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GROWTH AND MORPHOLOGY OF SO_4 GRAPEVINE ROOTSTOCK (*V. BERLANDIERI* X *V. RIPARIA*) AS AFFECTED BY DIFFERENT LEVELS OF SALINITY

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Abstract

A pot experiment was carried out during two seasons of 2016 and 2017 under shade- net greenhouse conditions. Four salinity treatments (control (tab water), 1500 ppm, 2500 ppm and 3500 ppm NaCl) were used to investigate the effect of irrigation with saline water on growth and morphological parameters in SO_4 grapevine rootstock. Growth parameters reflected in terms of shoot length and diameter, leaf area, fresh and dry weight of shoots for vegetative growth beside root number, length, fresh weight and dry weight for root system. The high concentration treatment (3500 ppm) led to death more than 85% of SO_4 transplants and excluded from any statistical analysis. Shoot length, shoot diameter, leaf area and shoot fresh and dry weights were significantly decreased by salinity in both seasons. Increasing salinity level showed a significant decrease in root system length and roots number in both seasons. Results showed decrease in root: shoot ratio by increasing salinity of irrigation water. Consequently the results revealed that SO_4 grapevine rootstock is relatively sensitive to salt stress.

***Key words*:** Grapevine, Rootstock, SO_4, Salinity, Growth, Morphological parameters.

Introduction

Water-related stress (drought and salinity) represents the common abiotic type of plant stresses (Bray *et al*., 2000). Salinity is a great risk for crop production in many areas around world (Zhu, 2000, Munns, 2002). Salinity affects about 10% of the land area in the world (Cheong and Yun, 2007). More than 80 million hectares of arable land worldwide are estimated to be affected by salinity (Munns and Tester, 2008).

Sodium chloride (NaCl) salt has the main role in causing toxicity and damage to plants. Na^+ and Cl^- have been taken as the major salinization factors in soils and plants (Gratten and Grieve, 1999). Salinity (NaCl) causes several problems in plants even when present at low levels. Depending on the concentration, salts can inhibit growth or even lead to plant death (Volkmar *et al*., 1998, Hasegawa *et al*., 2000, Munns, 2002).

Rootstock utilization has been significantly increased since the 1970s. Rootstocks vary in rooting ability and affect scion responses in growth and fruit quality and quantity (Paranychianakis *et al*., 2004, Koundouras *et al*., 2008). Grapevine rootstocks are used for tolerance to abiotic stresses such as: drought, high salinity and Fe^{2+} deficiency and resistance to various pests and diseases (Fisarakis *et al*., 2001, Walker *et al*., 2004, Marguerit *et al*., 2012).

This study is aimed to determine the effects of salinity (NaCl) on the growth and morphological parameters and the possibility of using these parameters to test the tolerance or sensitivity of grapevine genotypes to salt stress.

Material and Methods

Plant Material: The research was carried out during two successive seasons (2016-2017) in the research greenhouse at faculty of agriculture, Cairo University, Giza, Egypt. Hard wood cuttings of SO_4 grapevine rootstock (*V. berlandieri x V. riparia*) after treatment with indole buteric acid (1000 ppm) were planted in 10 L black plastic pots filled with sandy soil. Pots were placed in shade-net greenhouse for a period of 8 months. Nutrition solution was added at the 0.25-strength Hoagland nutrient concentration (Fozouni *et al*., 2012).

Salinity Treatments: Four salinity treatments were applied by adding sodium chloride (NaCl) to irrigation water (tap water or control, 1500, 2500 and 3500 ppm). All transplants were irrigated 2-3 times weekly with salt solutions and tap water for three months.

Measurements

Salinity symptoms measurements: Date of first salinity symptoms appearance was recorded for each treatment of rootstocks. Mortality rate was calculated at the end of experiment.

Vegetative growth parameters: Main Shoot length and diameter of each transplant were measured at the end of experiment. Leaf area was measured in each treatment using leaf area meter (Model CI 203, U.S.A.). Shoots of each transplant were weighed directly after separation from root system for determination of fresh weight.

Root system growth parameters: Root system length was measured (the longest main root) and main roots were counted. Root system of each transplant was weighed directly after separation from shoots and cleaning from the soil for determination of fresh weight.

Dry matter: Shoots and roots were oven dried at 70°C for 48 h. to determine dry weight. The ratio of root to shoot weight was obtained by dividing dry weight of root by the dry weight of shoot.

