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'Superior Seedless' grafted on three selected grapevine rootstocks grown on calcareous soil under diluted brackish water irrigation. I. Growth performances

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The authors declare no competing interests.

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Abstract: Mixing brackish water with conventional quality water for irrigation in ratios to maintain satisfactory vigor of grapevines might be a feasible management practice. The objective of this study was to evaluate the performance of three grape rootstocks that are used worldwide and locally; R110, 41B and P1103, irrigated with three salinity levels: 1.5, 3.0 and 5.0 dS m^{-1} in addition to the 0.8 dS m^{-1} control. A randomized complete block design was used with three blocks of 12 pots each. 'Superior Seedless' grafted on P1103 showed better performance regarding chlorophyll content, stem length and number of young leaves and even growth after bud break. It does seem that grapevine rootstocks that have either *V. rupestris* or *V. berlandieri* in their parentage are good candidates for salinity tolerance. It can be concluded that irrigation with diluted brackish water can be practiced for a certain period of time (two months from April to June); according to our findings under conditions of the experiment, to be followed by irrigation with good quality water in order to flush excessive salts out of the root zone.

1. Introduction

Worldwide, during the last two decades, effluent and saline water reuse for irrigation purposes has been becoming an increasingly common practice (Bustan *et al.*, 2005; Paranychianakis and Angelakis, 2008). However, effluent and saline water irrigation is also associated with potential disadvantages such as, spreading of infectious diseases, nutrients release to the environment and salt accumulation (Bustan *et al.*, 2005; Niu *et al.*, 2008). Salt accumulation in the soil profile causes adverse effects on many crop yields; mainly by causing osmotic stress. Thus, salt tolerant crops, cultivars or genotypes must be chosen to ensure that salinity-induced damage and/or yield reduction are minimal. Mixing low quality water (e.g. brackish water) with conventional quality irrigation water in ratios to keep the salinity of the irrigated soils below the threshold of the target crop might be an acceptable management practice and was reported by many researchers (e.g. Abdel Gawad and Ghaibeh, 2001).

Considerable yields were obtained using saline irrigation water (4-12 dS m^{-1}) in crops that had been previously defined as moderately sensitive to salt stress (Bustan *et al.*, 2004). In some crops (e.g., tomato) the reduction in the fresh yield was compensated by an increase in fruit dry weight and other quality parameters (Mizrahi *et al.*, 1988). Bustan *et al.* (2005) reported that the combination of fresh irrigation water (1.2 dS m^{-1}) and brackish water (7 dS m^{-1}) increased the yield level of melon in comparison to that of fresh water plants. In addition to the effects of salinity on crop yield, growth, leaf chlorophyll and mineral content are also affected. In this regard, vines that were grafted showed less Cl^- in the leaves compared to vines on their own roots (Walker *et al.*, 2004). Among the rootstocks studied, P1103 was the best chloride excluder based upon the results of leaf chloride concentrations. On the other hand, despite that own rooted 'Sultana' vines accumulated more Cl^- and Na^+ in the leaves, they were considered to better tolerate salinity conditions compared to those grafted based upon accumulating more dry matter (Fisarakis *et al.*, 2001).

There is great debate regarding the tolerance of grapevines to salinity. Moreover, contradictions can be found in the literature in terms of the salt tolerance of grapevine rootstocks implying that different factors are involved, which eventually determine grapevine response to salt stress. Southey and Jooste (1991) found that American hybrids performed poorly in response to salinity when used as rootstocks for the cultivar 'Colombard'. In addition, Cavagnaro *et al.* (2006) concluded that Argentinean cultivars performed better than European cultivars in an *in vitro* salinity evaluation study. Regarding differences in ranking rootstocks, Dardeniz *et al.* (2006) indicated that 41B was the most salt resistant rootstock, followed by 140Ru and P1103, and the least resistant was 5 BB. On the other hand, a previous study showed that the highest salt resistance was obtained when P1003 was used as a rootstock (Walker *et al.*, 2002). Our hypothesis is that alternate irrigation with diluted brackish water followed by irrigation with good quality water could result in, on one hand, saving fresh water for other uses and, on the other hand, establishing good vineyards. In addition, American rootstocks could perform differently under diluted brackish irrigation water. Therefore, the objective of this study is to evaluate the vigor performance of 'Superior Seedless' cultivar grafted on three pot grown rootstocks: P1103, R110 and 41B under different diluted brackish water irrigation levels to detect a suitable irrigation period with diluted brackish water, without showing adverse effects on growth.

