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Plant growth and yield of cucumber plants grafted on different commercial and local rootstocks grown under salinity stress



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ABSTRACT

This study aimed to determine the effects of different rootstocks and soilless media on the plant growth and yield of cucumber and on the leaf ion (Na^+ , Ca^{++} , K^+ and Cl^-) concentrations. Four commercial rootstocks (TZ148 F₁, RS841 F₁, Nun9075 F₁ and Avar F₁) and two local landraces (Local-1 and Local-3 belonging to *Cucurbita moschata* L.) were used as rootstock and grafted and non grafted plants were tested in three different salinity conditions (2.5 dS m^{-1} , 5.0 dS m^{-1} and 7.5 dS m^{-1}) on three different soilless media (cocopeat, perlite and rockwool) in spring period under greenhouse conditions. Salinity found to reduce root and shoot dry weight, and yield of plants in all growing media. TZ148, Nun9075 and Local-3 are found to improve tolerance of cucumber plants to saline conditions (5.0 and 7.5 dS m^{-1}) when used as rootstocks. Root and shoot dry weight, yield, Ca^{++} in leaves and K^+/Na^+ ratio in leaves were significantly decreased, but Na^+ and Cl^- concentration in leaves were increased under salt stress. Rootstock potential of Local-3 is also found to be quite good for cucumber under saline conditions.

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1. Introduction

Reductions in the available land for cultivation together with the increase in human population are the two main threats for sustainability in the world food supply (Shahbaz and Ashraf, 2013). Salinization of soil and irrigation water is one of the most devastating reasons in the decrease of availability of land. It has been estimated that salinity is affecting nearly 20% of the cultivated agricultural land and about half of all irrigated area around the world (Zhu, 2001). Salinity is an important environmental stress condition, which causes huge reductions in the cultivated land and crop yield (Yamaguchi and Blumwald, 2005). The main result of plants exposure to salt stress is water deficit due to low osmotic potential in rhizosphere and ion excess. Mainly Na^+ and Cl^- are high in salty environments and are potentially taken up at high rates by plants (Greenway and Munns, 1980). Uptake of these ions negatively affects membrane permeability of crops and interferes with the uptake of other ions (Hu and Schmidhalter, 2005). Excess

of salt also cause either stomatal closure or restricting the ability of CO_2 fixation which in turn cause reduction in photosynthetic capacity (Brugnoli and Lauteri, 1991). High salt accumulation in leaf causes leaf injuries and death (Munns et al., 2006). Tolerance to salinity stress conditions is variety sensitive and is related with many biological processes. Such as, Aktaş et al. (2012) reported that some salt-tolerant pepper genotypes show increases in some anti-oxidative stress enzymes and glutathione content.

Saline soils are defined as the soils with an electrical conductivity of more than 4 dS m^{-1} at $25 \text{ }^\circ\text{C}$ (nearly 40 mM NaCl) (Richards, 1954). However, it is well-known that sensitive plants are affected at about half of this salinity where some plants may be tolerant at about twice of this salinity (Jamil et al., 2011). James et al. (2006) reported that the plants' tolerance to salinity stress conditions depends on the ability of plants to exclude salt from the roots. Cucumber plant is moderately sensitive to salt stress (Jones et al., 1989). It is reported to tolerate an EC of about 2.5 dS m^{-1} where yield decreases by 13% with each unit of EC increase above the threshold value (Ploegman and Bierhuizen, 1970). Using salt-tolerant rootstocks is an effective way for reducing sensitivity; and improving crop yield and quality in fruit bearing vegetables (He et al., 2009; Öztekin et al., 2009; Santa-Cruz et al., 2002). As in watermelon production, using grafted plants is becoming an important production type in melon and cucumber production (Yetişir et al., 2007; Yarşi et al., 2017). However, there are still many combinations of rootstock and media which had not been studied

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under saline environments in different climatic conditions. On the other hand, there are some local genotypes which may have potential to be used as a rootstock against salinity stress conditions whereas no studies performed on them. In the light of this information, present work aimed to study the rootstock potentials of two local landraces (*Cucurbita moschata* L.) and four commercial rootstocks for cucumber under three different soilless media conditions against salinity.

