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Grafting Enables Cantaloupe to Tolerate More Saline Stress

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ABSTRACT

Grafting cantaloupe plants onto cucurbita rootstocks make it utilize by these rootstocks features i.e. higher absorption mass of water and nutrient, higher surface area and abiotic stress tolerance. The cantaloupe *Cucumis melo var cantaloupensis* Cv. Marella was grafted onto three rootstocks were Shintosa, Star and Cobalt. The plants were grown hydroponically in sand culture under three saline concentrations of 0, 100 and 150 mM NaCl for 30 days to investigate the effects of salinity on grafted Cantaloupe plants compared with non-grafted ones. The results proved that The results proved that grafted Cantaloupe plants had a better performance than the non-grafted ones especially grafted onto Star rootstock. Grafted plants recorded highest growth vigor as indicted by shoot and root fresh and dry biomass, shoot length, number of leaves and stem diameter compare to non-grafted plants under saline and control conditions. Mineral uptake was significantly affected by rootstocks and salinity levels. Accumulation of sodium (Na^+) was reduced in grafted plants compared with non-grafted ones. Nitrogen (N), Potassium (K^+) and Magnesium (Mg^{++}) uptake by shoots of both grafted and non-grafted Cantaloupe gradually decreased with increasing NaCl salt concentration. The concentration of K^+, N and Mg^{++} were higher in grafted plant leaves than non-grafted ones. Ratios of K^+/Na^+, N/Na^+ and Mg^{++}/Na^+ were affected by salt treatments and positively associated with plant growth traits. These ratios recorded higher values in grafted plants compared non-grafted ones under both saline and control conditions. It could recommended to grafting Cantaloupe to increase its tolerance to saline conditions.

Keywords: Cantaloupe; Grafting; Cucurbita rootstock; Salt stress; Physiological response; Chlorophyll fluorescence; Mineral element;

INTRODUCTION

Cucurbits, mainly watermelon, cucumber and cantaloupe have many features as they are cash crops. They are growing faster and they can be grown in more than one date along the year under Egyptian conditions. Limited availability of arable lands and water resources at the same time higher market demand for off-season cucurbits make the growers cultivate their vegetables under unfavorable environmental conditions under protected cultivation. These conditions, as well as consecutive cropping, could lead to rising soil salinity and subsequently be leading to serious crop losses (Davis *et al*., 2008; King *et al*., 2010). Salinity tolerance of vegetables is becoming more important in arid and semiarid regions due to scarce freshwater resources and increase soil salinity (Shannon and Grieve, 1999). Cantaloupe has located in the second or third order between cucurbits in terms of importance and/or cultivation area in Egypt. Where the agriculture became suffer from salinity, either in soils due to hot and dry climate and frequent cultivation without a commitment to crop rotation or in irrigation water because of water scarce and irrigation with low-quality water. According to Badr and Abou Hussein (2008), cantaloupe growth and yielding affected largely by the quantity and salinity of the irrigation water. Cantaloupe has classified as a moderately sensitive crop for salinity (Maas and Hoffman, 1977) and its salinity threshold level is 1.0 dS/m whereby 8.4% yield decline per dS/m unit (Shannon and Francois, 1978; Mangal *et al*., 1988). Hence grafting comes as an effective procedure to overcome the problem of salt stress, especially as breeding programs need a long time and great effort to produce cultivars able to tolerate salt stress. Grafting of vegetables, although it began globally in the 1920s but was recently adopted under Egyptian conditions (El-Sayed *et al*., 2014; Mohamed *et al*., 2014; El-Kersh *et al*., 2016). Therefore, further researches are needed to determine the salinity range which can be tolerated by the scions as well as morphological, physiological and biochemical changes that occur in plants due to cultivating grafted plants under saline conditions. Shannon and Grieve (1999) monitored many adverse effects in the vegetables due to salinity including growth rate reduction in general as well as smaller leaves, shorter stems, and a sometimes fewer number of leaves and flowers. Also deficiency of nutrient uptake because of the competition effects among cations or anions. Thus, the accumulation of Na and/or Cl may occur in leaves or portions thereof causing certain damage and calcium deficiency symptoms. The main targets of this study are: (1), to understand the behavior of grafted and non-grafted cantaloupe plants under salt stress and test whether grafting raises the salt tolerance of Cantaloupe. (2) to test whether the salt tolerance of grafted Cantaloupe plants was affected by the different rootstock hybrids used, to select the most salt tolerance among hybrids to use as rootstocks for grafted salt-sensitive Cantaloupe scions.