Statistical analysis: The data were analyzed by analysis of variance (ANOVA) using the general linear models ''GLM'' procedure of the SAS software (version 9.0, SAS Institute, Cary, NC). Significant differences between treatments were assessed by means of multiple Duncan range tests (Duncan, 1955). The high concentration treatment (3500 ppm) led to death more than 85% of SO_4 transplants and excluded from any statistical analysis.

Table 1: Appearing date of salinity symptoms and mortality rate of SO_4 transplants as affected by irrigation with saline water during 2016 and 2017 seasons.

Salinity treatments (ppm)	Season 2016		Season 2017	
	Date of first salinity symptoms appearance	Mortality rate (%)	Date of first salinity symptoms appearance	Mortality rate (%)
Tab water	-	0.00 [c]	-	0.00 [c]
1500	10th week	0.00 [c]	10th week	0.00 [c]
2500	6th week	51.85 [b]	6th week	48.15 [b]
3500	4th weeks	92.59 [a]	4th weeks	85.19 [a]

* Values shown are means, within each column, different letters indicate signiûcant differences according to means of multiple Duncan range tests ($P < 0.05$).

Results and Discussion

Salinity symptoms measurements

Salt injury symptoms appeared in all salinity treatments as shown in table 1. Symptoms were chlorosis, necrosis and leaf burn. Symptoms appeared earlier on transplants treated with highest level of salinity (3500 ppm). In the sixth week of treatment, salinity injury symptoms appeared on transplants irrigated with saline water (2500 ppm), then after 4 weeks by lowest level of salinity (1500 ppm). In this regard, severe salt injury symptoms (leaf burn, defoliation and shoot necrosis) were appeared on grapevine leaves at high salt concentration 100-150 mM Nacl (Mohammadkhani *et al*., 2012, Baneh *et al*., 2014).

There are no deaths among control transplants and that treated by lowest salinity level (1500 pmm). Mortality rate was significantly affected by increasing salt

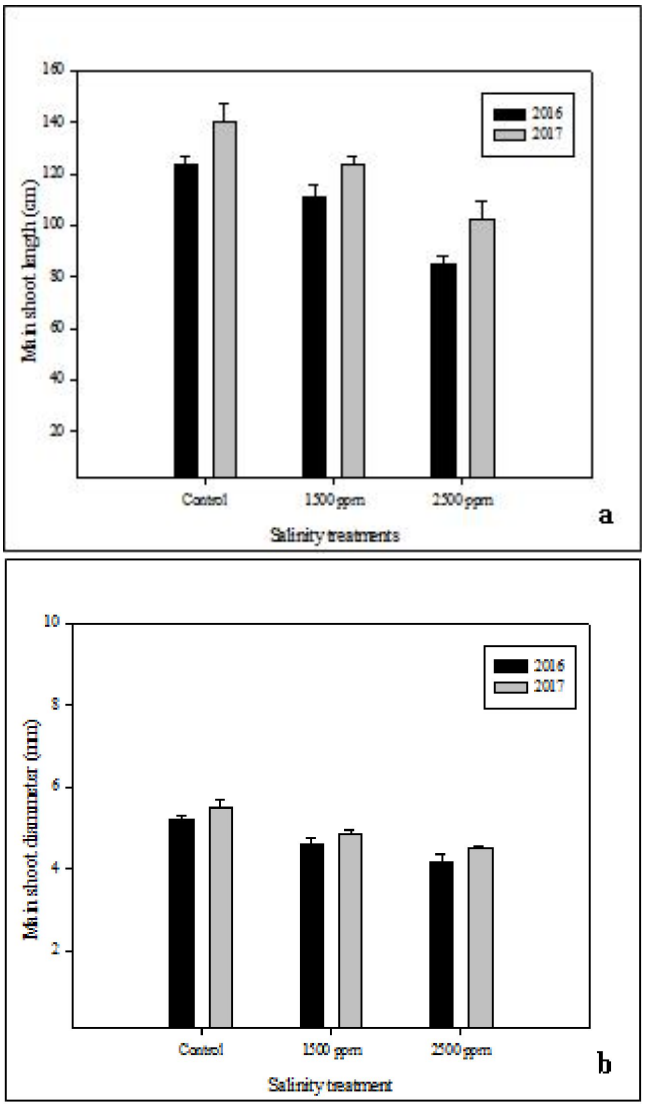

Fig. 1. Effect of salinity treatments on shoot length (a) and diameter (b).