2. Materials and methods

Falconstar F₁ hybrid cucumber cultivar was used as plant material in this study. Four commercial F₁ hybrids of *Cucurbita maxima* × *Cucurbita moschata* (Nun9075 “Nunhems”, RS 841 “DeRuiter Seeds”, TZ148 “Argis SA” and Avar F₁ “İstanbul Tarım AŞ”) and two local squash *Cucurbita moschata* L. landraces originated from Cyprus (Local-1 and Local-3) were used as rootstocks. These two local landraces were selected after a preliminary test, which conducted with 5 different landraces.

The experiment was carried out in a polyethylene greenhouse located in the west of North Cyprus in spring growing period at an air temperature of 16–33 °C and a relative humidity of 50–62%. The UV index was around 4–7 with 113–150 sun hours per month. The Falconstar cultivar was used as non grafted (control treatment) and as grafted onto given six different rootstocks. Rootstocks were grown in growbags and slice grafting method was performed for grafting. Fifteen days after grafting, plants were transferred into growing media on 5 March 2017 and experiments were continued for 67 days until the death of control plants. Fertilization of the plants was carried out automatically 3–4 times per day by adjusting the system to 200 radiations and 40% waste water. Following nutrient compositions were used in each irrigation to supply needed nutrient for the plants growth: (mg L⁻¹): 444 KNO₃, 333 MPK, 13 FeSO₄, 7 MnSO₄, 4 ZnSO₂, 1 CuSO₂, 0.4 MoSO₂, 333 CaNO₃, 111 MgNO₃, 333 NH₄ and 0.1 phosphoric acid (10%) in seedling period; 1000 KNO₃, 333 MPK, 4 Borax (10%), 13 FeSO₄, 7 MnSO₄, 4 ZnSO₂, 1.1 CuSO₂, 0.4 MoSO₂, 333 CaNO₃, 111 MgNO₃, 333 NH₄ and 0.1 phosphoric acid (10%) in flowering period; and 1111 KNO₃, 444 MPK, 4 Borax (10%), 13 FeSO₄, 7 MnSO₄, 4 ZnSO₂, 1.1 CuSO₂, 0.4 MoSO₂, 333 CaNO₃, 111 MgNO₃, 333 NH₄ and 0.1 phosphoric acid (10%) in harvesting period.

The experiment was designed as a factorial combination of seven grafting combinations, three salinity conditions and three growing media. The experiment was laid out in a split-split-plot design. The main factor of the experiment was defined as the three different salinity conditions, which are: 2.5 dS m⁻¹, 5.0 dS m⁻¹ and 7.5 dS m⁻¹. The second factor of the experiment was growing media where seedlings were planted in growbags filled with cocopeat, perlite or rockwool. The sub-plots of the experiment comprised six graft combinations and one non grafted Falconstar cultivar. Each unique treatment was arranged in a randomized complete-block design with three replicates per treatment and five plants were used for each replicate. Until 14th day of transplanting, all plants were irrigated with a nutrient solution of 2.5 dS m⁻¹. After that 2 out of 3 plants were subjected to salt stress with the electrical conductivity (EC) of the nutrient solutions 5.0 and 7.5 dS m⁻¹. Rest is continued to be irrigated with the same nutrient solution as control (2.5 dS m⁻¹).

2.1. Data collection

Thirty days after salt treatment, leaf samples collected from each graft combination from every single treatment and K⁺, Na⁺, Ca⁺⁺ and Cl⁻ ion concentrations were determined by Kacar (1984). Irrigation of the plants was continued until the death of control plants and then plants were harvested. During this period,

fruits harvested at commercial maturity, counted for each unique treatment and weighted. After harvesting the whole plants, roots and shoots were separated from the growth media and plant roots were cleaned-off from growth media under running water. Then the plant root and shoot materials were dried for 48 h at 70 °C in order to determine dry weights.

2.2. Statistical analysis

The data of the experiment was subjected to a three-factor anova with seven cultivars, three growing media and three salinity stress conditions using SPSS 20 and the means were separated using a Duncan's multiple range test at $P < 0.05$. Correlation coefficients between the total dry weight and ion concentrations in the leaves of cucumber plants were also calculated by using SPSS 20.