MATERIALS AND METHODS

Plant material, treatments and growth conditions.

The experiment was established in Spring–Summer 2017 in a 240 m^2 polyethylene greenhouse located in the Experimental Farm of El-Azhar University, Cairo Egypt. Plants were grown under natural temperature and light conditions. The greenhouse conditions were maintained at daily temperatures between 18 and 33 ◦C, and relative humidity of 15 to 23%. *Cucumis melo* L. Cv. Marella F1 (Rijk Zwaan, Holland) was grafted onto three squash rootstocks denoted Super Shintosa F1 hybrid (Tokita Seed CO., LTD, Japan), Star F1 hybrid (Erasem Pakura, New Zealand) and Cobalt RZ F1 hybrid (Rijk Zwaan, Holland) using the 'tongue approach grafting method' described by Lee (1994), whereas non-grafted melon transplants were used as a control. At the second or three leaves stage (March 20), grafted and non-grafted plants were transplanted into pots capacity 4 kg of well-washed sand. The pots were arranged in three rows inside the greenhouse. The space between plants within a row was 0.5 m and the distance between the centers of each adjacent two rows was 2 m, resulting in a plant density of one plant per m2. Plants were grown vertically without pruning the lateral branches.

The experiment design was a factorial complete randomized block design system involved 12 combinations of three nutrient solution concentrations which were non-salt control, 100 mM and 150 mM of NaCl along with four grafting treatments which were non-grafted plants and grafted others on three rootstocks. The experimental plot involved ten plants with three replicated for each treatment. The saline treatments were started after 7 days from the transplanting date. The basic (control) nutrient solution used in this experiment was a modified of Hoagland and Arnon (1950)formulation. All chemicals used were of analytical grade, with an electrical conductivity (EC) of 2.0 dS m−1. The saline nutrient solutions had the same basic composition plus an additional 100 mM and 150 mM of NaCl, respectively, giving EC values of 6.8 and 6.6 dS m−1, respectively. The pH of the nutrient solution for all treatments was 7.0 ± 0.5. All nutrient solutions were prepared using distilled water. Nutrient solution was pumped from independent tanks through a drip irrigation system, with one emitter per plant (pot) and an emitter flow rate was 2 l h−1. Irrigation scheduling was carried out using 5 to 17 times per day. The timing of the irrigations was adjusted to have at least 35% of the nutrient solution draining from the pots. At the end of the experiment, after 30 days from planting, five plants from each plot were rooted up and the following data were recorded:

- **Growth Traits:** Recorded on three plants from each replicate for the following traits; fresh shoot weight (g), fresh root weight (g), dry shoot weight (g) dry root weight (g), shoot length, number of leaves and stem diameter(cm).
- **Relative water content (RWC):** The estimation of leaf relative water content was determined according to (Weatherley, 1950).
- **Membrane stability index (MSI):** was determined according to Sairam *et al*., (2002
- **Determination of mineral elements in root and leaves:**

Total nitrogen (N) determined using Kjeldahl method according to the procedure described by A.O.A.C. (1985).

The phosphorous was determined by applying colorimetric method (Ascorbic acid) using spectrophotometer (Jen way 6/05) to Rouser *et al*. (1970).

Sodium (Na) and potassium (K) were determined by flame photometry (Jen way PFP7) as described by Page *et al.* (1982).

Magnesium (Mg) was assayed by atomic absorption spectrometry as described by Chapman and Pratt (1982).

Salt tolerance trait index (STI) at the plants was calculated by the following formula:

STI = Value of grafted plant /Value of non-grafted as control under same condition x 100

Leaf temperature: The leaf temperature was measured in fully expanded fourth leaf from the plant apex by using Li-1600 Steady State Porometer and was expressed as ˚C. The leaf temperature was measured weekly after the seedling establishment at 11 to 12 o'clock (leaf temperature was measured three times).

Leaf chlorophyll fluorescence (SPAD readings) was measured on attached 4^{th} leaves from plant apex via chlorophyll meter device, the SPAD-502 plus by Konica Minolta.