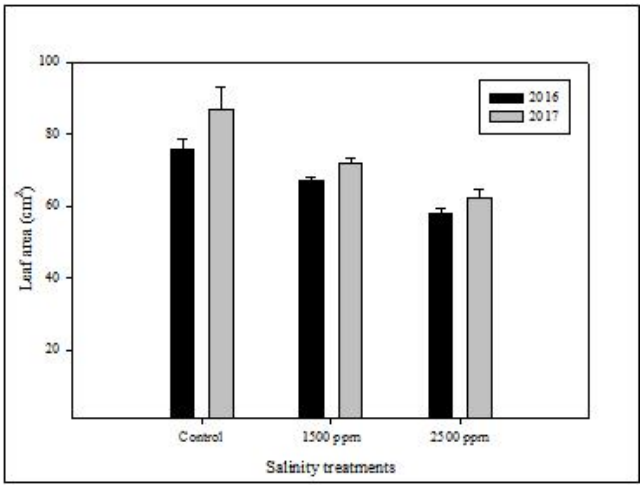

Fig. 2: Effect of salinity treatments on leaf area.

concentration in irrigation water compared with the control. The highest mortality rate was 92.6% in the first season and 85.1% in the second season by the highest salinity level (Table 1). Similarly, increasing salinity level of irrigation water decreased survival percentage (Salem *et al*., 2011). Grapevine mortality rates also increases as the concentration of salts in the irrigation water increases (Dag *et al*., 2015).

Vegetative growth measurements

Irrigation with saline water significantly decreased shoot length in both seasons. Highest concentration of salinity (2500 ppm) reduced shoot length with a decrease of 27.2: 31.1 % compared to the control transplants based on season. Transplants irrigated with tab water recorded the highest shoot length in both seasons about 123.63 and 140.27 cm respectively (Fig. 1a). The same trend with shoot diameter that was affected by salt stress. Control transplants represented the highest value of shoot diameter with 5.17 and 5.49 mm followed by transplants under saline conditions with reduction rate about 11: 19.5% according to salt concentration in irrigation water (Fig. 1b).

Previous studies on grapevine reported that shoot length was significantly reduced under salinity conditions (Askri *et al*., 2012, Fozouni *et al*., 2012, Doulati Baneh *et al*., 2015). Reduction rate of shoot length was between 18.1% and 33.5% (Saritha *et al*., 2016). Also, shoot diameter decreased with an increase in salt stress intensity in the studied grapevine cultivars (Doulati Baneh *et al*., 2014). Reduced cell elongation and cell division result in slower leaf appearance and inhibition of shoot growth (Munns, 2002).

The highest leaf area was achieved by transplants irrigated with tab water in both seasons (75.8 and 87.1 cm^2 respectively). There was a progressive significant reduction in leaf area with increasing salt level in the irrigation water. Leaf area extension was decreased with varying degrees among salinity levels. The lowest leaf area was observed in treatment with high salinity level in both seasons. The reduction rate of leaf area was about 11.7% and 23.5% respectively with increasing salinity levels from 1500 ppm to 2500 ppm in the first season and 17.7% and 28.3% in the second season compared to control transplants (Fig. 2).

In the same way, grapevine genotypes showed significant decrease in leaf growth under salinity conditions, especially in severe salinity (50 and 100 mM NaCl) treatments, as average leaf size decreased under salinity compared to the control about 16% - 23.4% at 100 mM NaCl (Mohammadkhani *et al*., 2012). Leaf area decreased more than 50% in saline treatments due a decrease in their size (Venier *et al*., 2018). The decline in leaf growth is the earliest response of glycophytes exposed to salt stress (Munns and Tester, 2008). High NaCl levels inhibited leaf expansion, largely due to an

