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Tolerance of Flame Seedless Grapes on Own Root and Grafts to Irrigation with Saline Solutions

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Abstract: A pot experiment was carried out during two seasons of 2009 and 2010 under greenhouse in the nursery of pomology department, Faculty of Agriculture, Cairo University. Grapevine cultivar Flame Seedless on own root or grafted on two grape rootstocks Freedom and Ramsey as well as previous two rootstocks rooted cutting were conducted to evaluate their growth and chemical compounds under the condition of irrigation with saline water. The obtained results indicated that, plants of Freedom rootstock and Flame on Freedom rootstock disclosed the first salt injury symptoms under high concentration of salinity (3000 and 4000 PPM) as they recorded the highest leaf proline content as well as the highest leaf and root content of Na and Cl. Also, Flame on Ramsey and Ramsey rootstock recorded the highest plant survival (%), vegetative growth dry weight (g) and leaf chlorophyll content. However, Flame Seedless recorded the highest values of leaf area, K and Ca contents in leaves. Based on the gained results, Flame on Ramsey besides Ramsey rootstock were the most tolerant plants to irrigation with the studied salinity treatments.

Keywords: Grapevine – Rootstocks – Ramsey – Freedom - Flame Seedless - Tolerance saline water.

INTRODUCTION

Grape is a popular fruit for both local consumption and exportation in many temperate and tropical countries throughout the world. It has been cultured for 5000 to 7000 years. Grape cultivation reached approximately 7.437141 ha world-wide with a total world production of over 66.93 million tons [1]. Grape growing in Egypt has progressively developed in the last few years to about 368290 Feddans [2]. Its exportation ranks second after citrus concerning the acreage. However, a great acreage is located at the new reclaimed lands which face problems of the salinity in both water and/or soil which can limit successful production or even survival.

It is well known that, Salinity stress is one of the main problems facing vine growers. Salt-affected soils occupy more than 70% of the earth's land surface and represent a major limiting factor in crop production [3]. Salinity of irrigation water can impair the performance of growth and production of grapevines [4]. The concentration and composition of dissolved constituents in water determine its suitability for irrigation [4, 5]. Salinity can adversely affect the plant water relations, growth and metabolism because it leads to increasing the negative water potential of xylem sap and the accumulation of potentially toxic levels of Na^+ and Cl^- ions in the leaf mesophyll of salt-sensitive plants [6]. Plants can withstand at high chloride concentrations by restricting uptake and transport of chloride to leaves or by an increase in the ability of their leaf tissues to tolerate high chloride concentrations [7].

It seems that, the ability of plants to tolerate salinity depends on their ability to exclude Na^+ and Cl^- from the leaves. Most grapes cultivars are considered as moderately salt tolerant under field conditions and are often grown in soils that are saline or subjected to stalinization by irrigation with underground water. However, grapevine response to salinity depends on several factors, such as rootstock-scion combination, irrigation system, soil type and climate. Moreover, changing some of these factors with the same irrigation water could produce entirely different results [8].

The adverse effects of salinity either of soil or water on growth were confirmed in different grapevine cultivars [9-12]. Sensitive rootstocks and *Vitis vinifera* could grow normally in soils containing 0.2 to 0.3% NaCl [13]. Also, *Vitis riparia* and *Vitis rupestris* died above 0.4% NaCl, whereas *Rupestris due lot* could with stand up to 0.7% NaCl. Salt Creek and 1103 Paulsen were of the most salt resistant rootstocks as they tolerate up to 0.8 to 1.5% NaCl [9, 14-16].

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The aim of this investigation was to illustrate the comparative salt tolerance of own rooted Flame Seedless cv., Ramsey and Freedom rootstocks as well as Flame Seedless grafts on these rootstocks.

MATERIALS AND METHODS

Plant Materials and Nursery Practices: In Egypt, Flame Seedless is the most popular grape cultivar while Freedom considers as are the most commercial rootstocks. Through the world, Ramsey considers the most grape rootstock tolerant to salinity condition; therefore a pot experiment was carried out during the seasons of 2009 and 2010 in the greenhouse of the pomology department nursery, Faculty of Agriculture, Cairo University. Six months old own rooted transplant of Flame Seedless cultivar, Freedom and Ramsey rootstocks as well as Flame Seedless grafted on the afore mentioned rootstocks were considered. The afore mentioned transplants were chosen of similar growth vigor. Each transplant was placed in a 10 kg plastic pot with drainage holes and that was full of washed sands. The pots were irrigated with tab water for one month and fertilized weekly during the course of the investigation with Hoagland nutrient solution at 0.5 L/pot [17]. All transplants were pruned to one main shoot after two weeks from transplanting. Irrigation was carried out manually to field capacity. Thirty percent excess water was added for leaching requirements after every two irrigation treatments.

Treatments: One month after transplanting, 525 uniform transplants were chosen and arranged in a split plot design with three replicates for each treatment and each replicate has 7 transplants. A combination of NaCl, $CaCl_2$, Na_2So_4 and $MgSO_4$ was used to achieve the following salt ratio 1 Cl^-: 1 Na^+: 1 $So_4^=$: 1 Mg^{++} and five saline water concentrations to represent the treatments of; control (tab water), 1000, 2000, 3000 and 4000 ppm which were prepared from previous salt combination and used for transplants irrigation up to 3 months in each season of the experiment.