2. Materials and Methods

Plant and soil material

Three grape rootstocks were evaluated in this study: R110 (*Vitis berlandieri* x *V. rupestris*), 41B (*V. berlandieri* x *V. vinifera*) and P1103 (*V. berlandieri* x *V. rupestris*). The rootstocks were purchased from Les Pépiniéristes du Comtat, Sarrians, France. After being imported, *Vitis vinifera* 'Superior Seedless' was grafted on the rootstocks in a local nursery; (Al-Bushra Nurseries, May, 2013). Grafted plant materials were planted in polyethylene bags filled with peatmoss.

The one year old grafted grapevine rootstocks were grown for several months to allow for the formation of a well-developed root system before applying treatments. Fertilizers and fungicides were applied as necessary.

The soil was brought from the southern Jordan Valley. The soil was relatively saline with an EC of 3.88 dS m^{-1}. Such soils are common in the Jordan Valley under the agricultural practices applied by farmers. Soil was crushed and sieved through 1 cm sieve and plastic pots (the working volume of the pots was 44 L) were filled with 50 kg each in order to roughly have a bulk density of 1.14 g cm^{-3}. A soil sample was taken to be analyzed for texture and some chemical properties (Table 1). The pots were placed in a controlled greenhouse. Grafted grapevines were transplanted in February and the growth was unified based on the number of buds and root length. The root system was cut back to 15 cm in length and the vegetative system was cut back to eight buds.

Table 1 - Chemical properties of the soil brought from the southern Jordan Valley

Soil property	Value
Soil texture	Clay
pH	8.25
EC 1:1	3.88 dS m^{-1}
Organic matter	1.99%
Ca	761.52 mg kg^{-1} soil
Mg	121.52 mg kg^{-1} soil
$CaCO_3$	450.00 g kg^{-1} soil
Soluble K	29.00 mg kg^{-1} soil
Soluble Na	85.00 mg kg^{-1} soil
Olsen-P	5.99 mg kg^{-1} soil
SO_4	27.73 mg kg^{-1} soil
Cl	1489.66 mg kg^{-1} soil

Irrigation treatments and experimental design

Brackish water was brought from Al-Karameh dam located in the Jordan Valley and stored in a galvanized tank. A water sample was taken to be analyzed for some chemical properties (Table 2). Three levels of irrigation water salinity, in terms of electrical conductivity (EC), were applied: 1.5, 3.0 and 5.0 dS m^{-1} in addition to the 0.8 dS m^{-1} control. The treatments were prepared by mixing the dam water with tap water. A portable conductivity meter (Model Cond 3210, WTW, Germany) was used to measure the EC and to obtain the determined salinity levels. A randomized complete block design was used with three blocks of 12 pots each. The grafted grapevines started to break the dormancy period during spring. Composite fertilizer (20: 20: 20), urea and ammonium sulfate were applied to the grapevines and growth was again unified before applying the assigned treatments. Irrigation with the assigned treatments started in May. All pots received the same amount of water whenever irrigation was applied. Each pot received a total amount of irrigation water equal to 446 mm. Irrigation was scheduled according to evaporation readings from free water surface (in mm) taken every 48 hours and corrected using proper grapevine crop coefficient of 0.30 (according to Food and Agriculture Organization of the United Nations- FAO).

Table 2 - Chemical analysis of brackish water used for irrigation in the current research

Water properties	Value
pH	8.62
EC	15.43 dS m^{-1}
Cl	6098.00 mg l^{-1}
Ca	801.60 mg l^{-1}
Mg	710.53 mg l^{-1}
K	144.45 mg l^{-1}
Na	2335.00 mg l^{-1}

Chlorophyll content and growth parameters

A SPAD-502 purchased from Minolta CO., LTD, Japan, was used to measure the chlorophyll content of fully expanded matured leaves before irrigation with brackish water on April, 2014 and after irrigation with water on June, 2014 and November, 2014. Shoot length, leaf area and number of newly formed leaves were recorded three times during the growing season of 2014 on June, August and October.

Leaf sampling and analysis

Fully expanded mature leaf samples were taken in June, August and October, 2014. Leaf fresh and dry weights were determined. Leaf water percentage was determined gravimetrically. After being dried, the leaf samples (5 leaves/plant) were analyzed for K, P, Na, Mg and Ca. Leaf area was also determined in November, 2014 by using a leaf area meter (AM300, Bioscientific Ltd., UK). A Cintra 5 spectrophotometer (GBC Scientific Equipment, Australia) was used for analyzing P. Flame photometer (Jenway, Germany) was used for analyzing K and Na. Ca and Mg were analyzed by titration with EDTA. Chloride was analyzed by titration with $AgNO_3$. Digestion and analysis methods followed the procedures of Estefan *et al.* (2013).

