaCl and Na₂SO₄, while Ruhl *et al.*, 1988 reported in Dogridge and Ramsey, Venugopal, 2007 recorded Thompson Seedless grafted on Salt Creek followed by Dogridge with recommended dose of fertilizers.

Table.1 Effect of varying chloride salts on growth parameters in different grape rootstocks

| Rootstocks | Avg. No. of Leaves Salts | | | | | Shoot length(cm) Salts | | | | | Dry wt of shoot(g) Salts | | | | |
|------------|--------------------------|------|-------------------|-------------------|------|------------------------|------|-------------------|-------------------|------|--------------------------|------|-------------------|-------------------|------|
| | NaCl | KCl | CaCl ₂ | MgCl ₂ | Mean | NaCl | KCl | CaCl ₂ | MgCl ₂ | Mean | NaCl | KCl | CaCl ₂ | MgCl ₂ | Mean |
| Dogridge | 85.7 | 86.8 | 87.4 | 88.4 | 87.0 | 60.1 | 60.2 | 65.4 | 71.0 | 63.2 | 37.1 | 40.3 | 42.0 | 42.9 | 40.6 |
| Salt Creek | 51.4 | 59.0 | 62.0 | 66.8 | 59.8 | 66.5 | 67.8 | 70.5 | 76.2 | 70.2 | 35.9 | 38.4 | 40.1 | 41.3 | 38.9 |
| RS-19 | 65.6 | 69.8 | 71.4 | 74.4 | 70.3 | 68.5 | 70.3 | 72.0 | 79.7 | 72.6 | 36.7 | 37.8 | 39.3 | 39.3 | 38.3 |
| SO4 | 73.4 | 79.2 | 80.4 | 82.6 | 78.9 | 80.2 | 75.2 | 69.4 | 72.1 | 74.2 | 36.5 | 38.1 | 39.1 | 39.5 | 38.3 |
| 1613-C | 83.4 | 84.4 | 85.6 | 87.0 | 85.1 | 61.2 | 73.6 | 68.6 | 66.9 | 67.6 | 37.0 | 38.5 | 39.2 | 39.4 | 38.5 |
| Mean | 71.8 | 75.8 | 77.3 | 79.8 | | 67.3 | 69.4 | 69.2 | 73.2 | | 36.7 | 38.6 | 39.9 | 40.5 | |
| | | SEm± | CD (0.05p) | | | | SEm± | CD (0.05p) | | | | SEm± | CD (0.05p) | | |
| R | | 1.60 | 3.16 | | | | 2.34 | 4.62 | | | | 2.0 | NS | | |
| S | | 1.43 | 2.82 | | | | 2.10 | 4.13 | | | | 1.79 | NS | | |
| RxS | | 3.2 | NS | | | | 4.69 | 9.24 | | | | 3.99 | NS | | |

Table.2 Effect of varying chloride salts on root parameters in different grape rootstocks