Statistical analysis:

The data were statistically analyzed mentioned by Gomez and Gomez (1984), using statistical software CoStat under windows for analysis of variance (ANOVA). The differences significances of among the combination treatments were determined according to Fisher's LSD test at 5% level.

RESULTS AND DISCUSSION

Behavior of grafted and non-grafted cantaloupe plants under salt stress.

Growth Parameters: The dry matter accumulation of grafted and non-grafted plants i.e. shoot and root biomasses were decreased in response to an increase of NaCl concentration in the nutrient solution. (Table 1) Grafting of Cantaloupe on cucurbita rootstocks of Shintosa, Star and Cobalt gave better growth when compared with non-grafted ones for all growth traits, i.e. fresh and dry biomass, plant height, stem diameter and the number of leaves under salt conditions. While the extent of reduction in the shoot and root dry weight and stem diameter of grafted Cantaloupe plants were significantly lower than that recorded in the non-grafted plants under both salinity levels of 100 and 150 mM of NaCl (Table: 1). The grafted plants on Star rootstock had a higher significant fresh weight compared to non-grafted plants (11.88 g/plant) at 100 mM NaCl. The biomass weight reduction of the shoot and root in comparison to control were clearly lower in grafted plants than those of the non-grafted plants. The highest biomass reductions were recorded with non-grafted plants at 150 mM NaCl compared to grafted ones onto the three rootstocks at the same concentration of NaCl (Table 1).

The highest values of shoot length (54.333 cm/plant), leaves number (13.33) and stem diameter (0.717 mm/stem) was obtained by grafting onto Star rootstock at 150 mM NaCl concentration compared to the other rootstocks and control (non-grafted) plants.

Acquired the maximum salt tolerance index (STI) 183.64 % for fresh shoot weight with grafting onto Star rootstock (Table 2), was observed followed by the Shintosa (139.95 %) when compared with non-grafting plant at sever stress 150mM NaCl. But the highest shoot dry weight was observed with Cobalt rootstock (201.67%) followed by Shintosa (192.28%) at the same NaCl concentration. However, the maximum STI value for root fresh weight (172.56) was recorded with grafting onto Star rootstock, while for dry root weight (196.25) was observed with Shintosa at 150 mM NaCl. The highest values of shoot length, leaves number and stem diameter were shown with grafting onto Star rootstock which recorded 108.11, 118.78 and 152.94 respectively at the same concentration of NaCl compared to non-grafted plants and grafted plants onto Cobalt and Shintosa rootstocks.

Table 1. Grows behavior of grafted and non-grafted cantaloupe plants under salt stress.

Grafted seedling	NaCl concentration	F.w shoot /plant	D.w shoot /plant	F.W Root /plant	D.W Root /plant	Shoot length	Leaves Number per plant	Diameter of stem
Non-grafted	0 mM NaCl	41.07	3.65	9.72	0.34	51.00	13.67	0.75
	100 mM NaCl	11.88	3.91	3.32	0.25	49.00	13.00	0.68
	150 mM NaCl	4.89	1.92	0.89	0.19	39.33	12.33	0.60
Grafted onto Star rootstock	0 mM NaCl	72.34	7.29	14.96	0.76	71.33	18.67	0.90
	100 mM NaCl	21.38	6.86	4.77	0.41	57.00	15.00	0.95
	150 mM NaCl	8.98	3.5	1.53	0.33	54.33	13.33	0.72
Grafted onto	0 mM NaCl	47.84	4.57	12.56	0.59	67.33	16.00	0.94
Cobalt	100 mM NaCl	11.34	5.08	3.68	0.32	47.00	13.67	0.86
rootstock	150 mM NaCl	6.46	3.87	0.61	0.29	46.67	12.67	0.66
Grafted onto	0 mM NaCl	66.45	7.19	13.34	0.59	71.67	17.67	0.96
Shintosa	100 mM NaCl	12.13	5.14	2.90	0.41	54.67	13.67	0.77
rootstock	150 mM NaCl	6.84	3.69	0.99	0.38	47.67	12.33	0.67
New LSD 5%(interactions)		5.07	0.47	1.40	0.15	9.44	1.82	0.11

Table 2. Salt tolerance index for growth parameters of grafted and non-grafted Cantaloupe plants under salt stress.