Measurements

Date of First Salinity Symptoms Appearance: The date of first salinity symptoms appearance was recorded for each group of transplants irrigated with some saline solution. Symptoms were previously described such as crumbling of the new growing leaves, chlorosis, leaf burn, leaf defoliation, shoot dieback and finally plant death [9].

Survival Percentage (%): After three months from irrigation with saline solution percentage of survival transplants were calculated by the following formula:

Survival percentage (%) = Number of survive transplants / Total number of transplants.

Growth Vigor Measurements: After two month from beginning salt treatments the average leaf area was measured according to Ahmed and Morsy [18] by use LA= 0.44 (L X W) +18.13 formula; LA: leaf area, L: Length of leaf and W: Width of leaf. Also, two transplants per replicate were carefully moved out from the pots, thoroughly washed several times with distilled water. The vegetative organ was dried at 70°c for 72 hour under vacuum and used to measure the dry weight and for plant chemical analyses.

Leaves Physiological Activities: Leaf chlorophyll content (SPAD value) was measured as total chlorophyll in the basal 6th and 7th leaves from shoot base monthly after beginning treatment of salt during both studied season using MINOLTA SPAD-502 apparatus. The Free proline concentration was measured calorimetrically in the dry matter of leaves using nonhydrin reagent according to Batels *et al.* [19].

Chemical Analyses: To assess the tolerance of genotypes to saline water and the effect of saline water on plant mineral content, 0.5 gram from the previous by dried leaves or roots for each replicate were taken and digested in a mixture of sulpharic and perchloric acids according to Piper [20], then leaf and root chloride content were determined (%) by titration with silver nitrate according to Jackson [21], while leaf content (%) of potassium and calcium as well as leaf and root sodium content (%) were determined according to Brown and Lilleland [22] by using spectrophotometer.

Statistical Analysis: Data recorded on vegetative growth traits and chemical compositions were subjected to normal statistical analysis as shown by Snedecor and Cochran [23]. Comparison among means was done using LSD at 5% level of probability.

RESULTS AND DISCUSSION

Effect of Irrigation with Saline Water on the Date of Salt Symptoms Appearance: Date of the visual observations in Table 1 showed that, the salt injury symptoms appeared earlier on the transplants irrigated with water containing high levels of salts i.e. 3000 and 4000 ppm rather than 2000 ppm which did not appear clear symptoms except in case of transplants of Freedom and Flame Seedless on Freedom rootstock. Under control (tab water) conditions and 1000 ppm salt concentration, the injury symptoms did not totally appear. At the treatments high salt levels (3000 and 4000 ppm), symptoms of salt appeared as chlorosis or loss of green color over the entire leaf, then necrosis or formation of leaf scorch especially near the leaf margin was noticed as areas of dead tissue extended, then damaged leaves are readily as soon as visual burn symptoms. Comparative response of considered plant material towards the conducted treatments show that, highest tolerance was dedicated to Flame Seedless on Ramsey rootstock. This graft combination did not show any injury except when treated with 4000 ppm solution and that was after 12 week from treatment. In contrast, Freedom and Flame on Freedom rootstock were the earlier plant materials that appeared symptoms under high concentration of salinity (3000 and 4000 ppm) just after 6 to 8 weeks in both seasons, followed by Flame Seedless which appeared symptoms after 7-9 weeks.

In this line, increasing salt concentration from 15 to 60 meq/L, gradually increased salt injury. It caused remarkable visual symptoms of marginal leaf burn and finally leaf defoliation in three grapevine cultivars, Edkawy, Flame Seedless and Ruby Seedless [24]. Also, the number of shedded leaves/plant and number of leaves with burned margin were increased positively with duration of salinization in Delight, Thompson Seedless, Early Superior, Black Rose, Ribier, Exotic and Queen grape varieties [11]. The toxicity symptoms are probably due to the uptake of the chloride ion [25].

Effect of Irrigation with Saline Water on the Survival Percentage of Transplants: Survival percentage in Table 2 was insignificantly affected with irrigation by 1000 solution compared with the control. Increasing the solution concentration decreases this percentage significantly to reach its least significant value when the concentration reached 4000 ppm. These results agreed with those of Gaser [24] who found that, increasing salt concentration of the irrigation water reduced the survival percentage and growth parameters of three grape cultivars. Also, Abd El-Wahab *et al.* [26] stated that "increasing levels of water salinity (1000, 2000 and 3000 ppm), particularly at 3000 ppm decreased survival percentage of Superior grape". The highest survival percentage was attained by Flame Seedless on Ramsey rootstock as well as and Ramsey. Whereas, the least significant percentage was attained by Flame Seedless on Freedom and Freedom transplant. Interaction data declare that, survival of Flame Seedless grafts on Ramsey rootstock weren't significantly affected with irrigation with saline solutions when it compared with control. This results mean that, Freedom and Flame on Freedom were very sensitive to salinity condition and this in confirm with Oakes [27] who reported that, all varieties grafted on Freedom were very sensitive. While, the present results disclosed that Ramsey and Flame on Ramsey were exhibited salt tolerance, this is in harmony with Hepaksoy *et al.* [28] as they indicated that Ramsey (Salt creek) was more tolerant to salinity. The tolerant of salt due to genetic back ground [29].