Soil analysis

The soil was analyzed for P, K, Ca, Mg, Na, Cl, pH and EC (1:1 soil: water extract) using the same previously mentioned instruments and procedures.

Statistical analysis

All statistical analyses were performed using SAS/STAT Version 9.2 and Analysis of Variance (ANOVA) was conducted by the PROC GLIMMIX procedure.

3. Results and Discussion

Soil and water analysis

One-year old grapevine rootstocks were grown on a calcareous clayey soil (45% $CaCO_3$). Soil chemical properties are presented in Table 1. The soil used in the current study is saline with relatively high organic matter. Such soils are common under agricultural practices applied in the Jordan Valley. In the Jordan Valley, farmers used to annually add organic materials, a practice that contributed to elevated salinity level. Plants were regularly irrigated with diluted brackish water at three salinity levels. The water chemical properties of the brackish water are presented in Table (2).

Brackish water used in the current study is extremely saline with total dissolved solids of approximately 9875 mg l^{-1}. Chloride formed approximately 60% of the ionic composition of the brackish water (before dilution) followed by sodium, which formed approximately 23%. Such high EC and Cl and Na concentrations justified the use of diluted brackish water obtained by diluting the latter with tap water in order to prepare irrigation water with three salinity levels as previously mentioned. The maximum salinity level of irrigation water was 5 dS m^{-1} electrical conductivity to avoid the buildup of salts in the growth medium far beyond the threshold EC of grapevines, which is approximately 2-3 dS m^{-1}.

SPAD chlorophyll reading

The analysis of variance of the chlorophyll content of fully expanded mature leaves showed no interaction effect among rootstock, salinity and time. Meanwhile, a significant rootstock by salinity interaction at ($P \leq 0.05$) was detected only in November as well as an expected salinity by time interaction ($P \leq 0.05$). Diluted brackish water effects on 'Superior Seedless' chlorophyll content were clearly observed in June and November (Table 3). In April, no interaction was noticed among rootstock-salinity combinations due to the fact that the soil used is originally saline and no considerable salt build up was expected yet as a result of irrigation. If non-saline soil was used, findings would not be of practical significance. In addition, brackish water was diluted before being used for irrigation. Salt build up could be expected if irrigation was practiced for longer period of time. However, salt build up is not favorable because it will adversely affect grape yield, which was not measured under the conditions of our experiment.

Table 3 - The effect of brackish water treatments on the average 'Superior Seedless' chlorophyll content measured in June and November for the three rootstocks

Treatment	June	November
R1 C	28.5±1.0	27±1.0
R2 C	27.6±1.2	27.6±1.1
R3 C	25.8±1.9	24.6±1.5
R1 S1	25.7±1.2	24.1±1.3
R2 S1	26.8±1.3	25.8±1.3
R3 S1	26.6±2.2	23.7±0.6
R1 S2	23.1±1.8 (3.3) [z]	22.9±1.6 (3.5)
R2 S2	23±1.3 (4.7)	22.5±1.0 (5.2)
R3 S2	25.1±1.1 (3.9)	22.2±1.2 (6.8)
R1 S3	20.5±0.7 (6.7)	18.8±0.7 (8.4)
R2 S3	23.8±3.2 (4.9)	12.9±3.6 (15.8)
R3 S3	23±2.7 (7.4)	18.1±0.5 (12.3)

R1 = P1103, R2 = 41B, R3 = R110.
C = Control 0.8 dS m^{-1}, S1 = 1.5 dS m^{-1}, S2 = 3.0 dS m^{-1}, S3 = 5.0 dS m^{-1}.
[z] = The number in parenthesis indicates the reduction in the SPAD reading compared to the reading before treatment in April.

As expected, chlorophyll content levels decreased for all three rootstocks (Table 3). However, 'Superior Seedless' showed higher chlorophyll content when grafted on P1103 compared to R110 and 41B in November at salinity level of 5.0 dS m^{-1} (Table 3). The highest reduction in 'Superior Seedless' chlorophyll content was observed when grafted on rootstock 41B, followed by R110 and the least reduction was observed for 'Superior Seedless' grafted on P1103.