3. Results

3.1. Plant growth

Results of present study showed that among the tested growing media, cocopeat is the most suitable media for growing cucumbers and is followed by perlite and rockwool. Root dry weight of the tested plants at 2.5 dS m⁻¹ as an average of all graft combination were measured as 42.88 g plant⁻¹ at cocopeat, 42.48 g plant⁻¹ at perlite and 28.85 g plant⁻¹ at rockwool (Table 1). Rockwool had been found to tight the plant roots and prevent the root development. Results also showed that the increase in the salinity stress in the environment is decreasing root and shoot dry weight of the plants. When comparing the shoot dry weight of all plants grown at 7.5 dS m⁻¹, similar results obtained with root dry weights and cocopeat media was found to have highest shoot dry weight with 28.85 g plant⁻¹ and followed by perlite and rockwool with 17.96 and 14.35 g plant⁻¹ shoot dry weights, respectively. No statistical difference had been found for the average root and shoot dry weight of plants irrigated with an EC of 5.0 dS m⁻¹ and 7.5 dS m⁻¹. These results suggest that, increase in the EC of irrigation water has considerable effect on the root and shoot development, but after a critical point (5.0 dS m⁻¹), the effect diminish. When the effects of rootstocks on the root dry weight were compared, it was noted that the highest root dry weight recorded in Falconstar cultivar (50.37 g) and followed by Local-3 cultivar (46.56 g) both irrigated with an EC of 2.5 dS m⁻¹. When comparing the rootstocks and growing media under an EC of 7.5 dS m⁻¹, it was observed that RS841 in cocopeat has highest root dry weight and was followed by Local-3 cultivar in cocopeat. These two graft combination was followed by FS/Nun9075 graft combination grown in perlite. Compared with the control (non grafted Falconstar), all graft combinations were found to have less shoot dry weight but the shoot dry weight of non grafted plants showed significant decrease at 5.0 and 7.5 dS m⁻¹ salinity stress. As in root dry weight, shoot dry weight of the tested plants were found to highest at cocopeat and followed by rockwool and perlite. Among the tested graft combinations, FS/RS841, FS/Nun9075 and FS/TZ148 are found to have the highest shoot dry or fresh weights.

Yield is a very important indicator for salinity stress where it is estimated to decrease as NaCl concentration increases. Results of present work verified this knowledge and highest yield was obtained from the plants grown under 2.5 dS m⁻¹ salinity stress condition and yield substantially decreased as NaCl concentration increases. At the lowest NaCl concentration (2.5 dS m⁻¹) highest yield was harvested from non grafted Falconstar cultivar and followed by FS/TZ148, FS/Nun9075 and FS/Avar. Local varieties had lower yield than other graft combinations. The non grafted Falconstar cultivar produced very low yield at 5.0 and 7.5 dS m⁻¹

Table 1
Root and shoot dry weights, plant yield and leaf ion (K^+ , Ca^{++} , Na^+ , Cl^- and K^+/Na^+) concentrations of Falconstar cucumber cv. grafted on different rootstocks and grown in different soilless media under different salinity stress conditions.