Effect of Irrigation with Saline Water on Morphological Parameters

Leaf Area: Data depicted in Table 3 indicated that, there was a progressive significant reduction in leaf area with raising salt level in the irrigation water. Generally, the lowest leaf area was associated with high salinity levels in both seasons. In other word, there was a negative relationship between salinity concentration and area of leaves. Changes of growth and development of plants exposed to salinity stress have been reviewed. Reduced cell elongation and cell division result in slower leaf appearance and inhibition of shoot growth [30]. Also, Chartzoulakis and Klapaki [31] reported that, high NaCl levels inhibited leaf expansion, largely due to an inhibition of cell division rather than to cell expansion.

Moreover, Flame Seedless transplant recorded significantly the largest leaf area (55.53 and 52.17 cm^2) in both seasons when comparing with the other transplants on the average. The interaction effect in Table 3 showed that, Freedom rootstock under salt concentration 4000 ppm attained significantly the lowest leaf area in both seasons. The decreasing rate is about 38 and 34.6% in both seasons respectively comparing to Freedom irrigated with tab water. While, the decreasing rate of leaf area of Flame is about 12.4% in the 1st season and 18% in the 2nd season when salinity was increased from control (tab water) to 4000 ppm. This means that, Freedom rootstock conceder a more sensitive to salinity comparing with Flame Seedless cultivar. These results are in harmony with Mehana *et al.* [32] who found that, grape cultivars (Flame, Crimson Seedless and Red roumi) have a significant larger leaf area compared to grape rootstocks (Freedom, Ramsey, 1103 Paulsen and Teleki 5c) under saline water.

Table 1: Appearing date of salt symptoms of tested grapevine as affected by irrigation with saline water during 2009 and 2010 seasons.

Salt treatments (ppm)	Flame	Freedom	Ramsey	F/Fr*	F/R**
			Season 2009		
Tab water	----	----	----	----	----
1000	----	----	----	----	----
2000	----	11th week	-----	12thweek	----
3000	9th weeks	7th weeks	12th week	8thweeks	----
4000	7th weeks	6th weeks	11th week	7thweeks	12th week
			Season 2010		
Tab water	----	----	----	----	----
1000	----	----	----	----	----
2000	----	11th Week	----	12thweek	----
3000	9th weeks	7th weeks	12th week	8th weeks	----
4000	7th weeks	6th weeks	11th week	7th weeks	12th week

*: Flame Seedless on Freedom rootstock **: Flame Seedless on Ramsey rootstock

Table 2: Survival percentage of tested grape plants in relation to irrigation with saline water during 2009 and 2010 seasons.

Salt treatments (ppm)	Flame	Freedom	Ramsey	F/Fr*	F/R**	Mean
			Season 2009			
Tab water	100 a	100 a	100 a	100 a	100 a	100 A
1000	100 a	100 a	100 a	100 a	100 a	100 A
2000	93.33 ab	66.67 e	100 a	73.33de	100 a	86.67B
3000	66.67 e	0.00 f	86.67 bc	0.00 f	100 a	50.67C
4000	0.00 f	0.00 f	80.00 cd	0.00 f	93.33ab	34.67D
Mean	72.00 B	53.33 C	93.33 A	54.67 C	98.67 A	
			Season 2010			
Tab water	100 a	100 a	100 a	100 a	100 a	100A
1000	100 a	100 a	100 a	100 a	100 a	100A
2000	86.67 b	66.67 c	100 a	73.33 c	100 a	85.33B
3000	66.67 c	0.00 d	86.67 b	0.00 d	100 a	50.67C
4000	0.00 d	0.00 d	73.33 c	0.00 d	86.67b	32.00D
Mean	70.67 B	53.33 C	92.00 A	54.67 C	97.33A	

*: Flame Seedless on Freedom rootstock **: Flame Seedless on Ramsey rootstock

Table 3: Leaf area (cm^2) of tested grape plants in relation to irrigation with saline water during 2009 and 2010 seasons

Salt treatments (ppm)	Flame	Freedom	Ramsey	F/Fr*	F/R**	Mean
			Season 2009			
Tab water	59.33 b	48.57h-j	51.03 fg	62.70 a	63.43 a	57.01A
1000	56.83 c	41.70 k	49.47g-i	55.97cd	54.83cd	51.76B
2000	55.63 cd	38.80 l	46.67 j	50.77f-h	52.27ef	48.83C
3000	53.83 de	36.30 m	43.30 k	48.33h-j	48.20ij	45.99D
4000	52.00 ef	30.10 n	42.20k	46.50j	46.97 j	43.55E
Mean	55.53 A	39.09 D	46.53 C	52.85 B	53.14 B	
			Season 2010			
Tab water	56.87 a	38.97 i	40.20 i	51.70 d	52.63cd	48.07A
1000	55.43ab	36.10 j	38.57 i	48.73ef	49.53e	45.67B
2000	53.80bc	32.43 k	35.80 j	46.93fg	46.90fg	43.17C
3000	48.1e-g	30.53 k	35.00 j	44.17h	44.67 h	40.49D
4000	46.63g	25.50 l	32.37 k	43.37h	43.57 h	38.29E
Mean	52.17 A	32.71 D	36.39 C	46.98 B	47.46 B	

*: Flame Seedless on Freedom rootstock **: Flame Seedless on Ramsey rootstock

Table 4: Vegetative growth dry weight (g) of tested grape plants in relation to irrigation with saline water during 2009 and 2010 seasons.