Grafted seedling	NaCl concentration	STI for F.w shoot	STI for D.w shoot	STI for F.W Root	STI for D.W Root	STI for Shoot length	STI for Number of leaves	STI for Diameter of stem	TSTI
Grafted onto	0 mM NaCl	176.14	199.78	153.89	220.52	139.87	136.59	120.44	163.89
Star	100 mM NaCl	179.94	175.68	143.92	163.12	116.33	115.38	139.51	147.70
rootstock	150 mM NaCl	183.64	182.73	172.56	166.61	138.14	108.11	118.78	152.94
Grafted onto	0 mM NaCl	116.49	125.06	129.17	170.57	132.03	117.07	125.78	130.88
Cobalt	100 mM NaCl	95.46	129.95	111.06	124.41	95.92	105.13	126.34	112.61
rootstock	150 mM NaCl	132.04	201.67	68.42	146.51	118.64	102.70	109.39	125.63
Grafted onto	0 mM NaCl	161.80	197.04	137.20	172.99	140.52	129.27	128.44	152.47
Shintosa	100 mM NaCl	102.10	131.52	87.54	161.68	111.56	105.13	112.20	115.96
rootstock	150 mM NaCl	139.95	192.28	111.65	196.25	121.19	100.00	111.60	138.99

The total salt tolerance index (TSTI) for growth parameters indicate that Star rootstock had recorded the highest values under all NaCl salinity concentrations compared to the other rootstocks and non-grafted plants. Finally, cultivation of grafted cantaloupe plants in salinity field up to 150 mM NaCl showed good vegetative growth compared to non-grafted plants. Thence, the better growth performance of grafted plants compared to the non-grafted ones under salinity stress might be attributed, at least, to differential root growth under salinity stress. This agrees with findings of Fernandez-Garcia *et al* (2004), Ruiz *et al* (2005) and Wei *et al* (2007). Also, Salam *et al* (2002) reported that length and number of lateral branches of vine produced from the grafted plants were better than those of the non-grafted plants. So, grafting vegetables include melon, as mentioned by Romero *et al.* (1997) onto different rootstocks, has been successfully demonstrated to increase salt tolerance of the plants via reducing Na+ toxicity. Our results support those found by Zhu *et al.* (2008) in cucumber that proves the ability of grafting for alleviating the salinity stress on the growth of Cantaloupe. The results demonstrate that grafting is a god strategy for improving the salt tolerance of Cantaloupe plants. In tomatoes, root dry mass decreased at salt stress compared to the untreated plant, but the reduction was smaller in grafted plants (He *et al.* 2009). Also, Zhu *et al.* (2008 a,b) and Huang *et al.* (2009a) observed that significantly declined in the root dry weight of grafted was lower than that recorded in non-grafted plants under salt stress in cucumber plants. Similar results were reported by (Yetisir and Uygur, 2010) in squash and bottle gourd rootstocks under saline stress conditions.

Leaf relative water content: RWC was significantly affected by salinity in grafted and non-grafted plant (Table 3). An obvious decrease of leaf RWC was observed with 100 and 150 mM NaCl compared with plants grown under unstressed conditions. The results illustrated that leaf relative water content (LRWC) was affected by grafting under salt condition. However, for grafted plants the enhancement in STI of LRWC was recorded 112.20 % in Star rootstock followed by 110.41% in Cobalt rootstock at 150 mM NaCl as comparing with non-grafted plants.

Thus, the similar leaf RWC for all rootstock may be attributed to the changes in components of the osmotic adjustment; higher accumulation of potassium was probably involved in the osmotic adjustment of the plants grafted onto Star and Shintosa rootstocks than the other plants. Similar to the results observed in tomato plants by (Estan˜ *et al.*, 2005) and Huang, *et al* 2009 b in cucumber plant. Water status in the plant under salt stress is the most limiting factor allows resuming growth (Yeo *et al.*, 1985). Trajkova *et al.*, (2006) suggested that Na^+ rather than Cl^- is the primary cause of salt damage in cucumber plant. Leaf relative water content was raise grafted plants when compared with non-grafted plants under salt condition El-Shraiy and Mostafa (2016). Also, Zhu *et al.* (2008b) reported that shoot water content in the leaves of grafted plants was higher than those of non-grafted ones at the same NaCl concentration.