The influence of salinity levels varied with time and rootstock (Table 3). Chlorophyll content of R1 (P1103) and R2 (41B) was adversely affected in June particularly at S2 and S3. In November, the adverse effect of salinity levels on R1 and R2 at S2 and S3 was even more obvious. However, R3 (R110) was mainly affected by S3 particularly in November. This might suggest that diluted brackish water can be used for irrigation for a short period of time (i.e. from April to June) followed by irrigation with better quality irrigation water. This can be true mainly for R3 (R110) followed by R2 (41B) and for a longer period for R1 (P1103).

Additional supply of Ca^{+2} can prevent the toxic effects of Na^{+} on leaf photosynthesis (Montesano and Van Iersel, 2007). It was indicated that the effect of salinity on leaf chlorophyll content is ion-specific and not due to a decrease in the osmotic potential of the nutrient solution. In our study, 'Superior Seedless' showed higher calcium ion content in both plant tissues and soil when grafted on P1103 compared to R110 and 41B. The mean 'Superior Seedless' leaf Ca content (mg g^{-1} dry weight) grafted on the three rootstocks at 5.0 dS m^{-1} measured in October was 29.40 when grafted on P1103; whereas it was 26.00 and 19.80 when grafted onto 41B and R110, respectively (Table 4). Meanwhile, the soil Ca content (mg g^{-1} soil) for the three rootstocks at 5.0 dS m^{-1} measured in October were as follow: 5.2, 4.7 and 4.5 when grafted on P1103, 41B and R110, respectively. This might explain the relatively better performance of P1103 under the conditions of the current study.

Moreover, 'Superior Seedless' grafted onto 41B showed a higher leaf Mg content in October, however, the reduction magnitude in leaf Mg content in October compared to June was the least in 'Superior

Table 4 - The effect of brackish water treatments on the average 'Superior Seedless' Ca leaf content (mg g^{-1} dry weight) grafted on the three rootstocks measured in April, June and November

Treatment	June	August	October
R1 C	40.6±2.9	50.0±6.7	25.2±4.5
R2 C	54.2±10.0	67.8±3.8	27.9±1.9
R3 C	43.0±4.1	46.8±3.3	19.5±2.0
R1 S1	42.5±1.5	42.5±5.0	24.2±1.3
R2 S1	55.8±4.9	56.4±5.1	21.8±5.0
R3 S1	36.1±0.0	41.7±3.7	24.0±1.4
R1 S2	47.8±6.2	58.3±16.0	21.8±4.0
R2 S2	52.9±2.9	74.5±0.8	23.5±3.4
R3 S2	40.9±3.0	46.5±3.4	23.4±3.0
R1 S3	38.2±6.4	59.9±12.9	29.4±9.7
R2 S3	44.9±12.7	72.2±9.4	26.0±5.0
R3 S3	42.5±1.0	56.9±4.0	19.8±1.7

R1 = P1103, R2 = 41B, R3 = R110.
C = Control 0.8 dS m^{-1}, S1 = 1.5 dS m^{-1}, S2 = 3.0 dS m^{-1}, S3 = 5.0 dS m^{-1}.

Seedless' grafted onto P1103 in comparison with R110 and 41B (Table 5), which might also explain the relatively better performance of P1103.

In addition, 'Superior Seedless' grafted onto P1103 showed a higher Mg leaf content at salinity level (S2) in October compared to June. Meanwhile, 'Superior Seedless' leaf Mg content decreased when grafted on 41B and R110 at the same level of salinity.

Stem length and number of leaves

The analysis of variance of stem length after irrigation with brackish water measured in June, August and October detected no interaction effect. However, a salinity effect was observed slightly in October. At the highest salinity level, 'Superior' showed longer stem length when grafted on P1103 compared to R110 and 41B (Table 6). However, the longer 'Superior Seedless' stem was not significantly different when grafted onto R110 but were significantly different when grafted onto 41B.

Table 5 - The effect of brackish water treatments on the average 'Superior Seedless' Mg leaf content (mg g^{-1} dry weight) grafted on the three rootstocks measured in April, June and November

Treatment	June	August	October
R1 C	18.1±3.0	19.3±1.2	7.6±1.9
R2 C	11.5±0.5	13.5±1.4	6.0±2.5
R3 C	11.5±1.9	18.1±3.5	7.9±0.8
R1 S1	12.8±1.1	12.8±4.9	7.6±2.6
R2 S1	13.6±3.3	12.5±1.1	7.5±0.9
R3 S1	14.6±2.2	14.8±0.5	7.9±1.1
R1 S2	11.5±0.2	13.6±1.4	13.6±3.2
R2 S2	12.5±1.6	11.7±0.7	10.2±0.8
R3 S2	10.2±2.2	15.4±3.8	7.8±0.9
R1 S3	11.0±1.0	14.8±1.9	9.2±2.3 (1.8)
R2 S3	15.4±0.4	16.0±0.7	12.8±1.6 (2.6)
R3 S3	11.2±1.8	17.3±2.1	8.4±1.1 (2.8)

R1 = P1103, R2 = 41B, R3 = R110.
C = Control 0.8 dS m^{-1}, S1 = 1.5 dS m^{-1}, S2 = 3.0 dS m^{-1}, S3 = 5.0 dS m^{-1}.
(z) = The number in parenthesis indicates the reduction in the SPAD reading compared to the reading before treatment in April.