Salt treatments (ppm)	Flame	Freedom	Ramsey	F/Fr*	F/R**	Mean
			Season 2009			
Tab water	17.07 hi	26.87 a	16.80 ij	20.33 ef	25.70 ab	21.35A
1000	14.2 k-n	21.80 cd	15.53 jk	15.27 kl	24.57 b	18.27B
2000	12.9m-o	18.43 gh	14.27k-m	12.80no	22.63 c	16.21C
3000	11.33 p	13.33mn	13.9 l-n	11.63op	21.17 de	14.27D
4000	7.37 q	10.87 k	13.0 m-o	11.00 p	19.03 fg	12.25E
Mean	12.57 D	18.26 B	14.70 C	14.21 C	22.62 A	
			Season 2010			
Tab water	17.10 f	27.07 a	17.03 f	20.60ab	26.20ab	21.60A
1000	14.43h-j	21.50 cd	15.87 fg	15.37gh	24.87 b	18.41B
2000	12.97 kl	18.63 e	14.63 g-i	12.83 kl	22.87 c	16.39C
3000	11.4 m	13.37 i-k	13.93 i-k	11.77lm	21.37 d	14.37D
4000	7.10 n	10.80 m	13.13 j-l	11.10 m	19.10 e	12.25E
Mean	12.60 D	18.27 B	14.92 C	14.33 C	22.88A	

*: Flame Seedless on Freedom rootstock **: Flame Seedless on Ramsey rootstock

Vegetative Growth Dry Weight (g): It's clear from the data in Table 4 that, leaves and shoot dry weight was significantly affected by different salinity levels in both seasons of investigation. Increasing salt levels in irrigation water much significantly reduced the dry weight of leaves and shoot to reach its least weight when using saline solution of 4000 ppm. On the average, Flame seedless grafts on Ramsey recorded the highest vegetative growth dry weight 22.62 & 22.88 g in both seasons. Whereas, significantly the least dry weight was attained by Flame Seedless grafts. Interactions show that (as a general trend) increasing solution concentration reduces the dry weight. Data recorded for 4000 ppm treatment show that Flame Seedless grafted on Ramsey rootstocks attained significantly the highest dry weight when compared with the other used plant material and it reduced the rate about 30 and 27.1% when comparing to Flame on Ramsey irrigated with tab water.

In this respect, Gaser [24]; Eissa *et al.* [12] and Rizk-Alla *et al.* [4] found that, increasing salt concentration of the irrigation water reduced the dry weight of vegetative organs per plant on grape cultivars and rootstocks. Moreover, Ahmed [9] found that, saline water irrigation decreased dry weight of plant aerial portion of some grape rootstocks at salinity level from 1000 up to 4000 ppm. Also, the reduction in growth with increasing salinity levels can be attributed to salinity-induced adverse change in leaf water relations which reduced photosynthesis, dehydrated proteins and protoplasm to a lower extent [33, 34]. Also, increasing salinity has an inverse relationship with stomata conductance and net photosynthetic rate leading to reduced photo-assimilation and dry matter production [35, 36]. This may be also because of osmotic effect of salt on root and toxic effect of accumulated ions on the plant tissues and the decreases in growth with increase in salinity were attributed to the osmotic effect rather than to specific ion toxicities [37-39].

Effect of Irrigation with Saline Water on Physiological Activities of Leaves: Leaf Chlorophyll Content (SPAD Value): On the average leaf content of chlorophyll in Table 5 was at its significantly highest magnitude in control because all treatments decreased it significantly. These decreases were in parallel with increasing the solution concentration to reach its least values when using 4000 ppm treatment. With respect to the used plant material Ramsey leaves attained significantly the highest leaf chlorophyll content. Whereas, least content was found in Flame Seedless leaves. Interaction data show that at highest concentration of saline water used (3000 and 4000 ppm) significantly highest chlorophylls content were found in Ramsey rootstock. Furthermore, in both seasons, Freedom recorded the highest decrease rate percentage about (52.4 and 54%) followed by Flame which recorded (45 and 45.4%) respectively with increased concentration of saline water from control to 4000 ppm. while, the lowest decreasing was recorded by Ramsey rootstock (26.2 and 28%).

The adverse effects of water salinity on total chlorophyll content in the leaves can be attributed to its negative action on interrupting and reducing the availability of water and nutrients particularly magnesium, destroying the building and conductance tissue and decreasing the biosynthesis of pigments and photosynthesis [40]. Also, Murkute *et al.* [41] recorded that, chlorophyll decreased under stress due to the suppression of specific enzymes that are responsible for the synthesis of photosynthetic pigments. Salt tolerant cultivars were better at maintaining their growth rate and

Table 5: Leaf Chlorophyll content of tested grape plants in relation to irrigation with saline water during 2009 and 2010 seasons