Membrane stability index: it decreased with salt stress in grafted and non-grafted Cantaloupe plants. The best membrane stability was shown in grafted plants onto Star rootstock (135.04) followed by Cobalt rootstock than grafted plants onto shintoza and non-grafted ones. The reduction in cell membrane stability index in leaves of grafted plants under salt stress has been mentioned by Chen and Wang (2008). Zhu *et al.* (2008b) who reported that shoot water content in the leaves of grafted plants was higher than those of non-grafted plants at the same NaCl stress conditions

Table 3. Effect of NaCl stress on MSI, RWC and Chlorophyll content of Cantaloupe grafted onto different rootstocks and non-grafted plants.

Grafting	*MSI*	RWC	Chl	STI for MSI	STI for RWC	STI for Chl
				0 mM NaCl		
Non-grafted	53.91	78.39	38.067			
Grafted onto Star rootstock	56.72	81.55	42.867	105.21	104.03	112.62
Grafted onto Cobalt rootstock	56.93	81.48	40.367	105.61	103.94	106.05
Grafted onto Shintosa rootstock	54.41	77.07	42.567	100.94	98.32	111.83
				100 mM NaCl		
Non-grafted	40.05	74.81	32.977			
Grafted onto Star rootstock	52.25	79.63	34.743	130.46	106.44	105.32
Grafted onto Cobalt rootstock	43.52	75.59	35.11	108.65	101.04	106.55
Grafted onto Shintosa rootstock	42.12	76.32	37.043	105.18	102.02	112.31
				150 mM NaCl		
Non-grafted	32.44	64.75	31.397			
Grafted onto Star rootstock	43.8	72.65	36.263	135.04	112.2	115.49
Grafted onto Cobalt rootstock	40.73	71.49	33.063	125.55	110.41	105.3
Grafted onto Shintosa rootstock	33	66.85	38.697	101.75	103.24	123.31
LSD 5 %	4.09	4.66	2.95			

Chlorophyll Content: the higher SPAD values of chlorophyll were recorded in grafted plant onto some rootstocks than others and non-grafted plants under severe salt conditions. The increment of the salt tolerance index had shown with Shintoza rootstock (123.31) followed by Star rootstock (115.49) comparing to non-grafted plants and grafted ones onto Cobalt rootstock at 150 mM of NaCl.

leaf temperature: Data in Table (4) shows that cantaloupe leaf temperature had increased with increasing salinity level. It recorded different values depending on planting cantaloupe with grafted and non-grafted seedlings as well as rootstock type. It appeared to be higher in non-grafted plants than grafted ones under all salinity levels.

Table 4. Effect of grafting and NaCl salinity concentration on Cantaloupe plant leaf heat temperature.

Grafting	0 mM NaCl	100 mM NaCl	150 mM NaCl
Non-grafted	26.9	28.4	29.2
Grafted onto Star rootstock	26.0	27.5	28.1
Grafted onto Cobalt rootstock	26.4	28.0	28.6
Grafted onto Shintosa rootstock	26.5	28.1	29.1

The grafted plants onto Stare rootstock recorded the least LT values followed by Cobalt rootstock while the highest LT values were obtained with grafting onto Shintoza rootstock. One of the salinity effects on the plants is a reducing of the absorbed water magnitude and subsequently, decreasing plant transpiration and relevant metabolic processes. Among transpiration benefits consuming the overload heat of plant canopy as a latent heat of water evaporation and then alleviate heat stress. Torrecillas *et al.* (1988) and Shackel (2007) found that leaf resistance and the temperature are affected by plant water status. Gonza´lez-Dugo *et al* (2006) concluded that the canopy heat could be used as an indication of cotton plant stress. In cotton and peanut, Shahenshah and Isoda (2010) reported that leaf temperature was increased significantly via the water stress.

Minerals percent

Na+ concentrations: Plant grafted onto Star, Cobalt and Shintosa rootstock had lower leaf Na contents than non-grafted plants under NaCl stress. In general, the Na+ accumulation in the roots and leaves increased gradually with increasing NaCl concentration (Table 5). However, the accumulation of Na+ in the leaves and the roots of the grafted plants onto the three rootstocks were significantly lower than in the non-grafted plants under the same NaCl concentration. Similarly, under 150 mM of NaCl, the average of Na+ concentration in root dry matter was from 0.28% to 0.38 % for grafted plants while in the non-grafted ones recorded 0.43 % of root dry matter.

