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Effects of Salt Stress on Vegetative Growth Parameters and Ion Accumulations in Cucurbit Rootstock Genotypes

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ABSTRACT

Salt stress leads to decreases in plant growth, development, yield and quality changes of many plant species. Winter squash and pumpkins were recommended for use of rootstocks for the grafted watermelon, melon and cucumber growing in the saline soils. Grafted seedlings recently are being used widely for vegetable crops grown in many countries of the world. In this study, it was aimed to identify differences in salt tolerance of local winter squash, bottle gourd, pumpkin genotypes, and their interspecific rootstock hybrids (*Cucurbita maxima x Cucurbita moschata*) by using some vegetative growth parameters and ion accumulations. Salt was applied at 4,8,12, and 16 dS m^{-1}NaCI salinity levels for each genotypes. Non-salt-treated plants were kept as controls. Plant vegetative growth parameters such as plant height, stem diameter, leaf number and leaf area were negatively affected by salt stress. The results showed that NaCI treatment caused an increase in Na+ ion concentration and decreased in K^+, and Ca^{++} ion concentrations. In conclusion, Cucurbit rootstock genotypes showed large variation in their response to salt tolerance. Seven pumpkin inbred lines (G2, G3, G4, G7, G29, G30, and G31), three winter squash inbred lines (G9, G12, and G13), three interspecific hybrids of *C. maxima* x *C. moschata* (G14, G15, and G40) were found as salt tolerant. We would highly recommend use of promising salt tolerant rootstock genotypes for grafted watermelon, melon and cucumber seedling production.

Keywords: winter squash, pumpkin, hybrid, rootstock, growth, resistance, salinity.

Introduction

Salinity is one of the most important abiotic stress factors that cause reduction in plant growth, development and yield values. Plant species can differ markedly in their responses to salt tolerance (Dasgan and Koc 2009; Kusvuran *et al*., 2011). In terms of salt resistance; there are differences between family, genera, species and significant differences between genotypes (Belkhodja *et al*., 1994). Most of vegetable crops are sensitive to salt stress and these can't survive under saline conditions. Salt stress changes the plant's morphological and physiological traits and biochemical responses (Sevengor *et al*., 2011; Kusvuran *et al*., 2013). The plants have lower growth rates and their leaves are mostly small, with a dark green color in salt stress (Greenway and Munns 1980). In the presence of excess salt during plant growth Na^+ and Cl^- are accumulated in different plant organs (Levitt 1980; Kurtar *et al*., 2016). Many researchers have reported that long term salinity stress causes ion toxicity, water deficiency in older leaves and occurrence of the carbohydrate deficiency in young leaves (Greenway and Munns 1980; Franco *et al*., 1993; Tipirdamaz and Ellialtioglu 1997; Demir 2009; Kuşvuran 2010; Kurtar *et al*., 2016). Therefore, salt resistance often depends on the ability of the plant to develop adaptive strategies under stress conditions (Kachout *et al*., 2012; Ors and Suarez 2016).

Winter squash and pumpkin species are members of the genus Cucurbita within the economically important *Cucurbitaceae* family. There are three economically important Cucurbita species, namely *Cucurbita pepo*, *Cucurbita maxima* and *Cucurbita moschata*, which have different climatic adaptations, and are widely distributed, in agricultural regions worldwide (Robinson and Decker-Walters 1997; Paris and Brown 2005; Wu *et al*., 2007; Balkaya *et al*., 2009; Balkaya *et al*., 2010). Winter squash and pumpkin are usually grown for their fruits i.e. immature for summer squash, and mature for the winter squash and pumpkin.