Salt treatments (ppm)	Flame	Freedom	Ramsey	F/Fr*	F/R**	Mean
			Season 2009			
Tab water	35.67 cd	42.37 a	40.00 ab	39.63 b	39.97ab	39.53A
1000	29.03f-h	34.03 cd	36.07 c	33.97c-e	33.23de	33.27B
2000	26.37ij	29.10f-h	34.00 cd	29.07f-h	31.50ef	30.01C
3000	21.00lm	23.03 kl	30.40 fg	28.37g-i	27.63hi	26.09D
4000	19.63 m	20.17 m	29.53f-h	23.93jk	25.97ij	23.85E
Mean	26.34 D	29.74 C	34.00 A	30.99BC	31.66 B	
			Season 2010			
Tab water	36.33cd	43.03a	40.97 b	39.63 b	40.73b	40.14A
1000	29.63hi	34.73de	36.90 c	35.00c-e	33.43ef	33.94B
2000	26.57k	29.13h-j	34.03 e	28.77 ij	31.9fg	30.08C
3000	21.47lm	23.00 l	30.93 gh	27.53 jk	28.2i-k	26.23D
4000	19.83m	19.80 n	29.50 hi	23.03 l	26.43k	23.72E
Mean	26.77D	29.94 C	34.47 A	30.79BC	32.14B	

*: Flame Seedless on Freedom rootstock **: Flame Seedless on Ramsey rootstock

Table 6: Leaf proline content (%) of tested grape plants in relation to irrigation with saline water during 2009 and 2010 seasons.

Salt treatments (ppm)	Flame	Freedom	Ramsey	F/Fr*	F/R**	Mean
			Season 2009			
Tab water	0.122 no	0.152 m	0.175 l	0.128 n	0.111 o	0.138E
1000	0.212 k	0.255j	0.184 l	0.225 k	0.184 l	0.212D
2000	0.389 h	0.435 g	0.310 i	0.388 h	0.306 i	0.366C
3000	0.481 f	0.549 d	0.392 h	0.494ef	0.420 g	0.467B
4000	0.597 c	0.690 a	0.534 d	0.620 b	0.508 e	0.590A
Mean	0.360 C	0.416 A	0.319 D	0.370 B	0.306 E	
			Season 2010			
Tab water	0.13 pq	0.163 o	0.184 n	0.143 p	0.121 q	0.148E
1000	0.223m	0.267 k	0.196 n	0.239 l	0.192 n	0.223D
2000	0.399 i	0.456 g	0.323 j	0.397 i	0.315 j	0.378C
3000	0.490 f	0.556 d	0.404 i	0.510 e	0.432 h	0.478B
4000	0.608 c	0.701 a	0.545 d	0.640 b	0.515 e	0.602A
Mean	0.370 C	0.429 A	0.331 D	0.386 B	0.315 E	

*: Flame Seedless on Freedom rootstock **: Flame Seedless on Ramsey rootstock

avoiding metabolic disorders such as chlorophyll deficiency under salt stress conditions [42]. Furthermore, Charbaji and Ayyoubi [43] indicated that, Chlorophyll content of Ashlamesh, Helwani and Kassofee were significantly decreased by increasing salinity. Also, Sourial *et al.* [44] found that, increasing salinity level depressed pigments contents of Dogridge and Thompson Seedless.

Leaf Proline Content (%): Data illustrated in Table 6 clearly indicated that, leaf proline content of control plants which irrigated with tab water was significantly the lowest. This content was increased significantly with increasing the concentration of the saline solution to reach the peak with 4000 ppm treatment. On the average leaf content of proline was significantly the least with grafts on Ramsey rootstock. Whereas, the highest content of proline was in leaves of Freedom rootstock. Interaction data show that (for each plant material used) leaf proline content was increased with increasing the salinity concentration. With 4000 ppm treatment highest content was observed in Freedom rootstock leaf whereas the lowest content was obtained by grafts on Ramsey rootstock.

Accordingly, The relationship between the leaf proline content under salt stress condition and tolerant of grape rootstocks to salinity it was cleared by Ahmed [9] who indicated that, the capacity of the grape rootstocks to accumulate proline was found to be positively correlated with the salt level in the irrigation water. Moreover, leaves of more tolerant 1103Paulsen and 140Ruggeri rootstocks contained the least significant content of proline as compared with Harmony, SO4 and Teleki 5C rootstocks. Also, Mehana *et al.* [32] was in harmony with our data which found that the leaves of 1103 Paulsen and Salt creek rootstocks recorded the lowest proline percentage comparing with Freedom and Teleki 5c rootstocks which recorded the highest proline percentage. Moreover, increasing proline content in the leaves is due to increasing water salinity might be attributed to the increase of hydrolytic enzymes caused by chloride salts and salinity [45]. Also, XiuCai *et al.* [46] showed that, the proline and soluble sugar were very important osmotic adjustable organic substances to grapes under salt stress. While Al-Absi [47] concluded that, proline accumulation is not a salinity tolerance mechanism of grapevines, but it merely an indication of salt injury and could be involved in osmotic adjustment and it was highly correlated with inhibition of vegetative growth.

Effect of Irrigation with Saline Water on Plant Mineral Content

Leaf and Root Sodium Content (%): It is clear from the data presented in Tables 7 and 8 that, control plants recorded significantly the lowest values of leaf and root Na content. Increasing salinity concentration in the irrigation water was associated with a considerable and significant increase in the percentage of Na in both plant organs and reached the peak when using 4000 ppm. Ramsey rootstock attained significantly the lowest content of leaf and root sodium, grafts on Ramsey rootstock was followed. Whereas, the highest contents were found in roots and leaves of Freedom rootstock. The effect of interaction showed that using 4000 ppm of saline water irrigation the least sodium accumulations was found in roots and leaves of Ramsey rootstock, followed by Grafts on Ramsey rootstock. While, Freedom rootstock under 4000 ppm saline water attained significantly the highest leaf and root Na content. This means that Freedom rootstock conceder a more sensitive to Na comparing to other grapevine plants in this investigation.