Graft combinations	Salinity levels (dS m ⁻¹)	Root dry weight (g)	Shoot dry weight (g)	Yield (kg plant ⁻¹)	K ⁺ (%)	Ca ⁺⁺ (%)	Na ⁺ (%)	Cl ⁻ (%)	K ⁺ /Na ⁺ ratio
FS/Nun9075	2.5	34.07 c	68.70 de	6.77 bc	1.65 bc	9.81 ab	0.06f	0.34 f	29.61 a
	5.0	7.63 ef	19.19 fe	2.57 de	1.67 bc	7.02 cd	0.58 d	1.24 de	3.81 efg
	7.5	7.88 ef	21.93 f	1.19 fg	1.60 bcd	6.69 cd	0.60 d	1.94 c	3.03 efg
FS/RS841	2.5	33.92 c	73.92 cd	5.71 bc	1.06 e	11.4 a	0.16f	0.30 f	8.03 e
	5.0	8.71 ef	22.18 f	2.64 de	1.20 b–e	7.79 cd	0.62 d	1.35 de	2.08 efg
	7.5	10.47 ef	23.26 f	1.49 ef	1.15 de	5.26 ef	0.63 d	1.75 c	2.29 efg
FS/TZ148	2.5	40.77 b	82.01 c	7.05 b	1.29 b–e	10.4 ab	0.10f	0.26 f	13.46 d
	5.0	7.14 ef	20.40 f	2.78 d	1.35 b–e	7.12 cd	0.69 d	1.18 de	4.05 efg
	7.5	7.48 ef	22.27 f	1.25 ef	0.97 e	4.33 f	0.48 de	1.42 d	3.24 efg
FS/Avar	2.5	33.9 c	60.29 e	6.74 bc	1.70 b	10.18 ab	0.13f	0.34 f	28.07 ab
	5.0	8.98 ef	19.43 fe	2.63 de	1.11 de	6.79 de	0.62 d	1.22 de	2.53 efg
	7.5	6.89 ef	17.89 fe	1.06 fg	1.27 b–e	6.36 de	0.75 cd	2.25 b	1.76 fg
FS/Local-1	2.5	26.89 d	60.61 e	2.54 de	2.29 a	10.93 ab	0.09f	0.35 f	24.08 bc
	5.0	3.67 f	9.83 g	1.12 fg	1.43 b–e	7.40 cd	0.61 d	1.23 de	2.46 efg
	7.5	4.28 f	15.61 fe	0.63 gh	1.16 de	5.03 ef	0.60 d	1.94 c	2.19 efg
FS/Local-3	2.5	46.56 ab	93.33 b	5.42 c	2.20 a	9.44 b	0.11f	0.35 f	19.05 c
	5.0	9.78 ef	24.89 f	2.17 de	1.73 b	7.96 c	0.73 cd	1.23 de	2.53 efg
	7.5	7.50 ef	20.00 f	0.47 h	1.75 b	6.56 de	1.04c	1.94 c	2.84 efg
Falconstar (control)	2.5	50.37 a	113.78 a	8.58 a	1.29 b–e	9.81 ab	0.21 e	0.34 f	6.72 ef
	5.0	11.86 e	14.33 fe	1.29 ef	1.43 b–e	6.69 de	2.88b	1.91 c	0.51 g
	7.5	6.93 ef	21.74 f	0.81 gh	1.37 b–e	6.20 de	3.28 a	2.88 a	0.42 g
Growing media Perlite	2.5	42.48 a	80.25 a	5.20 b	1.91 a	9.19 c	0.13 d	0.34 d	23.1 a
	5.0	8.69 cd	16.22 d	1.81 d	1.32 b	6.34 e	1.22 ab	1.23 c	1.52 c
	7.5	8.27 cd	17.96 cd	0.78 d	1.17 b	4.66 f	0.92 bc	2.22 a	2.14 c
Rockwool	2.5	28.85 b	79.50 a	5.56 b	1.52 b	10.25 b	0.10 d	0.33 d	17.53 b
	5.0	6.02 cd	13.92 d	1.44 d	1.41 b	6.98 e	0.96 bc	1.28 c	2.35 c
	7.5	4.60 d	14.35 d	0.81 d	1.32 b	4.91 f	1.40 a	2.16 a	1.21 c
Cocopeat	2.5	42.88 a	77.10 a	7.56 a	1.48 b	11.75 a	0.14 d	0.31 d	14.67 b
	5.0	10.05 c	25.69 bc	3.23 c	1.52 b	8.43 d	0.70c	1.44 bc	3.84 c
	7.5	9.17 c	28.85 b	1.38 d	1.48 b	7.75 d	0.84 bc	1.59 b	3.41 c

Values followed by the same letter or letters within the same column are not significantly different at a 5% level Duncan's multiple range test.

salt concentrations. At these higher salt concentrations, FS/TZ148, FS/Nun9075, FS/RS841 and FS/Avar had higher yield than other graft combinations and non grafted control plants as well. Two local squash material tested as rootstock found to be sensitive to high salinity stress and the yield decreased substantially. However, FS/Local-3 found to be slightly tolerant to 5.0 dS m⁻¹ salinity stress. Among the tested growing media, cocopeat was noted to have higher yield than other growing media for each salinity stress conditions. On the other hand, yield results of the grafted and non grafted plants under tested minimum salinity stress (2.5 dS m⁻¹) showed that grafting cause slight stress on the plants where non grafted Falconstar found to have highest yield.