Table 6 - The effect 5.0 dS m^{-1} on average stem length (cm) for the three rootstocks measured in October

Rootstock	Stem length (cm)
P1103	110±6.0 a
41B	89±5.0 b
R110	100±10.0 ab

Different letters in a column indicate significant differences at P≤0.05 according to Fisher's Protected LSD.

This indicates that 'Superior Seedless' bud grafted on P1103 showed more growth compared when grafted onto 41B. Another indication of the vigorosity and tolerance of P1103 was the total number of leaves counted in June, August and October. According to the analysis of variance, no interaction effect was detected. However, a main rootstock and salinity effect were detected in June, August and October.

Generally, in the months of August and October and at the levels of S2 (3.0 dS m^{-1}) and S3 (5.0 dS m^{-1}), 'Superior Seedless' bud showed more number of leaves when grafted onto P1103 followed by R110 and the least number was when grafted onto 41B (Table 7). This also supports the vigor and indication of tolerance of P1103. In addition, the results of the total counting coincide well with the shoot length

Table 7 - Effect of treatments on average number of 'Superior Seedless' leaves grafted on the three rootstocks counted in June, August and October

Treatment	June	August	October
R1 C	23.7±3.6	31±3.2	60.3±5.2
R1 S1	17.3±1.5	26.3±0.4	49±5.3
R1 S2	17±0.9	24.3±2.7	36.3±3.3
R1 S3	14.7±1.2	21.7±2.7	31.3±2.5
R2 C	22.3±0.7	27±1.4	51.3±3.6
R2 S1	18.3±1.0	23±1.2	41±5.6
R2 S2	16.7±0.8	20.3±1.8	31±3.9
R2 S3	14.3±0.4	18±0.7	30.7±2.5
R3 C	25.3±3.9	35.3±3.3	62.3±5.7
R3 S1	22.7±2.5	26.7±2.5	49.3±7.8
R3 S2	19.7±1.8	24±2.1	36±3.7
R3 S3	17± 1.2	20.7±1.5	33.7±2.9

R1 = P1103, R2 = 41B, R3 = R110.
C = Control 0.8 dS m^{-1}, S1 = 1.5 dS m^{-1}, S2 = 3.0 dS m^{-1}, S3 = 5.0 dS m^{-1}.

results presented in Table 6.

Leaf area

Regarding the 'Superior Seedless' leaf area, the analysis of variance revealed no interaction or rootstock effect but a salinity effect. The reduction of leaf area by water stress (Gomez-del-Campo *et al.*, 2002) and by salinity treatments is very well documented on various crops such as tomatoes (Montesano and Van Iersel, 2007), olives (Al-Absi *et al.*, 2003) and chrysanthemums (Lee and Van Iersel, 2008). The previous studies indicated the effect of salinity on leaf area is mainly through the osmotic effect of the solution which mainly depends on the total amounts of salts in the nutrient solution. Our findings are consistent with the previous mentioned studies. Leaf area decreased with increasing salinity levels (Fig. 1). However, relatively larger 'Superior Seedless' leaves were noticeable when grafted on P1103 compared to 41B and R110. It is worth mentioning that the reduction of chlorophyll SPAD readings is attributed to the salinity effects, not to the leaf area since both parameters, chlorophyll SPAD and leaf area, were reduced with increasing the salinity levels.

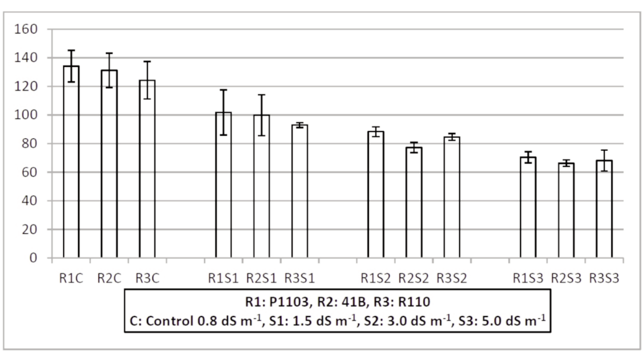

Fig. 1 - The effect of treatments on average 'Superior Seedless' leaf area (cm^2) grafted on the three rootstocks measured on November, 2014.