The Na+ concentration in the grafted plants roots showed lower values by about 11.63 % to 34.88 % than that of non-grafted plants. While the Na+ percent in dry shoot tissues had recorded 0.84 to 1.19 % in grafted plant but in non-grafted ones had recorded 1.53% under the same concentration of NaCl. In other words, the Na+ percent in shoot was less by about 22.22 % to 45.10% than that of non-grafted plants shoot. Salt exclusion in the shoot and root of salt ions caused improved vigor in grafted plants and gave the higher growth parameter compared to non-grafted others. The majors' common effect of soil salinity is the growth inhibition due to direct Na+ and Cl− toxicity at biochemical level. However, for many plants, including vegetables such as cucumber, melon, watermelon, tomato, and eggplant, Na+ is the primary cause of ion-specific damage (Tester and Davenport, 2003; Varlagas *et al*., 2010).

The improved salt tolerance of grafted plants has often been related with lower Na+ contents in the shoot (Table 5). Salt tolerance mechanisms can occur in a wide range of organizational levels from the cellular level (e.g., compartmentation of Na+ within cells) to the whole plant (e.g., exclusion of Na+ from the plant and exclusion of Na+ from the shoot) (Tester and Davenport, 2003 and Møller *et al.*, 2009). Plants grafted onto convenient rootstocks inhibited the transport of Na+ from root to shoot (Estan˜ *et al.*, 2005; Goreta *et al.*, 2008 and Zhu *et al.*, 2008a).

Table 5. Mineral percent concentration (%) in roots and leaves of grafted and non-grafted Cantaloupe plants under salt stress condition.

Grafted seedling	Root			Leaves		
	0 NaCl	100 NaCl	150 NaCl	0 NaCl	100 NaCl	150 NaCl
		Na % D.W				
Non-grafted	0.23	0.35	0.43	1.078	1.31	1.53
Grafted onto Star rootstock	0.18	0.27	0.32	0.539	0.67	1.04
Grafted onto Cobalt rootstock	0.14	0.19	0.28	0.693	0.82	0.84
Grafted onto Shintosa rootstock	0.1	0.33	0.38	0.627	0.9	1.19
LSD 5 %		0.038			0.05	
		K % D.W				
Non-grafted	5.99	2.42	2.39	3.421	2.6	2.21
Grafted onto Star rootstock	2.76	1.06	0.52	4.543	3.62	2.77
Grafted onto Cobalt rootstock	3.95	0.55	0.61	6.226	3.45	2.6
Grafted onto Shintosa rootstock	1.57	0.72	0.52	5.665	4.47	3.62
LSD 5 %		0.5			0.3	
		N % D.W				
Non-grafted	7.23	3.56	3.24	26.675	12.98	12.81
Grafted onto Star rootstock	4.81	3.56	2.84	20.482	13.78	12.97
Grafted onto Cobalt rootstock	3.2	3.16	2.9	21.362	12.98	13.78
Grafted onto Shintosa rootstock	4.01	3. 16	2.84	20.482	14.18	15.79
LSD 5 %		2.02			2.69	
		P % D.W				
Non-grafted	0.07	0.08	0.07	0.671	0.36	0.51
Grafted onto Star rootstock	0.07	0.07	0.07	0.605	0.35	0.32
Grafted onto Cobalt rootstock	0.07	0.07	0.16	0.539	0.36	0.46
Grafted onto Shintosa rootstock	0.04	0.09	0.08	0.539	0.43	0.4
LSD 5 %		0.004			0.08	
		Mg % D.W				
Non-grafted	0.18	0.07	0.06	1.452	1.28	1.25
Grafted onto Star rootstock	0.1	0.07	0.08	1.727	1.5	1.87
Grafted onto Cobalt rootstock	0.09	0.06	0.06	2.079	1.76	1.93
Grafted onto Shintosa rootstock	0.09	0.09	0.04	1.826	1.82	1.56
LSD 5 %		0.05			0.09	

For K+ accumulation and K/Na ratio: In general, the concentrations of K+ in the root and leaves of the three grafted and non-grafted Cantaloupe plants decreased significantly when NaCl concentration increased, (Table 6). However, the accumulation of K+ in the root of non-grafted plants was higher than those of grafted ones at all NaCl concentrations used. On the contrary, the accumulation of K+ in the leaves of grafted plants was higher than in those of non-grafted plants at the same NaCl stress conditions. The best accumulation of K (4.47 and 3.62% for Dry matter) was recorded in leaves of grafted plants onto Shintosa rootstock followed by those onto Star rootstock (3.62 and 2.77%) at both salt stress concentrations 100 and 150 mM NaCl compared to non-grafted plants which recorded 2.60% and 2.21% at the same treatments of salt stress.