3.2. Ion concentrations

K⁺ concentrations in the leaves of FS/Local-1 and FS/Local-3 are found to be higher than the other treatments. It was also noted that concentrations of K⁺ in the leaves of these two graft combinations and; FS/Avar and Falconstar showed significant decrease as NaCl concentration increased. However, in other treatments, concentrations of K⁺ in the leaves of plants had no significant change or fluctuations. On the other hand, concentrations of K⁺ in different growing medias is found to be significantly equal, except perlite at 2.5 dS m⁻¹ which was found to be significantly higher than the all other treatments. The concentrations of Ca⁺⁺ in the plant leaves decreased significantly as NaCl concentration increased. On the other hand, the concentrations of Ca⁺⁺ in the grafted and non grafted plants were found to be similar at the same NaCl stress except FS/TZ148 which was found to be significantly lower than

the other treatments. The concentrations of Ca⁺⁺ in the leaves of graft combinations grown in perlite were found to be the lowest where as the highest concentrations were determined at cocopeat growing media. In every single treatment, Leaf Na⁺ concentrations found to increase progressively as NaCl concentration increased. Furthermore, as expected the leaf Na⁺ concentrations of the all graft combinations were found to be significantly lower than the concentrations in the non grafted control plants under the same NaCl stress. Under the highest NaCl stress condition (7.5 dS m⁻¹), the lowest concentrations of Na⁺ was recorded in FS/TZ148 graft combination and was followed by FS/Local-1, FS/Nun9075 and FS/RS841. It is also clear from the results that the plants grown in rockwool growing media (under high NaCl stress) had the highest concentrations of Na⁺ in their leaves as compared with other growing media. However, the leaf Na⁺ concentrations of plants grown in rockwool were still significantly lower than those of the control plants.

The Cl⁻ concentrations in the leaves of all graft combinations, including non grafted control plants increased with increasing NaCl concentration. However, the leaf Cl⁻ concentrations of the grafted plants were significantly lower than those in the non grafted plants, similarly with the limiting of Na⁺ concentrations. Moreover, the concentration of Cl⁻ in leaves was found to be significantly affected by NaCl stress conditions; and salinity x grafting interaction. Thus, the lowest values were recorded on FS/TZ148 (at highest EC: 7.5 dS m⁻¹) as 1.42% and highest at same EC on non grafted Falconstar as 2.88%. When comparing the growing media, cocopeat was found to be more effective than perlite and rockwool media in limiting Cl⁻ accumulation in plants.

Table 2

Correlation coefficients between total dry weight and some other parameters of Falconstar cucumber cv. grafted onto different rootstocks in different growing media.

Graft combinations	Salinity levels (dS m ⁻¹)	Yield	Media salinity	Leaf K ⁺	Leaf Na ⁺	Leaf Ca ⁺	Leaf Cl ⁻	Leaf K ⁺ /Na ⁺	Leaf Ca ⁺ /Na ⁺
FS/Nun9075	2.5	0.914**	-0.825**	0.985**	-0.889**	0.686*	-0.138	0.982**	0.984**
	5.0	0.940**	-0.836**	-0.961**	-0.919**	0.941**	0.204	0.973**	0.975**
	7.5	0.927**	-0.856**	-0.916**	-0.913**	0.926**	-0.785*	0.968**	0.985**
FS/RS841	2.5	0.889**	-0.809**	0.354	-0.943**	0.740*	0.776*	0.930**	0.917**
	5.0	0.969**	-0.815**	-0.772*	-0.833**	0.909**	-0.280	0.972**	0.977**
	7.5	0.916**	-0.843**	-0.612	-0.741*	0.927**	-0.832**	0.830*	0.955**
FS/TZ148	2.5	0.858**	-0.849**	0.988**	-0.865**	0.927**	0.603	0.989**	0.987**
	5.0	0.956**	-0.834**	-0.831**	-0.962**	0.881**	0.270	0.987**	0.989**
	7.5	0.950**	-0.836**	0.218	-0.460	0.790*	-0.797*	0.815**	0.935**
FS/Avar	2.5	0.814**	-0.820**	0.780*	-0.721*	0.836**	-0.478	0.792*	0.794*
	5.0	0.942**	-0.834**	-0.512	-0.751*	0.854**	-0.086	0.974**	0.975**
	7.5	0.943**	-0.851**	-0.295	-0.286	0.892**	-0.042	0.639	0.670
FS/Local-1	2.5	0.819**	-0.820**	0.943**	-0.867**	0.802*	-0.822**	0.995**	0.993**
	5.0	0.839**	-0.837**	0.810*	-0.826**	0.805*	-0.141	0.971**	0.967**
	7.5	0.776*	-0.766*	0.732*	-0.959**	0.923**	-0.640	0.970**	0.968**
FS/Local-3	2.5	0.823**	-0.864**	-0.987**	-0.796*	0.987**	-0.497	0.950**	0.968**
	5.0	0.900**	-0.951**	0.983**	-0.932**	0.845**	0.469	0.984**	0.985**
	7.5	0.880**	-0.818**	0.901**	-0.942**	0.069	0.533	0.978**	0.962**
Falconstar (control)	2.5	0.839**	-0.833**	-0.641	-0.987**	0.910**	0.376	0.989**	0.989**
	5.0	0.922**	-0.856**	0.333	-0.991**	0.989**	0.190	0.988**	0.990**
	7.5	0.934**	-0.850**	0.336	-0.915**	0.914*	-0.042	0.975**	0.974**