| Rootstocks | Avg. No. of Roots Salts | | | | | Avg. Length of Root (cm) Salts | | | | |
|------------|----------------------------|------|-------------------|-------------------|------|--------------------------------|-------|-------------------|-------------------|-------|
| | NaCl | KCl | CaCl ₂ | MgCl ₂ | Mean | NaCl | KCl | CaCl ₂ | MgCl ₂ | Mean |
| Dogridge | 55.2 | 59.3 | 60.7 | 63.8 | 59.7 | 42.0 | 43.2 | 43.1 | 42.9 | 42.8 |
| Salt Creek | 42.7 | 45.1 | 44.9 | 47.1 | 45.0 | 39.2 | 42.0 | 42.1 | 42.3 | 41.4 |
| RS-19 | 45.1 | 46.3 | 49.3 | 49.9 | 47.7 | 35.3 | 40.8 | 40.4 | 39.6 | 39.0 |
| SO4 | 47.3 | 47.5 | 51.1 | 51.7 | 49.4 | 37.6 | 38.5 | 40.6 | 41.2 | 39.4 |
| 1613-C | 47.2 | 52.6 | 53.5 | 54.6 | 52.0 | 35.2 | 39.3 | 41.2 | 41.7 | 39.4 |
| Mean | 47.5 | 50.2 | 51.9 | 53.4 | | 37.9 | 40.8 | 41.5 | 41.5 | |
| | | SEm± | CD (0.05p) | | | | SEm± | CD (0.05p) | | |
| R | | 1.00 | 1.97 | | | | 1.32 | 2.61 | | |
| S | | 0.89 | 1.76 | | | | 1.18 | 2.33 | | |
| RxS | | 1.99 | NS | | | | 2.64 | NS | | |
| Rootstocks | Dry wt. of Roots (g) Salts | | | | | Root volume (cc) Salts | | | | |
| | NaCl | KCl | CaCl ₂ | MgCl ₂ | Mean | NaCl | KCl | CaCl ₂ | MgCl ₂ | Mean |
| Dogridge | 21.1 | 24.2 | 25.8 | 26.7 | 24.5 | 92 | 92 | 102 | 116 | 100.5 |
| Salt Creek | 17.3 | 19.4 | 21.0 | 23.1 | 20.1 | 82 | 118 | 94 | 126 | 105 |
| RS-19 | 18.2 | 20.4 | 23.9 | 24.3 | 21.7 | 84 | 116 | 118 | 138 | 114 |
| SO4 | 20.8 | 20.4 | 22.2 | 23.2 | 21.6 | 90 | 106 | 124 | 130 | 112.5 |
| 1613-C | 17.5 | 19.0 | 20.0 | 21.2 | 19.4 | 84 | 96 | 104 | 118 | 100.5 |
| Mean | 19.0 | 20.6 | 22.6 | 23.7 | | 86.4 | 105.6 | 108.4 | 125.6 | |
| | | SEm± | CD (0.05p) | | | | SEm± | CD (0.05p) | | |
| R | | 1.21 | 2.39 | | | | 5.78 | 11.39 | | |
| S | | 1.09 | 2.14 | | | | 5.17 | 10.17 | | |
| RxS | | 2.43 | NS | | | | 11.55 | NS | | |

Table.3 Effect of varying chloride salts on dry weight of root to shoot ratio, Na and chloride content in different grape rootstocks

| Rootstocks | Root to Shoot Ratio | | | | | Sodium content (%) | | | | | Chloride content (%) | | | | |
|------------|---------------------|------|-------------------|-------------------|------|--------------------|------|-------------------|-------------------|------|----------------------|------|-------------------|-------------------|------|
| | Salts | | | | | Salts | | | | | Salts | | | | |
| | NaCl | KCl | CaCl ₂ | MgCl ₂ | Mean | NaCl | KCl | CaCl ₂ | MgCl ₂ | Mean | NaCl | KCl | CaCl ₂ | MgCl ₂ | Mean |
| Dogridge | 0.5 | 0.6 | 0.6 | 0.6 | 0.60 | 0.22 | 0.05 | 0.04 | 0.04 | 0.09 | 0.98 | 0.88 | 0.80 | 0.81 | 0.87 |
| Salt Creek | 0.5 | 0.5 | 0.5 | 0.6 | 0.50 | 0.26 | 0.05 | 0.04 | 0.04 | 0.10 | 1.30 | 1.31 | 0.95 | 1.00 | 1.14 |
| RS-19 | 0.5 | 0.5 | 0.6 | 0.6 | 0.60 | 0.20 | 0.04 | 0.04 | 0.03 | 0.08 | 1.17 | 1.06 | 1.05 | 0.87 | 1.04 |
| SO4 | 0.5 | 0.5 | 0.6 | 0.6 | 0.50 | 0.14 | 0.04 | 0.04 | 0.04 | 0.06 | 1.22 | 1.07 | 1.05 | 0.94 | 1.07 |
| 1613-C | 0.5 | 0.5 | 0.5 | 0.5 | 0.50 | 0.10 | 0.05 | 0.04 | 0.04 | 0.06 | 1.17 | 1.04 | 1.08 | 0.88 | 1.04 |
| Mean | 0.5 | 0.5 | 0.6 | 0.6 | | 0.18 | 0.05 | 0.04 | 0.04 | | 1.17 | 1.07 | 0.99 | 0.90 | |
| | | SEm± | CD | | | | SEm± | CD | | | | SEm± | CD | | |
| | | | (0.05p) | | | | | (0.05p) | | | | | (0.05p) | | |
| R | | 0.02 | 0.03 | | | | 0.01 | 0.02 | | | | 0.05 | 0.10 | | |
| S | | 0.01 | 0.03 | | | | 0.01 | 0.02 | | | | 0.05 | 0.09 | | |
| RxS | | 0.03 | NS | | | | 0.02 | 0.03 | | | | 0.10 | NS | | |