Irrigation with saline water produced a transient increase in the EC of the 'root weighted with saturated soil solution'. This increase caused a decline in leaf water potential and an increase in leaf petiole Na^+ and Cl^- contents [48]. So, it was cleared from many investigations that, increasing salt concentration in irrigation water increased leaves Na-content [49-53]. Moreover, Singh *et al.* [54] found that the cv. Perlette is tolerating 175 mM NaCl followed by cultivars Pusa Seedless and Beauty Seedless (up to 150 mM NaCl). Na content increased up to 100 mM NaCl in most of the genotypes. Viana *et al.* [55] reported that, the more salt-sensitive cv. 420-A and IAC 313 translocated a large amount of Na to the leaves while the more tolerant IAC 766, IAC 572 and Riparia do Traviu showed greater retention of Na in roots. Also, about the effect of salinity on root Na content, Miklos *et al.* [56] evaluated the salt tolerance in *V. vinifera*, hybrids Cserszegi Fuszeres and Generosa grafted on Berlandieri x Riparia T5C and Georgikon 28 rootstocks. Plant development and concentrations of sodium and other minerals were evaluated, Georgikon 28 grafts showed high levels of sodium retention in roots. Sodium enhanced potassium translocation to shoots.

Recently, Ben-Gal *et al.* [57] studied the response of grapevines (*Vitis vinifera*) to salinity and reported that the Grapevine response to salinity was observed through involve two mechanisms: (i) a reduction in transpiration and growth which began as soon as salinity experienced; and (ii) vine mortality which was correlated with salinity level, a sharp increase in Na and Cl content of leaves.

Leaf and Root Chloride Content (%): Chloride content of both leaves and roots (Tables, 9 and 10) was increased significantly and progressively with increasing the used salts concentration. Significantly the least accumulation was detected in roots and leaves of Ramsey rootstock. Accumulation in roots and leaves of grafts on Ramsey rootstock was followed. The results revealed that increasing salinity level in the irrigation water was followed by a subsequent increment in the percentage of Cl in the grape cultivar and rootstocks leaves and roots. The lowest Cl values came from control plants, however, Cl% was gradually increased with increasing salinity levels and reached uppermost values with the highest salinity levels (3000, 4000 ppm) in leaf and root in the first and second seasons respectively. Regarding to the effect of saline water irrigation on leaf Cl percentage, Flame Seedless on Freedom rootstock recorded the highest values of Cl-leaves (1.83 and 1.90), followed by Freedom rootstock (1.76 and 1.80) then Flame Seedless cultivar (1.63 and 1.65) in the first and second seasons, respectively. While, Flame Seedless on Ramsey and Ramsey rootstock recorded the lowest values (1.54, 1.55, 1.47 and 1.48) respectively, through the two studied seasons. Data of root Cl^- content showed that, control plant recorded the highest significant percentage with Freedom then Flame on Freedom while the lowest percentage recorded with Ramsey followed by Flame on Ramsey in both seasons. Under high concentration (3000 and 4000 ppm) Flame Seedless on Freedom and Freedom rootstock recorded the highest values of Cl-leaf content in both seasons. While, Ramsey rootstock recorded the lowest values of leaf Cl content. This may lead to conclude that Freedom rootstock is more sensitive to Cl comparing with Ramsey rootstock.

Table 7: Leaf sodium content (%) of tested grape plants in relation to irrigation with saline water during 2009 and 2010 seasons

Salt treatments (ppm)	Flame	Freedom	Ramsey	F/Fr*	F/R**	Mean
			Season 2009			
Tab water	0.33 u	0.34 tu	0.33 u	0.36 s	0.35 st	0.34 E
1000	0.51 q	0.56 o	0.46 r	0.53 p	0.46 r	0.50 D
2000	0.70 k	0.77 i	0.59 n	0.73 j	0.62 m	0.68 C
3000	0.84 g	0.92 d	0.66 l	0.86 f	0.72 jk	0.80 B
4000	1.44 c	1.73 a	0.80 h	1.52 b	0.88 e	1.27 A
Mean	0.76 C	0.87 A	0.57 E	0.80 B	0.60 D	
			Season 2010			
Tab water	0.34 p	0.36 p	0.34 p	0.37 p	0.36 p	0.35 E
1000	0.52 no	0.58 lm	0.47 o	0.55mn	0.48 o	0.52 D
2000	0.73 hi	0.80 fg	0.60 kl	0.75 gh	0.64 jk	0.70 C
3000	0.86 e	0.97 d	0.68 ij	0.88 e	0.74 h	0.82 B
4000	1.49 c	1.89 a	0.77 gh	1.57 b	0.85 ef	1.31 A
Mean	0.79 C	0.92 A	0.57 E	0.82 B	0.61 D	

*: Flame Seedless on Freedom rootstock **: Flame Seedless on Ramsey rootstock

Table 8: Root sodium content (%) of tested grape plants in relation to irrigation with saline water during 2009 and 2010 seasons