* $P < 0.05$.** $P < 0.01$; ($n = 9$).**Table 3**

Correlation coefficients between total dry weight and some other parameters of Falconstar cucumber cv. grafted onto different rootstocks as an average of three different growing media (perlite, rockwool and cocopeat).

Graft Combinations	Yield	Media salinity	Leaf K ⁺	Leaf Na ⁺	Leaf Ca ⁺	Leaf Cl ⁻	K ⁺ /Na ⁺ in Leaf	Ca ⁺ /Na ⁺ in Leaf
FS/Nun 9075	0.896**	-0.814**	0.135	-0.873**	0.743**	-0.800*	0.825**	0.930**
FS/RS841	0.898**	-0.788**	-0.068	-0.660**	0.824**	-0.823**	0.699**	0.661**
FS/TZ148	0.847**	-0.823**	0.199	-0.613**	0.754**	-0.821**	0.916**	0.923**
FS/Avar	0.920**	-0.804**	0.173	-0.540**	0.768**	-0.769**	0.532**	0.761**
FS/Local-1	0.775**	-0.747**	0.769**	-0.795**	0.571**	-0.781**	0.933**	0.684**
FS/Local-3	0.852**	-0.868**	0.392*	-0.667**	0.699**	-0.852**	0.887**	0.919**
Falconstar (control)	0.885**	-0.840**	-0.213	-0.960**	0.822**	0.865**	0.868**	0.880**

* $P < 0.05$.** $P < 0.01$; ($n = 27$).

K⁺/Na⁺ ratio in the leaves is a good indicator of tolerance to salinity stress of crops and as expected, least K⁺/Na⁺ ratio was measured at non grafted Falconstar cultivar. At the EC of 2.5 dS m⁻¹ FS/Nun9075 graft combination was found to have highest K⁺/Na⁺ ratio and followed by FS/Avar and FS/Local-1 and FS/Local-3. At higher salinity stress conditions, again FS/Nun9075 was found to have higher K⁺/Na⁺ ratio but FS/Avar and FS/Local-1 were noted to have lower K⁺/Na⁺ ratio. On the other hand, K⁺/Na⁺ ratio of FS/TZ148 and FS/RS841 graft combinations were higher at 7.5 dS m⁻¹. When comparing the growing media, perlite was found to have highest and cocopeat to have lowest K⁺/Na⁺ ratio at 2.5 dS m⁻¹, however at higher EC conditions cocopeat was found to have higher K⁺/Na⁺ ratio.

Correlation between total dry weight and leaf ion concentrations of cucumber plants were then calculated (Table 2). The total dry weight was found to be negatively correlated with the media salinity and Na⁺ concentration in the leaves while it was positively correlated with leaf Ca⁺⁺ content and, K⁺/Na⁺ and Ca⁺⁺/Na⁺ ratios. On the other hand, concentrations of K⁺ in the leaf was positively correlated with total dry weight in perlite growing media and negatively correlated in rockwool and cocopeat growing media for FS/Nun9075, FS/RS841, FS/TZ148 and FS/Avar grafting combinations. For the FS/Local-3 and non grafted Falconstar treatments, negative correlation was found in perlite and positive correlation (moderate, weak or negligible) was recorded in rockwool and cocopeat

growing media. A very strong positive relationship was determined between the total dry weight and yield of the plants for all graft combinations under every salinity stress conditions.