Table.4 Effect of varying chloride salts on K, Ca and Magnesium content in different grape rootstocks

| Rootstocks | Potassium content (%) | | | | | Calcium content (%) | | | | | Magnesium content (%) | | | | |
|------------|-----------------------|------|-------------------|-------------------|------|---------------------|------|-------------------|-------------------|------|-----------------------|------|-------------------|-------------------|------|
| | Salts | | | | | Salts | | | | | Salts | | | | |
| | NaCl | KCl | CaCl ₂ | MgCl ₂ | Mean | NaCl | KCl | CaCl ₂ | MgCl ₂ | Mean | NaCl | KCl | CaCl ₂ | MgCl ₂ | Mean |
| Dogridge | 1.88 | 2.37 | 1.34 | 1.17 | 1.69 | 1.72 | 1.51 | 1.96 | 1.63 | 1.70 | 0.67 | 0.67 | 0.68 | 1.26 | 0.82 |
| Salt Creek | 1.78 | 2.46 | 1.39 | 1.12 | 1.69 | 1.53 | 1.53 | 2.05 | 1.46 | 1.64 | 0.70 | 0.68 | 0.71 | 1.05 | 0.78 |
| RS-19 | 1.79 | 2.35 | 1.67 | 1.53 | 1.84 | 1.68 | 1.49 | 2.40 | 1.60 | 1.79 | 0.71 | 0.66 | 0.66 | 1.14 | 0.79 |
| SO4 | 1.42 | 1.83 | 1.25 | 1.11 | 1.40 | 1.78 | 1.58 | 2.82 | 1.63 | 1.95 | 0.64 | 0.69 | 0.65 | 0.99 | 0.74 |
| 1613-C | 1.32 | 1.70 | 0.86 | 0.89 | 1.19 | 1.63 | 1.47 | 2.59 | 1.56 | 1.81 | 0.64 | 0.63 | 0.67 | 1.06 | 0.75 |
| Mean | 1.64 | 2.14 | 1.30 | 1.17 | | 1.67 | 1.51 | 2.36 | 1.58 | | 0.67 | 0.67 | 0.68 | 1.10 | |
| | | SEm± | CD | | | | SEm± | CD | | | | SEm± | CD | | |
| | | | (0.05p) | | | | | (0.05p) | | | | | (0.05p) | | |
| R | | 0.09 | 0.17 | | | | 0.10 | 0.19 | | | | 0.03 | NS | | |
| S | | 0.08 | 0.15 | | | | 0.09 | 0.17 | | | | 0.03 | 0.06 | | |
| RxS | | 0.17 | NS | | | | 0.19 | NS | | | | 0.06 | NS | | |

Fig.1 Effect of different chloride salts on 'Na' content (%) in leaf in different grape rootstocks