The vigor of P1103 and higher chlorophyll content, longer shoot and more leaves did not significantly increase the leaf fresh and dry weights (Figs. 2 and 3). Our findings also are in agreement with Walker *et al.* (1997) who found that leaf relative water contents were not affected by rootstock or salinity treatments.

Figure 3 illustrates the effect of the three rootstocks and salinity levels on 'Superior Seedless' leaf water content. Except for salinity level 1 (1.5 dS m^{-1}), 'Superior Seedless' leaves when grafted on P1103 showed relatively higher water content compared when grafted on 41B and R110.

The P1103 rootstock seems to activate a certain mechanism at high soil salinity levels (particularly at

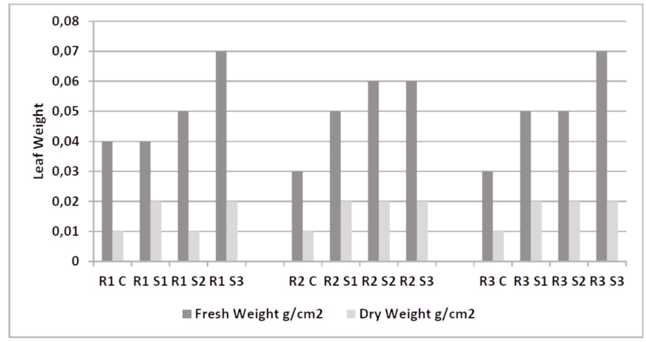

Fig. 2 - The effect of the three rootstocks and salinity on the ratio of 'Superior' leaf fresh and dry weights (g) to leaf area (cm^2).

S2 and S3). On the other side, 41B and R110 were not adversely affected by the salinity levels. Our findings are similar to those of Walker *et al.* (1997) who found that the relative water contents were not affected by rootstock or salinity treatments.

A correlation analysis has been conducted to figure out the major ions that had the greatest effect on soil salinity and consequently on rootstock performance. Results showed that the correlation between soil EC and the concentration of Cl, Na, Ca and Mg ions were 0.97, 0.95, 0.83 and 0.5; respectively. This clearly proved that Cl, Na and Ca were the major ions that influenced the response of rootstocks to soil salinity levels. Such results reflected well the chemical composition of water used for irrigation (Table 2). Many researchers focused on Cl exclusion, such as Walker *et al.* (2004) who reported that P1103 was the best chloride excluder. Our focus will be on Na exclusion by reporting the leaf K: Na ratio.

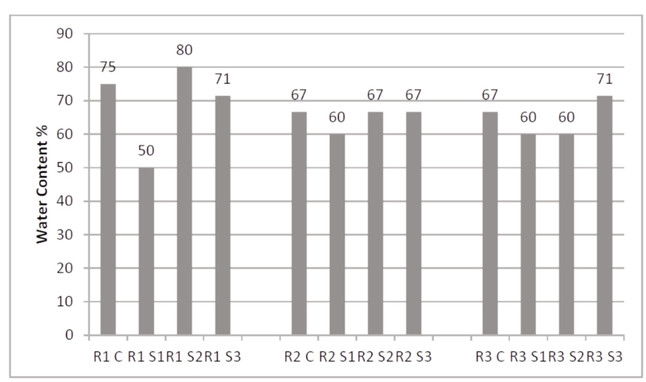

Fig. 3 - The effect of the three rootstocks and salinity levels on 'Superior Seedless' leaf water content.

Concerning the leaf K:Na ratio, as shown in figure 4, it can be seen that in August, the order of the rootstocks is as follows: R110>41B>P1103. However, Na concentration in leaves became significantly higher than that of K (K:Na ratio 1) for R110 and 41B, but particularly for 41B. On the other hand, in October,

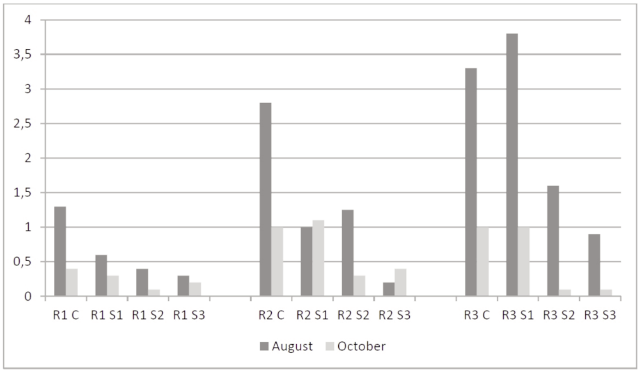

Fig. 4 - ‘Superior Seedless’ leaf K:Na ratio grafted on the three rootstocks at the different salinity levels measured in August and October.