Increases in Na⁺ concentrations in plant tissues was believed to decrease the total dry weight due to salinity stress. Results of the present study verified this knowledge and non grafted Falconstar cultivar had the highest negative correlation coefficient for total dry weight and leaf Na⁺ concentration (Table 3). The smallest correlation coefficient for total dry weight and Na⁺ concentration in leaf was determined in FS/Avar and followed by FS/TZ148 and FS/RS841. It was observed that the highest correlation among the total dry weight and K⁺/Na⁺ ratio in leaf was found at FS/Local-1 and is followed by FS/TZ148. The smallest correlation was determined at FS/Avar graft combination. FS/Avar graft combination found to have the highest positive relationship among the total dry weight and yield where as the FS/Local-1 had the lowest correlation.

4. Discussions

Grafting is a widely used technique in vegetables and fruits to improve resistance against environmental stress conditions (drought, salinity, high/low temperature, etc.), pathogens, adverse soil conditions and nutrient deficiency (Rivero et al., 2003;

Edelstein et al., 2005; Yetişir et al., 2007; Hussain et al., 2014). Results of the present study showed that plant growth and yield in cocopeat media were significantly better than in rockwool and perlite media under salinity stress. Better performance of cocopeat might be due to the higher water and nutrient holding capacity. Cocopeat reported to have a cation exchange capacity around 50–100-fold of perlite, which provides stability of pH and affect the absorption of nutrients. In a similar study Mahjoor et al. (2016) reported higher eggplant yield in cocopeat than in perlite under 7 dS m⁻¹ water salinity. Results of present study are in conjunction with the previous studies reporting negative effects of salt concentration on the root and plant development (Ashraf and Tufail, 1995; Kurum et al., 2013). It can clearly be understood from the results that the cucumber growth either grafted or not was inhibited by salinity stress. According to Ashraf and O'leary (1997) salt inhibits cytokinesis and cell expansion and in turn it negatively affects the root and shoots developments.

Present study also revealed that the grafting improves plant growth and total yield under saline conditions in which total yield of the non grafted Falconstar cultivar was lowest at 5.0 and 7.5 dS m⁻¹ saline conditions. Among the tested rootstocks, Nun 9075, RS841, TZ148 and Local-3 were found to increase plants tolerance to salinity stress under an EC of 5.0 dS m⁻¹ and RS841 was also found to increase plants tolerance under an EC of 7.5 dS m⁻¹. These results validated the findings of many previous studies who reported positive effect of grafting on yield under saline conditions (Zhu et al., 2008; Yetişir and Uygur, 2010; Colla et al., 2012; Voutsela et al., 2012; Kurum et al., 2013; Abu-Zinada, 2015; Yarşi et al., 2017). Rootstocks of RS841 and TZ148 were also reported by Yarşi et al. (2012) and rootstocks of Nun9075 and RS841 were reported by Uysal et al., (2012) to improved fruit yield and quality for melons under saline conditions. Discussions of present results made it possible to say that not only commercial genotypes such as Nun 9075, RS841 and TZ148, but also a local landrace (Local-3) have rootstock potential for cucumber under saline conditions.

K⁺ is one of the three essential elements for plants, which plays an essential role in plant development, especially in fruit growth (Kacar, 1984). Maathuis and Amtmann (1999) reported that physicochemical structures of Na⁺ and K⁺ are similar which means that high concentrations of Na⁺ at transport sites might cause K⁺ deficiency. In this experiment, K⁺ concentrations in the leaves of FS/Local-1 and FS/Local-3 are found to be higher than the other treatments and it decreased as NaCl concentration increased. It was also noted that K⁺ concentrations in the leaves of these two graft combination and; FS/Avar and Falconstar showed significant decrease as NaCl increased. However, in other treatments, leaf K⁺ concentrations had no significant change or fluctuations. On the other hand, concentrations of K⁺ in plants grown on different growing media are found to be significantly equal, except perlite at 2.5 dS m⁻¹ which was found to be significantly higher than the all other treatments. Under the same NaCl stress conditions, K⁺ concentrations in the leaves of FS/Nun9075 and FS/Local-3 plants were recorded to be higher than the non grafted control plants. Other grafting combinations found to be significantly similar with the non grafted control. These results partially implied the general knowledge about grafting which states that it alleviates K⁺ deficiency under NaCl stress. Total dry weight was positively correlated with K⁺ contents of some grafting combinations (especially in perlite) and negatively correlated with some other (especially in rockwool and cocopeat).