Table 6. Ratios of mineral content in roots and leaves of grafted and non-grafted Cantaloupe plants under salt stress condition.

Grafted seedling	K/Na ratio in Roots			K/Na ratio in leaves		
	0 NaCl	100 NaCl	150 NaCl	0 NaCl	100 NaCl	150 NaCl
Non-grafted	26.0	6.9	5.6	3.2	2.0	1.4
Grafted onto Star rootstock	15.3	3.9	1.6	8.4	5.4	2.7
Grafted onto Cobalt rootstock	28.2	2.9	2.2	9.0	4.2	3.1
Grafted onto Shintosa rootstock	15.7	2.2	1.4	9.0	5.0	3.0
	N/Na ratio in Roots			N/Na ratio in leaves		
Non-grafted	31.4	10.2	7.5	24.7	9.9	8.4
Grafted onto Star rootstock	20.9	10.2	6.6	19.0	10.5	7.4
Grafted onto Cobalt rootstock	13.9	9.0	6.7	19.8	9.9	9.0
Grafted onto Shintosa rootstock	17.4	9.0	6.6	19.0	10.8	10.3
	P/Na ratio in Roots			P/Na ratio in leaves		
Non-grafted	0.3	0.2	0.2	0.6	0.3	0.3
Grafted onto Star rootstock	0.3	0.2	0.2	0.6	0.3	0.2
Grafted onto Cobalt rootstock	0.3	0.2	0.4	0.5	0.3	0.3
Grafted onto Shintosa rootstock	0.2	0.3	0.2	0.5	0.3	0.3
	Mg/Na ratio in Roots			Mg/Na ratio in leaves		
Non-grafted	0.8	0.2	0.1	1.3	1.0	0.8
Grafted onto Star rootstock	0.4	0.2	0.2	1.6	1.1	1.2
Grafted onto Cobalt rootstock	0.4	0.2	0.1	1.9	1.3	1.3
Grafted onto Shintosa rootstock	0.4	0.3	0.1	1.7	1.4	1.0

These results indicated that grafting facilitates the transport of K+ to the leaves and alleviates K deficiency under NaCl stress. Also these results imply that a decrease in K+ accumulation resulted in growth inhibition in Cantaloupe non-grafted plants, and might contribute to the increase in Na+ accumulation under salt stress. However, the K+/ Na+ ratio in the leaves of grafted plants was significantly higher than the ratio in the non-grafted plants. In general, clearly better maintenance of potassium homeostasis in leaves plant grafted compared with non-grafted under NaCl stress. The metabolic toxicity of Na+ is largely a result of its capability to compete with K^+ for binding sites essential for cellular function. K^+ plays an essential role in the growth of all plants and more than 50 enzymes are activated by K^+, and Na^+ cannot be used as a substitute in this role (Bhandal and Malik, 1988). A similar result was obtained in Phaseolus plant (Bayuelo-Jimenez *et al.* 2003). Studies showed that the Na^+/K^+ ratio in the leaves of plants subjected to salt stress is a better overall indicator of the ability of the plant to select and use K^+ under Na+ salinity, to the extent that the maintenance of high K^+/Na^+ ratio is important for salt tolerance (Santa-Cruz *et al.* 2002). Grafted plants have a higher K^+ content which seems to relate to the higher salt tolerance compared with self-grafted of cucumber plants under NaCl stress (Zhu *et al.*, 2008a and Huang *et al.*, 2009a). The salt tolerance of grafted was associated with xylem K^+ but not Na^+ in tomato plants (Albacete *et al.*, 2009). However, the direct relationship between leaf potassium homeostasis and salt tolerance of grafted plants has not yet been established.