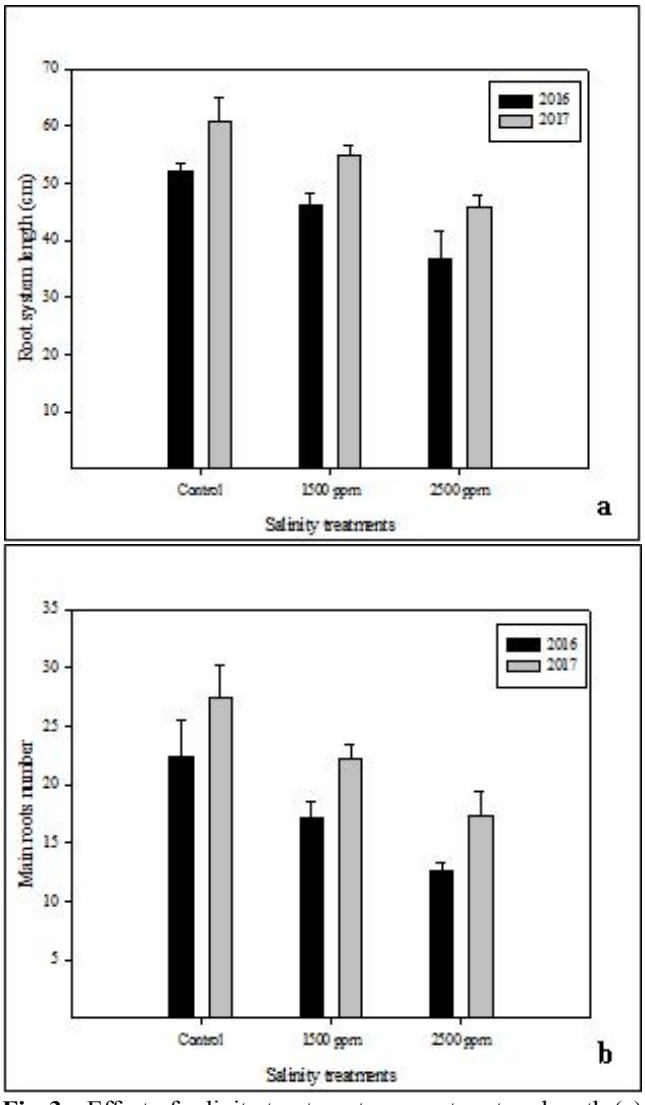

Fig. 3: Effect of salinity treatments on root system length (a) and main roots number (b).

inhibition of cell division rather than to cell expansion (Chartzoulakis and Klapaki, 2000).

Root system growth parameters

Transplants irrigated with tab water recorded the highest root length in both seasons (52.1 and 60.7 cm respectively). Irrigation with saline water significantly decreased root length in both seasons. The lowest value of root length was observed in transplants treated with highest concentration (2500 ppm) of salinity in both seasons (Fig. 3a). In the same way, roots number was decreased significantly with increasing salt concentration of irrigation water. Control transplants showed the highest root number in both seasons. Roots number was decreased in transplants under saline conditions from 19.4 and 23.4% according to season under lowest level of salinity (1500 ppm) to 36.9 and 43.5% under highest level of salinity (2500 ppm) (Fig. 3b).