Salt treatments (ppm)	Flame	Freedom	Ramsey	F/Fr*	F/R**	Mean
			Season 2009			
Tab water	0.61 o	0.53 q	0.55 pq	0.63 no	0.59 op	0.58 E
1000	0.83 kl	0.91 ig	0.63 no	0.87 jk	0.67 n	0.78 D
2000	0.99 fg	1.04 f	0.74 m	1.03 f	0.81 n	0.92 C
3000	1.11 e	1.22 cd	0.80 l	1.17 d	0.89 ij	1.04 B
4000	1.23 bc	1.32 a	0.92 hi	1.28 ab	0.97 gh	1.15 A
Mean	0.96 B	1.01 A	0.73 D	1.00 A	0.79 C	
			Season 2010			
Tab water	0.61 op	0.56 P	0.55 P	0.65 no	0.61 op	0.60 E
1000	0.85jk	0.95 hi	0.62 op	0.91 ij	0.66 no	0.80 D
2000	1.05 fg	1.09 ef	0.70 mn	1.07 fg	0.80 kl	0.94 C
3000	1.15 de	1.30 ab	0.76 lm	1.20 cd	0.91 ij	1.07 B
4000	1.27 bc	1.37a	0.84 jk	1.31 ab	1.00 gh	1.16 A
Mean	0.99 B	1.05 A	0.70 D	1.03 A	0.80 C	

*: Flame Seedless on Freedom rootstock **: Flame Seedless on Ramsey rootstock

Table 9: Leaf chloride content (%) of tested grape plants in relation to irrigation with saline water during 2009 and 2010 seasons

Salt treatments (ppm)	Flame	Freedom	Ramsey	F/Fr*	F/R**	Mean
			Season 2009			
Tab water	0.97 n	1.22 l	1.02 mn	1.23 l	1.08 m	1.10 E
1000	1.38 jk	1.51 hi	1.26 l	1.55 h	1.31 kl	1.41 D
2000	1.67 g	1.75 eg	1.44 ij	1.79 ef	1.51 hi	1.63 C
3000	1.97 cd	2.06 c	1.72 fg	2.24 b	1.81 e	1.96 B
4000	2.16 b	2.23 b	1.92 d	2.34 a	1.97 cd	2.13 A
Mean	1.63 C	1.76 B	1.47 E	1.83 A	1.54 D	
			Season 2010			
Tab water	0.98 p	1.23 n	1.02 op	1.25 n	1.07 o	1.11 E
1000	1.41 ln	1.54 jk	1.72 n	1.62 ij	1.32 mn	1.43 D
2000	1.69 hi	1.80 fg	1.46 kl	1.84 ef	1.52 k	1.66 C
3000	1.98 d	2.16 c	1.74 gh	2.33 b	1.83 ef	2.01 B
4000	2.19 c	2.30 b	1.91 de	2.43 a	1.99 d	2.17 A
Mean	1.65 C	1.81 B	1.48 E	1.90 A	1.55 D	

*: Flame Seedless on Freedom rootstock **: Flame Seedless on Ramsey rootstock

Table 10: Root chloride content (%) of tested grape plants in relation to irrigation with saline water during 2009 and 2010 seasons

Salt treatments (ppm)	Flame	Freedom	Ramsey	F/Fr*	F/R**	Mean
Season 2009						
Tab water	0.52 l	0.52 l	0.41 o	0.55 k	0.51 l	0.50 E
1000	0.57 j	0.62 h	0.44 n	0.60 i	0.55 k	0.55 D
2000	0.66 g	0.73 e	0.50 m	0.70 f	0.56 j	0.63 C
3000	0.75 d	0.81 c	0.54 k	0.80 c	0.62 h	0.71 B
4000	0.80 c	0.87 a	0.57 j	0.85 b	0.70 f	0.76 A
Mean	0.66 C	0.71 A	0.49 E	0.70 B	0.59 D	
			Season 2010			
Tab water	0.51m	0.50 m	0.39 p	0.52 l	0.50 m	0.48 E
1000	0.54 k	0.59 i	0.41 o	0.58 i	0.53 l	0.53 D
2000	0.64 h	0.66 g	0.46 n	0.68 f	0.56 j	0.60 C
3000	0.72 e	0.76 d	0.52 l	0.78 c	0.64 h	0.69 B
4000	0.78 c	0.85 a	0.56 jk	0.83 b	0.71 e	0.74 A
Mean	0.64 D	0.67 A	0.47 D	0.68 A	0.59 C	

*: Flame Seedless on Freedom rootstock **: Flame Seedless on Ramsey rootstock

The obtained results are in agreement with those of Sykes [58] who concluded that, the ability to exclude Cl by Ramsey rootstock is probably due to the action of many genes. Chloride content in the leaf was increased by increasing salinity treatments [51, 59, 60, 9]. Moreover, Bravdo *et al.* [61] irrigated Cabernet Sauvignon vines grafted on 140 Ruggeri or Salt Creek with saline water with EC varying between 2.5 to 6 dS/m. They found that chloride accumulation in the leaves was significantly lower in all vines grafted on 140 Ruggeri than on Salt Creek. Also, Mehana *et al.* [32] indicated that, the 1103 paulsen rootstock has a reduction in leaf and shoot Cl and Na contents compared to Ramsey rootstock under irrigation by saline water at 2640 ppm.