Cucurbit plants are grafted onto various rootstock species and varieties using a range of grafting methods. Cucurbit crops that are commonly grafted include watermelon, melon and cucumber. The most common rootstocks for watermelon are bottle gourd, interspecific hybrids between *C. maxima* and *C. moschata* and wild watermelon (*C. lanatus* var. *citroides*) (Davis *et al*., 2008; Karaagac and Balkaya 2013). The compatibility of watermelon with any of these rootstocks is generally high, although there is variability within the species (Yamamuro and Marukawa 1974; Karaagac 2013; Gungor and Balkaya 2016). The most commonly used *Cucurbita* spp. rootstock is interspecific *C. maxima* × *C. moschata* hybrid (Colla *et al*., 2010). The use of rootstocks has been shown to enhance the vigor of the scion through the resistance to soil pathogens and tolerance to low soil temperatures and/or salinity (Ruiz *et al*., 1997). The use of rootstock is a valid strategy in increasing salt tolerance by reducing sodium toxicity.In a research, interspecific *C. maxima* × *C. moschata* hybrids were found as resistant to salt stress. *C. moschata* and *Lagenaria siceraria* genotypes showed tolerant level resistance against to salt stress (El-Shraiy *et al*., 2011).

In terms of salt tolerance, genotypic variations were found by Sevengor (2010) between local squash and pumpkin cultivars in Turkey (Balkaya and Kandemir 2015). Winter squash and pumpkin can be grown on unproductive land without irrigation in many regions of Turkey. Therefore, winter squash and pumpkin growing can be considered as a suitable alternative for the problem of salinity or drought in areas (Sevengor *et al*., 2011; Kurtar *et al*., 2016).

Grafting onto salt-tolerant rootstock is an effective method for increasing the salt tolerance of plants. Grafting has been found to improve the salt tolerance of tomato (Estan *et al*., 2005; Santa-Cruz *et al*., 2002), eggplant (Wei *et al.,* 2007; Curuk *et al*., 2009), watermelon (Yetisir and Uygur 2010; Gungor and Balkaya 2016), melon (Edelstein *et al*., 2005; Dasgan *et al*., 2015), and cucumber (Zhu *et al.,* 2008). Grafting can raise the salt tolerance of watermelon and melon (Yetisir and Uygur 2010; Dasgan *et al*., 2015). The aim of this study was to identify differences in salt tolerance of local winter squash, bottle gourd, pumpkin genotypes and their interspecific *C. maxima* x *C. moschata* rootstock hybrids by using some vegetative growth parameters and ion accumulations.

Materials and Methods

Materials:In this study, 17 inbred winter squash lines, 20 inbred pumpkin lines, 7 interspesific rootstock hybrids (*C. maxima* x *C. moschata*) and Shintoza F_1, Obez F_1 rootstock cultivars, 1 bottle gourd genotype (*Lageneria siceraria*), and one pumpkin cultivar (cv. Titan) were used (Table 1). These genetic materials, consisting of winter squash and pumpkin lines were developed at the S5-S6 generation, and interspecific rootstock hybrids between *C. maxima* and *C. moschata* rootstock were also obtained from breeding program for grafted watermelon by Balkaya *et al*., (2011) and Karaagac (2013).

Growth condition:This study was carried out in the controlled plant growth cabin of the Department of Horticulture, during 2013-2014. Seeds were germinated in a mixture of peat: perlite of 2:1 ratio. After 14 days of sowing, seedlings were transferred to plastic pots (7 l volumes) containing perlite. The nutrient solution utilized a modified Hoagland's solution (9 g/l$Ca(NO_3)_2$; 2.5 g/lK_2SO_4; 4.5 g/l $MgSO_4$; 2 g/l KH_2PO_4; 0.035 g/l H_3BO_3; 0.015 g/l $MnSO_4$; 0.01 g/l $CuSO_4$; 0.012 g/l $(NH_4)_6Mo_7O_{24}$; 0.02 g/l $ZnSO_4$, 0.3 g/l Fe EDTA), and it was renewed every 3 days. The base nutrient solution without added salts served as control in this study.

Salt treatment: Salt solution treatment application was started when the seedlings have reached at 4-5 true leaf stage. Sodium chloride was used as salt resource. Salt treatments were applied 4 different EC values (4, 8, 12, 16 dS m^{-1}). Non-salt-treated plants were kept as controls. After the salt treatment, all pots were covered with aluminum foil to prevent loss of salt by evaporation.