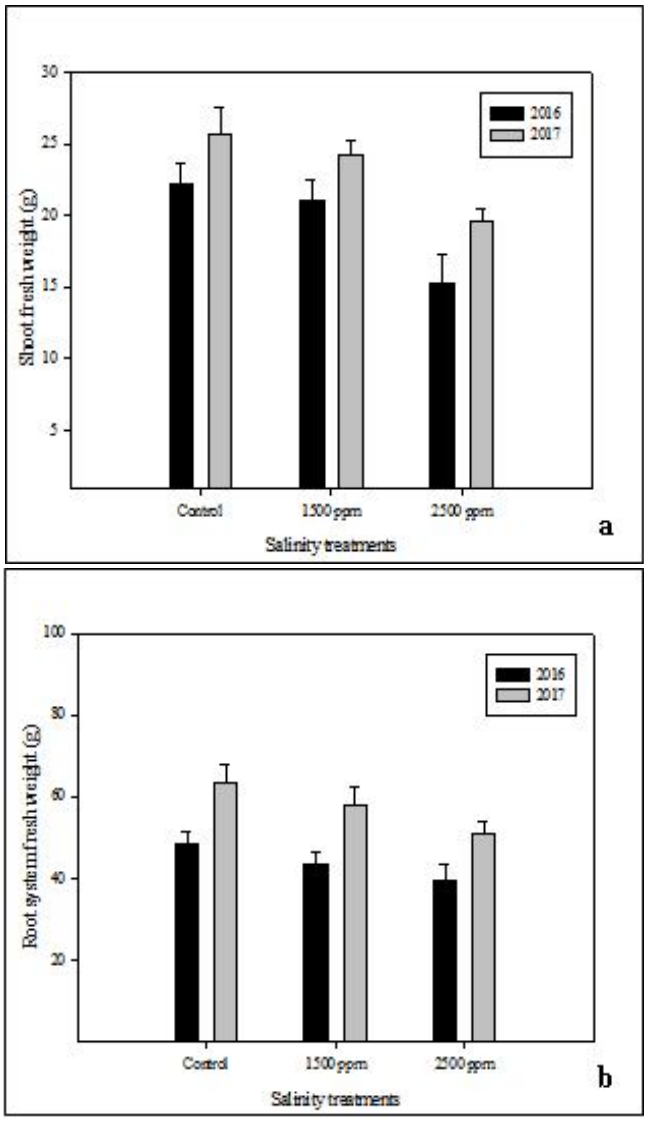

Fig. 4: Effect of salinity treatments on fresh weight of shoot (a) and root system (b).

Root lengths were significantly reduced at all salinity levels (Fozouni *et al*., 2012, Mohammadkhani *et al*., 2012). The higher NaCl concentrations declined root length (Upreti and Murti, 2010). Saline root irrigation (25 mM NaCl) depressed root growth by 17% (Stevens *et al*., 1996). The presence of NaCl at 80, 120 and 150 mM decreased the root number of all grapevine varieties under *in vitro* conditions (Charbaji and Ayyoubi, 2004). There are reports that salinity stress reduces root extension growth and also influences negatively the root hair length and density in many plant species (Peterson and Farquhar, 1996).

Fresh weight of transplant parts

Fresh weight of transplant parts was significantly affected by all levels of salinity comparing to control transplants in both seasons. Control transplants recorded the highest fresh weight of aerial parts (22.2 and 25.7 g) and root system (48.7 and 63.6 g) in both seasons. Increasing salt concentration of irrigation water to 2500 ppm led to significant decrease in fresh weight of aerial parts about 23.8 to 31.4% less than control transplants (Fig. 4a). Increasing salinity level of irrigation water led to significant decrease in fresh weight of root system by about 9.2 to 19.7% less than control transplants according to salt concentration in irrigation water and season (Fig. 4b).

With regard to these parameters, increasing salinity levels had a significantly decreasing effect on fresh and dry weights of both root and stem (Bybordi, 2012). Fresh weight of vine shoots and roots was decreased as compared to control with increasing salinity treatments (Mohammadkhani *et al*., 2012). Also, limited growth due to NaCl observed in grapevine cultivars under *in vitro* conditions (Alizadeh *et al*., 2010). Salinity reduced shoot fresh weight by reducing both shoot length and total leaf area (Mohammadkhani *et al*., 2012).

Dry matter

Increasing salinity level showed a significant reduction in dry weight of shoot and root system. Increasing salinity level to 2500 ppm showed a significant reduction in dry weight of shoots around 30.2% in first season and 33.65% in second season (Fig. 5a). The lowest dry weight of root was presented in transplants treated with highest salinity level (2500 ppm) in both seasons (15.1 and 18.8 g respectively). Dry weight of roots decreased 25.6 to 46.9 % according to salinity level and season compared to control transplants (Fig. 5b).

Similar reduction of dry matter weight of grapevine under salinity conditions was previously reported by (Shani and Ben-Gal, 2005). Dry weights of all vine parts were

significantly reduced at all salinity levels (Mohammadkhani *et al*., 2012). Salinity decreased the vine dry weight through decreasing shoot length and total leaf area (Bybordi, 2012). The decrease in plant biomass due to salinity may be related to physlogical drought, ion toxicity and nutrition imbalance(Saritha *et al*., 2017).

Root/shoot ratio

The lowest Root/shoot ratio was recorded by transplants irrigated with highest salinity level in both seasons (2.13 and 2.41 respectively). There was a progressive significant decrease in root/shoot ratio with increasing salt level in the irrigation water. The highest root/shoot ratio was observed in transplants irrigated with tab water in both seasons. The decrease rate of root/shoot ratio was about 14.9% and 24.1% respectively with increasing salinity levels in the first season and 10.1% and 19% in the second season compared to transplants irrigated with tab water (Fig. 6).