Nitrogen and magnesium: Their levels were higher in leaves of all grafted plants than non-grafted ones under salt treatments. While the Phosphorous content, no trends were indicated by any salt treatment used. These results indicated that the improved uptake of the nutrient elements in the grafted plants especially Nitrogen and Magnesium increases the photosynthesis which leads to increase fresh and dry weight and subsequently another growth trait. Different works have reported that grafting affects the uptake and transport of N, Mg and Ca. The improve uptake of the nutrient elements in the grafted plants increases the photosynthesis; especially under optimum conditions, which is reflected in the improvements in yield (Hu *et al* 2006; Pulgar *et al* 2000; Zhu *et al* 2006 and Rivero *et al* 2003). The results of this research indicated that the improved uptake of the nutrient elements in the grafted Cantaloupe plants especially Nitrogen and Magnesium increases the photosynthesis which leads to increasing in fresh and dry weight and growth traits. Also ameliorate of plant leaf heat temperature, relative water content and better membrane stability when compared with non-grafted plants.

CONCLUSION

The results indicated that, grafting of cantaloupe on salt tolerance rootstock (especially Star) gave better growth, as indicated by fresh and dry weights, plant height and stem diameter comparing with non-grafted plants under salt stress conditions. The higher salt tolerance of grafted Cantaloupe plants is associated with lower Na+ concentrations and Na+/K+ ratio and higher K+ concentrations in the leaves. Also the salt tolerance of grafted Cantaloupe plant is related to the rootstock hybrids. In our research, grafted plants develop two physiological and biochemical mechanisms to cope with salt stress. These strategies include (a) salt exclusion in the root and leaves, (b) better maintenance of potassium homeostasis in leaves plant grafted when compared with non- grafted plants.

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التطعيم يُمَكِن الكنتالوب من تحمل المزيد من الإجهاد الملحى.

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تطعيم نباتات الكنتالوب على أصول القرعيات يجعلها تستفيد من مميزات الأصول من حيث إرتفاع كتلة امتصاص الماء والمغذيات، وزيادة مساحة السطح وأيضاً تحمل النبات للإجهاد الغير حيوى. فقد تم تطعيم نباتات الكنتالوب كوكوميس ميلو -كانتالوبنسيس على ثلاثة أصول وهم شينتوزا وإستار وكوبالت. ثم زرعت النباتات فى الرمل مستخدمين المحاليل المائية فى الزراعة، ثم تم معاملة النباتات بثلاثة تركيزات من ملح كلوريد الصوديوم وهى (0 و100 و 150 ملى مول)، وذلك لمدة 30 يوما لدراسة آثار الملوحة على نباتات الكنتالوب المطعمة مقارنة بالنباتات الغير مطعمة منها. وقد أظهرت النتائج أن النباتات المطعمة سجلت أعلى معدلات نمو بالنسبة للكتلة الحيوية الطازجة والجافة للمجموع الخضرى والمجموع الجذورى، وطول المجموع الخضرى، وعدد الأوراق وقطر الساق مقارنة بالنباتات غير مطعمة تحت ظروف المعاملة بملح كلوريد الصوديوم والغير معاملة أيضاً. وقد تأثر إمتصاص العناصر بشكل كبير بواسطة إستخدام الأصول ومستويات الملوحة المختلفة، فقد إنخفض تراكم الصوديوم فى النباتات المطعمة مقارنة مع غير المطعمة منها. وقد انخفض أيضا إمتصاص كلاً من النيتروجين (N) والبوتاسيوم (+ K) والماغنيسيوم (مغ ++) للنباتات المطعمة وغير المطعمة لنبات الكنتالوب تدريجيا مع زيادة تركيز المعاملة بملح كلوريد الصوديوم. وكان تركيز البوتاسيوم والنيتروجين والماغنسيوم أعلى تراكماً فى أوراق النبات المطعمة عن مثيلتها الغير مطعمة تحت نفس الظروف. وقد تأثرت نسب البوتاسيوم والنيتروجين والماغنسيوم إلى الصوديوم بشكل ملحوظ بمعاملات الملح، وترتبط إرتباطا إيجابيا بقياسات النمو للنبات، وقد سجلت أيضاً هذه النسب أعلى القيم فى أوراق النباتات المطعمة مقارنة بغير المطعمة تحت كل من المعاملة بالملوحة والغير معاملة. وأخيراً، أثبتت النتائج أن نباتات الكنتالوب المطعمة كان لها أداء أفضل من تلك غير مطعمة وخاصة تلك المطعمة على أصل إستار والتى قد يوصى بإستخدامها كأصول يمكن أن يُطَعم عليها الكنتالوب وخاصاً تحت الظروف الملحية.