41B and R110 rootstocks particularly at salinity levels S2 (3.0 dS m^{-1}) and S3 (5.0 dS m^{-1}) showed higher Na concentration in leaves than that of K (very low K:Na ratio). This might indicate that none of the investigated rootstocks is Na excluder; particularly P1103. P1103, which seems to be Na include, took up Na in greater amounts than the other rootstocks starting from earlier stages of treatment applications. This mechanism (Na uptake) could help the grapevine to relief the osmotic stress, by maintaining the water potential gradient and consequently increase water uptake. Jogaiah *et al.* (2014) found that the maximum osmotic potential was recorded on P1103 rootstock. This might explain the relatively higher leaf water content observed in P1103 as mentioned above.

Growth after bud break

In order to obtain data regarding cumulative effects of the treatments on number of ‘Superior Seedless’ leaves after bud break, total numbers of leaves/vine were counted on April of the following year. Analysis of variance showed that there was no interaction effect however; rootstocks did show such an effect ($P \leq 0.05$). P1103 shows vigorous growth in terms of leaves compared to the other two rootstocks (Fig. 5). Except for the control, there were significant differences between P1103 and the two other rootstocks at the three salinity levels (Fig. 5). This might indicate that P1103 was less affected by diluted brackish water irrigation.

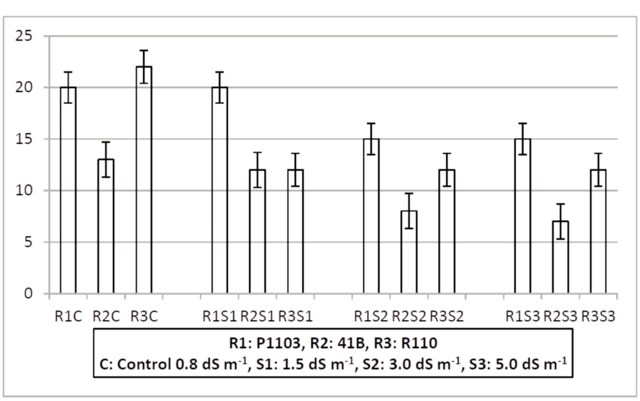

Fig. 5 - The effect of the salinity level treatments on the total number of leaves per grapevine counted in April of the following year for the three rootstocks.

4. Conclusions

Scion is dependent on the rootstock for all things coming from the soil and there could be a considerable effect of rootstock on the vine performance (Creasy and Creasy, 2009). Therefore, rootstock choice should be taken with careful consideration. P1103 (*V. berlandieri* x *V. rupestris*) rootstock seems to be a suitable choice for irrigating with diluted brackish water. Irrigating ‘Superior Seedless’ vines grafted on P1103 with diluted brackish water, up to 3.0 dS m^{-1}, from April until June could be a practical procedure to be adopted by grape growers in the Jordan Valley. However, irrigation should be followed by irrigation with fresh water especially that by the end of the experiment the soil EC reached approximately 6.0 dS m^{-1}. In addition, our findings coincide well with the findings of many researchers such as (Troncoso *et al.*, 1999; Walker *et al.*, 2002). It does seem that grapevine rootstocks that have either *V. rupestris* or *V. berlandieri* in their parentage are good candidates for salinity tolerance.

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References

ABDEL GAWAD G., GHAIBEH A., 2001 - *Use of low quality water for irrigation in the Middle East.* - Proc. Symp. Sustainable Management of Irrigated Land for Salinity and Toxic Elements Control, US Salinity Laboratory Riverside, California, USA.

AL-ABSI K., QRUNFLEH M., ABU-SHARAR T., 2003 - *Mechanism of salt tolerance of two olive* Olea europaea *L. cultivars as related to electrolyte concentration and toxicity.* - Acta Horticulturae, 618: 281-290.

BUSTAN A., COHEN S., DE MALACH Y., ZIMMERMANN P.,

GOLAN R., SAGI M., PASTERNAK D., 2005 - *Effects of timing and duration of brackish irrigation water on fruit yield and quality of late summer melons.* - Agric. Water Manag., 74(2): 123-134.