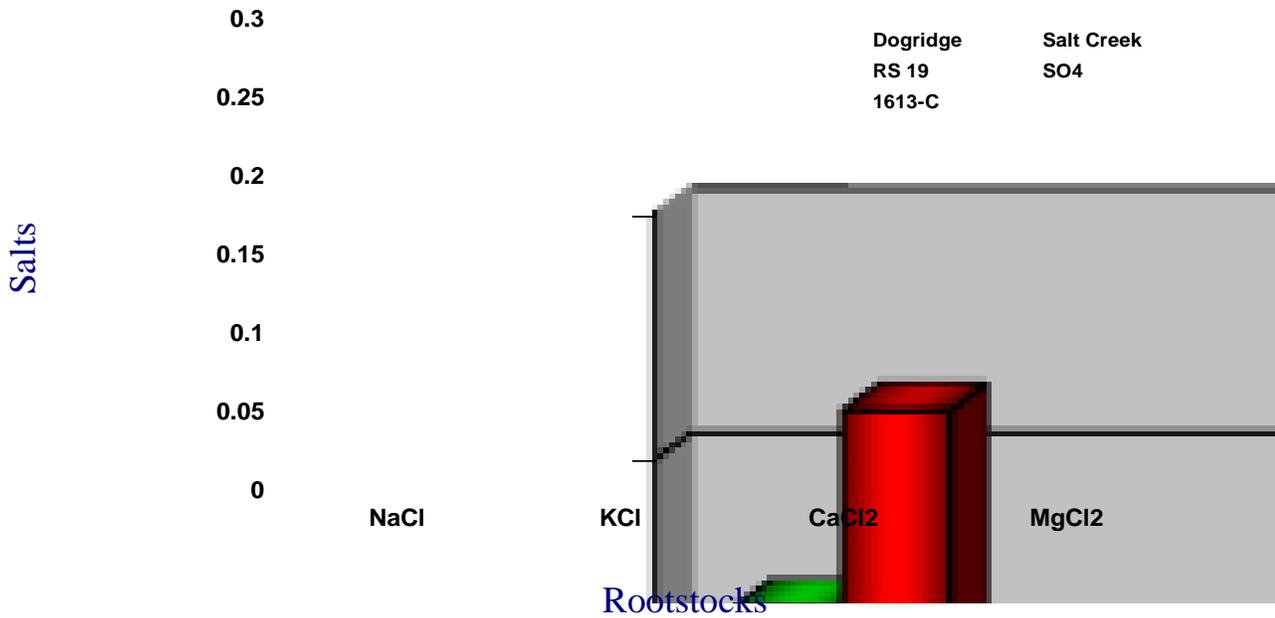
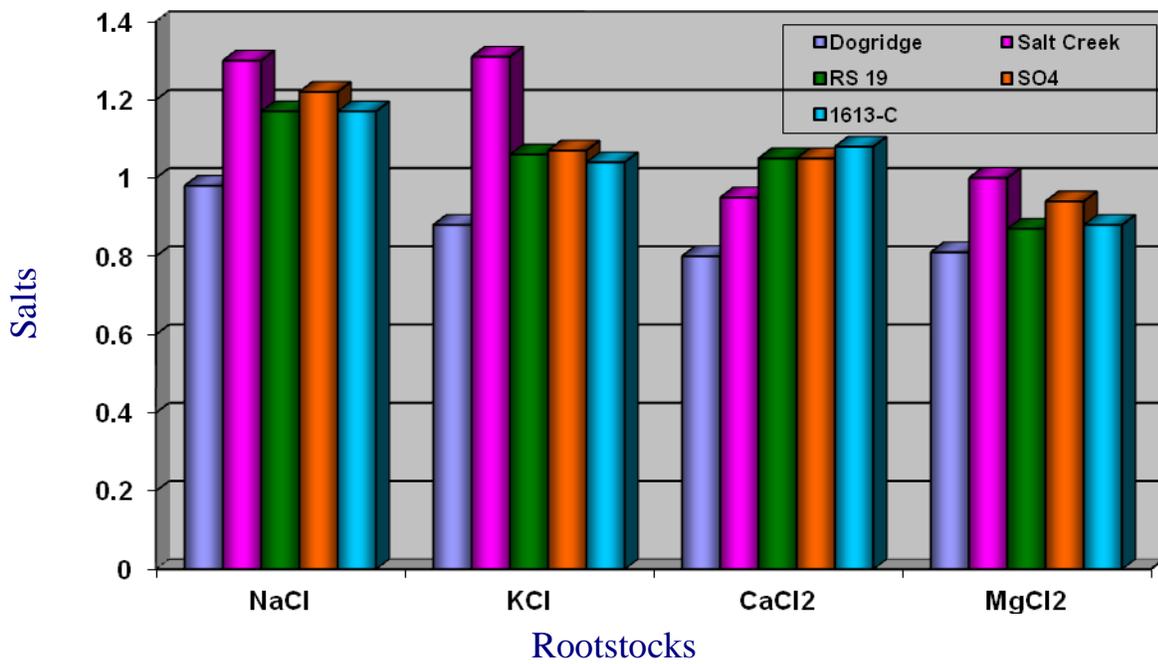


Fig.2 Effect of different chloride salts on 'Cl' content (%) in different grape rootstocks



The variation observed in chemical concentration in leaves of different genotypes might be due to influence of inherent character in genotypes used and their differences in adaptability to soil salinity.