Plant vegetative growth parameters: At the end of 30 days after salt treatment, stress responses of experiment genetic materials were evaluated using by some plant vegetative growth parameters such as plant height, stem diameter, leaf number, leaf area, shoot dry weight, root dry weight (Kusvuran 2010). All genetic materials were also classified for their salt tolerance according to leaf damage symptoms by using 0-5 scale symptom scores (Yildiz 2014). Control plants and undamaged plants were defined as “0” value.

Determination of ion contents: Ion contents (Na^+, K^+ and Ca^{++}) were determined according to Kacar (1984). For the ion determination, the plants were separated into shoot and leaves. These plant sections were dried at 70°C for 48 h. Na^+, K^+ and Ca^{++} concentrations were measured by using FLAME spectrometer.

Statistical analysis: The experimental design was randomized plot. Each treatment was replicated three times with ten plants. The results were analyzed using JUMP 5.0.1, and the mean values were compared using the least significant difference test ($P<0.05$).

Results and Discussion

In this study, salt stress treatments have caused various effects in all Cucurbit rootstock genotypes. The first characteristic response of plants under salt toxicity has shown a significant decrease in vegetative growth. According to the results, the plant height was significantly decreased compared to control plants with the increasing salt concentration doses in all Cucurbit rootstock genotypes (Table 2). The highest decrease was recorded in G40 interspecific hybrid as 96.3% (Table 2). The least decrease among these genotypes were determined as G9 (30.3%), G8 (41.4%) and G15 (43.7%), respectively. This decrease values was changed from 83.0 to 89.2% ratios between Shintoza F_1 (G32) and Obez F_1 (G33) rootstock cultivars. At the end of this study, plant height values were found at lower levels in all genotypes under salt stress compared to control treatment (Table 2).

After the salt treatment, terminal and edges of older leaves turn yellow along with the slowdown in plant growth. After that, this situation continues in the form of leaf chlorosis by moving towards the main xylem vessels and at later stage chlorosis is transformed into necrosis. Necrosis causes drying in leaf (Bergmann 1992; Ertekin 2010). In this study, the number of leaves in all genotypes was decreased under salt stress treatments. These values were found between 0- 80.3% amongst Cucurbit rootstock genotypes (Table 2). The highest reducing ratios were found in G17 (80.3%), G16 (77.0%) genotypes and Shintoza F_1 cultivar rootstock (74.5%) for the leaf number trait. Under salt stress condition, the least affected genotypes were determined as G12 (0%), G3 (9.5%) and G2 (12.2%) lines, respectively.

The leaf area values of all Cucurbit genotypes were decreased with salt treatments. The highest decrease was observed in G16 (92.9%), G20 (92.3%), and G43 (91.4%), respectively (Table 3). The leaf area decreasing ratio of Shintoza F_1 and Obez F_1 rootstock cultivars were changed from 73.0% to 81.1%. In this study, the effect of salinity in Cucurbit rootstock genotypes were generally apparent as all reduced vegetative growth parameters. These plants had possessed smaller leaves and sometimes fewer leaves.

At the end of salt stress (16 dS m^{-1}), Na^+ ions values were increased in all Cucurbit rootstock genotypes (Figure 1). In this study, the least increasing value of Na% were observed respectively in G9 (420.0%), G15 (433.3%), G5 (520.0%) and G3 (525.0%) genotypes compared to the control treatment. These genotypes have been found more selective in terms of salt ion content. In contrast, genotypes G31, G28, G19 and G29 accumulated a relatively larger quantity of Na^+ ions in to their texture. Munns (2002) reported that salt resistance plants have received Na and Cl ions to their texture at lower rates according to sensitive plants. Yetisir and Uygur (2009) also mentioned which Cucurbita and Lageneria rootstocks developed some mechanism to avoid physiological damage caused by excessive accumulation of Na^+ ion in leaves and shower higher performance than watermelon under salinity stress.

K^+ ion contents of Cucurbit rootstock genotypes showed large variation (Figure 2). Genotypes G5 (9.7%), G14 (12.2%), G3 (18.0%) and G30 (20.8%) had the maximum protecting ability of their K^+ ion content compared to control. In some genotypes, significant decrease in K ion content was found under salt stress conditions. The highest decrease in value of K ion content was determined in G41 genotype (81.6%). Shintoza F_1 and Obez F_1 rootstock cultivars also showed similar results.