BUSTAN A., SAGI M., DE MALACH Y., PASTERNAK D., 2004 - *Effects of saline irrigation water and heat waves on potato production in an arid environment.* - Field Crops Research, 90(2-3): 275-285.

CAVAGNARO J., PONCE M., GUZMÁN J., CIRRINCIONE M., 2006 - *Argentinean cultivars of* Vitis vinifera *grow better than European ones when cultured* in vitro *under salinity.* - Biocell, 30(1): 1-7.

CREASY G., CREASY L., 2009 - *Grapes. Crop production science in horticulture.* - CABI, Cambridge, MA, USA, pp. 312.

DARDENIZ A., MÜFTÜOĞLU N., ALTAY H., 2006 - *Determination of salt tolerance of some American grape rootstocks.* - Bangladesh J. Bot., 35(2): 143-150.

ESTEFAN G., SOMMER R., RYAN J., 2013 - *Methods of soil, plant, and water analysis: A Manual for the West Asia and North Africa Region.* - Third Edition. International Center for Agricultural Research in the Dry Areas (ICARDA).

FISARAKIS I., CHARTZOULAKIS K., STAVRAKAS D., 2001 - *Response of Sultana vines (*V. vinifera *L.) on six rootstocks to NaCl salinity exposure and recovery.* - Agric. Water Manag., 51(1): 13-27.

GOMEZ-DEL-CAMPO M., RUIZ C., LISSARRAGUE J., 2002 - *Effect of water stress on leaf area development, photosynthesis, and productivity in Chardonnay and Airen grapevines.* - American Journal of Enology and Viticulture, 53(2): 138-143.

JOGAIAH S., RAMTEKE S., SHARMA J., UPADHYAY A., 2014 - *Moisture salinity stress induced changes in biochemical constituents and water relations of different grape rootstock cultivars.* - Intern. J. Agron., 1-8.

LEE M.K., VAN IERSEL M., 2008 - *Sodium chloride effects on growth, morphology, and physiology of chrysanthemum (*Chrysanthemum x morifolium*).* - HortScience, 43(6): 1888-1891.

MIZRAHI Y., TALEISNIK E., KAGAN-ZUR V., ZOHAR Y., OFFENBACH R., MATAN E., GOLAN R., 1988 - *A saline irrigation regime for improving tomato fruit quality without reducing yield.* - J. Amer. Soc. Hort. Sci., 113(2): 202-205.

MONTESANO F., VAN IERSEL M., 2007 - *Calcium can prevent toxic effects of Na^+ on tomato leaf photosynthesis but does not restore growth.* - J. Amer. Soc. Hort. Sci., 132(3): 310-318.

NIU G., RODRIGUEZ D., AGUINIGA L., 2008 - *Effect of saline water irrigation on growth and physiological responses of three rose rootstocks.* - HortScience, 43(5): 1479-1484.

PARANYCHIANAKIS N., ANGELAKIS A., 2008 - *The effect of water stress and rootstock on the development of leaf injuries in grapevines irrigated with saline effluent.* - Agric. Water Manag., 95(4): 375-382.

SOUTHEY J., JOOSTE J., 1991 - *The effect of grapevine rootstock on the performance of* Vitis vinifera *L. (cv. Colombard) on a relatively saline soil.* - S. Afr. J. Enol. Vitic., 12(1): 32-41.

TRONCOSO A., MATTE C., LAVEE S., 1999 - *Evaluation of salt tolerance of* in vitro *grown grapevine rootstock varieties.* - Vitis, 38(2): 55-60.

WALKER R., BLACKMORE D., CLINGELEFFER P., CORRELL R., 2002 - *Rootstock effects on salt tolerance of irrigated field grown grapevines (*Vitis vinifera *L. cv. Sultana). 1. Yield and vigor inter-relationships.* Australian J. Grape and Wine Res., 8: 3-14.

WALKER R., BLACKMORE D., CLINGELEFFER P., CORRELL R., 2004 - *Rootstock effects on salt tolerance of irrigated field grown grapevines (*Vitis vinifera *L. cv. Sultana). 2. Ion concentrations in leaves and juice.* Australian J. Grape and Wine Res., 10: 90-99.

WALKER R., BLACKMORE D., CLINGELEFFER P., IACONO F., 1997 - *Effect of salinity and Ramsey rootstock on ion concentrations and carbon dioxide assimilation in leaves of drip-irrigated, field-grown grapevines (*Vitis vinifera *L. cv. Sultana).* - Australian J. Grape and Wine Res., 3: 66-74.