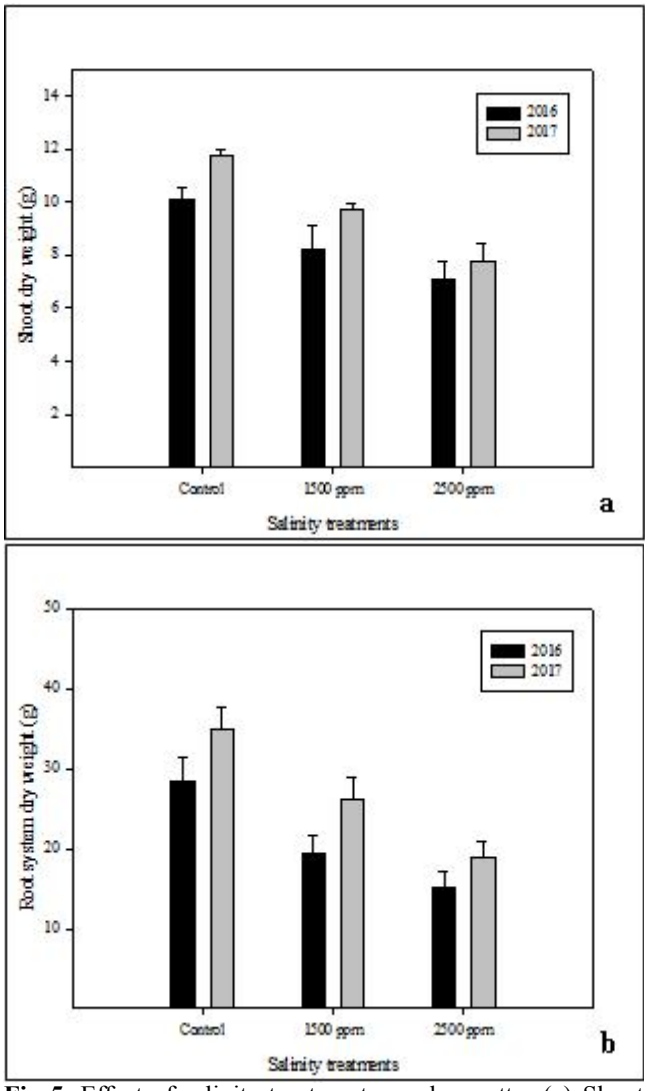

Fig. 5: Effect of salinity treatments on dry matter (a) Shoot dry weight (b) Root system dry weight.

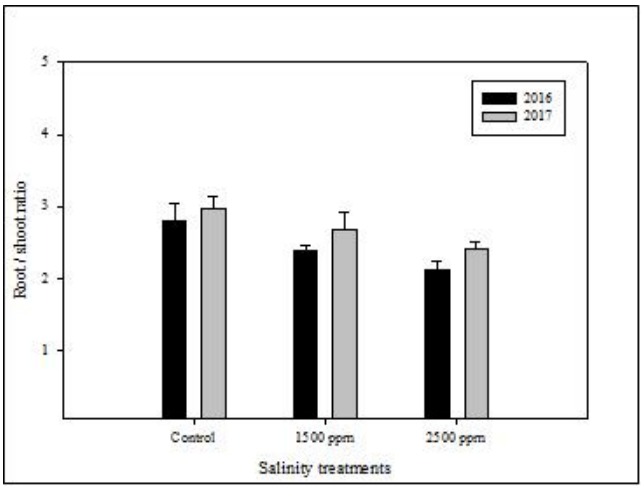

Fig. 6: Effect of salinity treatments on root/shoot ratio.

In this regard, root/shoot ratio decreased in grapevine rootstocks by increasing salinity levels from 4 to 32 meq Cl^-/l (Saritha *et al*., 2016). However, The root/shoot dry mass ratio, showed increasing trends up to 100 mM NaCl in short-term response (two or three weeks after salt treatment). The accumulation of dry matter decreased more in shoots than in root and resulted in higher root/shoot ratio (Upreti and Murti, 2010, Fozouni *et al*., 2012).

Conclusion

The growth and morphological parameters of SO_4 grapevine rootstock were compared under shade-net greenhouse conditions using four salinity treatments. The high concentration treatment (3500 ppm) led to death more than 85 % of SO_4 transplants. Irrigation with saline water resulted in reduction of growth factors of SO_4 transplants in both seasons. According to the above mentioned results, it can be concluded that SO_4 grapevine rootstock is relatively sensitive to salt stress.

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