Leaf Potassium Content (%): This parameter was significantly decreased with increasing the water salinity concentration and reached the least percentage when 4000 ppm saline water was used. On the average leaves of Flame Seedless attained significantly the highest concentration (Table 11). Those of Ramsey and Flame grafted on Ramsey rootstock were followed. Interaction shows that using tab water for irrigation resulted in a K content that was statistically equal in leaves of all used plant materials. This content was reduced significantly by increasing the salinity concentrations in manures that differed with the used plant material. Under 4000 ppm treatment K content was highest in Flame Seedless, Ramsey and grafted on Ramsey.

Table 11: Leaf Potassium content (%) of tested grape plants in relation to irrigation with saline water during 2009 and 2010 seasons

Salt treatments (ppm)	Flame	Freedom	Ramsey	F/Fr*	F/R**	Mean
			Season 2009			
Tab water	1.74 a	1.71 a	1.71 a	1.71 a	1.68 a	1.71 A
1000	1.56 b	1.40 de	1.48 c	1.43 cd	1.44 cd	1.46 B
2000	1.48 c	1.30 f-h	1.40 de	1.32 fg	1.37 d-f	1.37 C
3000	1.34 e-g	1.17 j	1.48 g-i	1.21 ij	1.28 g-i	1.26 D
4000	1.23 h-j	1.00 k	1.18 j	1.03 k	1.15 j	1.12 E
Mean	1.47 A	1.32 C	1.41 B	1.34 C	1.39 B	
			Season 2010			
Tab water	1.76 a	1.73 a	1.72 a	1.73 a	1.70 a	1.73 A
1000	1.58 b	1.42 d-f	1.49 cd	1.44 c-e	1.46 cd	1.48 B
2000	1.50 c	1.31 gh	1.42 d-f	1.33 gh	1.38 e-g	1.39 C
3000	1.36 f-h	1.19 j	1.31 gh	1.23 ij	1.30 hi	1.28 D
4000	1.24 ij	1.03 k	1.21 j	1.04 k	1.17 j	1.14 E
Mean	1.49 A	1.34 C	1.43 B	1.36 C	1.40 B	

*: Flame Seedless on Freedom rootstock **: Flame Seedless on Ramsey rootstock

Table 12: Leaf calcium content (%) of tested grape plants in relation to irrigation with saline water during 2009 and 2010 seasons

Salt treatments (ppm)	Flame	Freedom	Ramsey	F/Fr*	F/R**	Mean
			Season 2009			
Tab water	3.05 a	2.87 a-c	2.71 cd	2.93 ab	2.91 ab	2.89A
1000	2.78 bc	2.40 e-g	2.24 gh	2.55 de	2.47 ef	2.49B
2000	2.50 e	2.11 hi	2.01 ij	2.37 e-g	2.30 f-h	2.26C
3000	2.13 hi	1.75 k-m	1.64 l-n	1.98 ij	1.84 jk	1.87D
4000	1.89 jk	1.61 mn	1.52 n	1.83 j-l	1.77k-m	1.73E
Mean	2.47 A	2.15 D	2.02 E	2.33 B	2.26 C	
			Season 2010			
Tab water	2.96 a	2.82 ab	2.67 bc	2.89 a	2.83 a	2.83A
1000	2.66 c	2.20 fg	2.11 g-i	2.42 d	2.29 d-f	2.36B
2000	2.40 de	2.02 h-j	1.89 jk	2.27 ef	2.14 f-h	2.14C
3000	1.98 ij	1.65 m-o	1.58 no	1.88 jk	1.76k-m	1.77D
4000	1.81 kl	1.52 op	1.41 p	1.72 l-n	1.59 no	1.61E
Mean	2.36 A	2.04 D	1.93 E	2.24 B	2.12 C	

*: Flame Seedless on Freedom rootstock **: Flame Seedless on Ramsey rootstock

In this regard, Shehata *et al.* [62] and Walker *et al.* [14] indicated that, vines grown under saline conditions accumulated less K compared with the control. Also, Walker *et al.* [14] applied salinity treatments of 0.43, 1.7 and 3.4 dS/m through a drip-irrigation system to 4-year-old vines of own-rooted Sultana (SO) and Sultana on Ramsey rootstock (SR). And they found that Leaf K^+ concentrations were higher in SR, but decreased with increasing salinity.

Leaf Calcium Content (%): Control (tab water irrigated) plant material attained significantly the highest leaf Ca content (Table 12). Increasing the concentration of the used saline solution decreased this content significantly to reach the least percentage with 4000 ppm. Flame Seedless transplant attained significantly the highest leaf content of calcium. Whereas, Ramsey transplant attained significantly the least content. Interactions declare that with using 4000 ppm saline water highest Ca content was found in Flame Seedless transplant. Comparable results were attained by grafts on both rootstocks in the first season and grafts on Freedom rootstock in the second one.

Similarly, Allam *et al.* [63] investigated the effect of irrigation with saline water (0.0, 0.1%, 0.2% and 0.3% NaCl + CaCl2 at 1:1) on two grapevine cultivars (Thompson Seedless and Bez-El-Anza). They noticed that, Ca was increased under 0.1% salinity level than those of 0.2% and 0.3% salinity levels for both cultivars. Hooda *et al.* [49] Indicated that, the leaf Ca decreased with an increase in soil salinity.

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