The Ca content recorded with Dogridge and Salt Creek was lower as compared to SO₄ and 1613-C and RS-19. Venugopal (2007) in his field experiment reported the lowest calcium content with Thompson Seedless grafted on Salt Creek followed by Dogridge and 1613-C. The reports from NRC, Pune reveal lowest calcium content in Thompson Seedless grafted on Salt Creek as compared to B2/56, Dogridge and 1613-C (NRC annual Report, 2004-2005).

No significant differences among rootstocks were recorded with regards to Mg content in leaf. The studies at NRC, Pune also reported non-significant differences in magnesium content at bud differentiation stage in Thompson Seedless either on its own root or when grafted on Dogridge, Salt Creek and 1613-C (NRC annual Report, 2004-2005). Similar results obtained by Venugopal (2007).

The application of CaCl₂, MgCl₂ and KCl salts did not have significant influence the uptake of Na⁺ ion. The rootstocks like 1613-C, SO₄ which recorded low accumulation of monovalent cations i.e. Na & K content on the other hand recorded higher concentration of divalent cation i.e. Ca⁺². While Dogridge, Salt Creek, RS-19 which recorded high Na⁺ and K⁺ content, recorded low Ca⁺² content (Figs. 1 and 2).

Chloride (Cl⁻) composition in leaf

Salinity tolerance was also associated with their ability to exclude Cl⁻. In the present study there a significant effect of accompanying cation on chloride content in leaf. Higher chloride content in leaf was

recorded with NaCl application followed by KCl, while lower chloride content was recorded with CaCl₂ and MgCl₂ which were on par with each other. It can be inferred that absorption of Cl⁻ was higher when associated with monovalent cations Na⁺ and K⁺ when compared to divalent cations Ca⁺² and Mg⁺². High chloride exclusion ability represents the salt tolerance (Walker *et al.*, 2003). Significantly lowest chloride content was recorded with Dogridge rootstock. Whereas the highest chloride content were recorded with Salt Creek (1.14%) and was on par with other rootstocks. The most tolerant rootstocks are those capable of maintaining low Cl concentrations in either their own foliage or that of the scion (Alexander, Groot-Obbink, 1971; Downton, 1977a; 1977b) 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).

However of the grapevine rootstocks rated as tolerant to salinity due to their ability to prevent Na and/or Cl uptake and translocation to aerial parts of the vines (Tregeagle *et al.*, 2006). In the present study though the Dogridge rootstock recorded lowest chloride content it recorded higher Na⁺ content in leaf. The results were supported Kuiper (1968) who also reported an inverse relation between chloride and sodium transport capacities by grape root lipids suggesting that rootstocks that transport chloride readily should restrict sodium transport and vice versa. There is often a negative correlation between Na⁺ and Cl⁻ concentration in the leaves.

The relative salt tolerance was assessed based on growth parameters, dry weight of root to shoot ratio—and also on the ability of rootstocks to limit uptake of Na and Cl ions. The Cl salts associated with divalent cations MgCl₂ and CaCl₂ treatments recorded the higher number of average roots, leaves, length

of longest root, dry weight of roots per plant and also dry weight of root to shoot ratio when compared to those associated with monovalent cations KCl and NaCl. The application of CaCl₂, MgCl₂ and KCl salts did not have significant influence the uptake of Na⁺ ion. The Cl accumulation in leaf was significantly higher when applied in the form of NaCl followed by KCl and it was significantly lower when applied in the form of CaCl₂ and MgCl₂ salt. The order of tolerance to chloride salts by grape rootstocks was in of the order CaCl₂ >MgCl₂ > KCl >NaCl salts. Grapevine rootstocks rated as tolerant to salinity due to their ability to prevent Na and/or Cl uptake and translocation to aerial parts of the vines based on the above criteria Dogridge is commonly used rootstock in problematic soil due to its high vigour, high dry weight of root to shoot ratio and less accumulation of chlorides in leaves.

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How to cite this article:

Saritha, K., D. Vijaya, B. Srinivas Rao and Padma, M. 2017. Relative Salt Tolerance of Different Grape Rootstocks to Different Chloride Salts. *Int.J.Curr.Microbiol.App.Sci*. 6(11): 24-33. doi: <https://doi.org/10.20546/ijcmas.2017.611.003>