Leaf Ca⁺⁺ concentrations of test plants (either grafted or not) decreased significantly as NaCl concentration in the growing media increased. The concentrations of Ca⁺⁺ in the leaves of graft combination grown in perlite were found to be lowest where as the highest concentrations were determined at cocopeat growing media. Accumulation of Ca⁺⁺ in the leaves is reported to be a factor in

improving salt tolerance (Navarro et al., 2002). Results of present work confirmed this knowledge by decreasing Ca⁺⁺ content under saline conditions. One of the most important results of present work is that the Na⁺ concentrations of leaves increased as NaCl concentration in the growing media increased, while the leaf Na⁺ concentrations of all grafted plants were recorded to be significantly lower than the concentrations in the non grafted control plants. On the other hand, a negative correlation with Na⁺ and total dry weight was calculated. These results are in conjunction with the results of Zhu et al. (2008) and Daşgan et al. (2002). James et al. (2006) reported that the plants' ability to grow under NaCl concentrations is associated with the plants' ability to exclude and/or mobilize Na⁺ ions. Thus, results of present research implied that the grafting plays an important role in elimination of NaCl stress by limiting the transport of Na⁺ ions. The results of present research also support the findings of Aktaş et al. (2006), who reported a positive correlation between the leaf Na⁺ concentrations and the leaf symptoms, but no correlation with leaf symptoms and K⁺ or Ca⁺⁺ concentrations of leaf.

Cl⁻ reported to play a crucial role in osmotic adjustment where excessive accumulation may result in toxicity and inhibit plant growth (Ashraf and Harris, 2004). Similar with the uptake of Na⁺, the concentrations of Cl⁻ in the leaves of graft combinations in present study were found to be significantly lower than those in non grafted plants. In this present study, negative correlation was determined with Cl⁻ accumulation and total dry weight of plants which reveals that higher accumulation of Cl⁻ cause growth inhibition. This result is in agreement with the findings of Ashraf and Harris (2004) but is not coincident with the findings of Bayuelo-Jimenez et al. (2003).

In present research, the concentrations of K⁺/Na⁺ in the leaves was decreased at non grafted Falconstar cultivar and increased at graft combinations. According to Santa-Cruz et al. (2002) and Zhu et al. (2008) high ratio of K⁺/Na⁺ in leaf is crucial for plants' tolerance to NaCl stress conditions. Results of present work are in agreement with the results of Zhu et al. (2008) where the Na⁺ contents increased and the leaf K⁺/Na⁺ ratio decreased significantly under NaCl stress, whether grafted or not. However, the leaf K⁺/Na⁺ ratio of graft combinations was recorded to be significantly higher than the ratio in non grafted plants. Concerning the K⁺/Na⁺ ratios in the leaves of varieties, the highest K⁺/Na⁺ ratio (at 5.0 dS m⁻¹) was observed in FS/TZ148 (4.05) and followed by FS/Nun9075 (3.81) and FS/Local-3 (2.53). All other graft combinations had higher ratio than non grafted control plants. Similarly, the highest K⁺/Na⁺ ratio (at 7.5 dS m⁻¹) was observed in FS/TZ148 (3.24) and followed by FS/Nun9075 (3.03) and FS/Local-3 (2.84). Results showed that plant growth was positively correlated with the K⁺/Na⁺ ratio which reveals the knowledge that grafting raises salt tolerance by limiting Na⁺ accumulation and catalysing the transport of K⁺, thus to increase K⁺/Na⁺ ratio.

5. Conclusions

According to obtained results, root dry weight, shoot dry weight, yield, Ca⁺⁺ in leaves and K⁺/Na⁺ ratio in leaves of plants were significantly decreased, but Na⁺ and Cl⁻ concentration in leaves of plants were increased under salt stress. Na⁺ accumulation has played an important role against salt resistance and it was observed that TZ148, Nun9075 and Local-3 [*Cucurbita moschata* L. landraces] decrease the accumulation of Na⁺ in cucumber and improves tolerance when used as rootstock. Sensitive genotypes were found to have higher amount of Na⁺ and lower ratio of K⁺/Na⁺. Rootstock potential of Local-3 is quite promising for cucumber, and maybe for other Cucurbitaceae family crops, especially under saline conditions both on soil and in soilless culture. For this new and more detailed studies are needed.

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Conflict of interest

None.

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