Plants provide their balance with the help of inorganic ions under salt stress. The osmotic potential in the cell increases and more water can enter to the cell by taken K^+ with active absorption and accumulation in plants (Koc 2005; Kusvuran 2010). Therefore, K^+ content in the cell is important for maintenance of osmotic equilibrium. Romero *et al*., (1997) reported that increasing Na^+ concentration in leaves causes K^+ deficiency due to antagonist effect of Na^+ and K^+ ions.

Calcium is an important element to maintain cell membrane integrity and provide selectivity of ion intake and transportation. Higher salt concentrations caused to reduce intake of Ca^{+} ion and ion imbalance in plant. (Cramer *et al*., 1986; Huang and Redman 1995). Calcium ion contents under salt stress are given in Figure 3. Calcium ions of all Cucurbit genotypes decreased under salt stress. The highest reductions were determined in G15 (13.7%), G28 (14.1%), G9 (18.4%) and G7 (23.0%) genotypes, respectively. These values were found 67.9% for Obez $F_1$and 30.4% Shintoza F_1.

K^{+}/Na^{+} and Ca^{++}/Na^{+} ratio were calculated due to Na^{+}, K^{+} and Ca^{++} ion contents. These results are shown in Figure 4 and Figure 5. K/Na and Ca/Na ratios decreased with the increasing salt concentration in all Cucurbit rootstocks genotypes. Kusvuran(2010) mentioned that decrease in Ca/Na ratios effected plant growth negatively. Similar results were found in this study.

According to the combined results of vegetative growth parameters and ion analysis; seven pumpkin inbred lines (G2, G3, G4, G7, G29, G30, and G31), three winter squash inbred lines (G9, G12, and G13), three interspecific hybrids of *C. maxima* x *C. moschata* (G14, G15, and G40) were selected as salt resistant genotypes for rootstock breeding program.

Conclusion

Salinity is a major abiotic stress factors limiting crop production. Winter squash and pumpkins that can be grown without irrigation are a good alternative for the soils with salinity problems in arid and semi-arid ecology. The use of rootstocks has been shown to enhance tolerance to salinity. Grafting onto salt-tolerant rootstock is an effective method for increasing the salt tolerance of plants. In this study, winter squash, pumpkin, their interspecific hybrids, and bottle gourd genotype were exposed to salt stress at increasing EC levels (4, 8, 12, and 16 dS m^{-1}. According to obtained results, vegetative growth parameters such as plant height, stem diameter, the number of leaves and leaf area were significantly decreased, but the number of dry leaves were increased under salt stress. Na^{+} accumulation has played an important role against salt resistance. Na^{+} increased in all Cucurbit genotypes depending on the salt treatments. It was found that sensitive genotypes had higher amount of toxic ion accumulation under salt stress. These results also showed that salt tolerant Cucurbit rootstock genotypes had taken More K^{+} and Ca^{++} ions selectively than the remaining other genotypes. At the end of this study, seven pumpkin inbred lines (G2, G3, G4, G7, G29, G30, and G31), three winter squash inbred lines (G9, G12, and G13), three interspecific hybrids of *C. maxima* x *C. moschata* (G14, G15, and G40) were found as salt tolerant. These findings suggest that selected promising salt tolerant rootstock genotypes will be used for grafted watermelon, melon and cucumber seedling production in near future.

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Table 1. Accession number and work codes of the used genetic materials in the experiment.

Species/Cultivar	Work Code	Accession Number
Pumpkin	G1	B15
	G2	BE11
	G3	BA10
	G4	BY13
	G5	B4
	G6	BM15
	G7	B1
	G16	MOE 1
	G17	MOE 2
	G18	MOE 3
	G22	14 BO 01
	G27	14 BO 03
	G28	05-19
	G29	05-14
	G30	Sarı-01
	G31	Pembe-05
	G44	05 ME 11
	G45	19 İS 06
	G46	05 AM 02
	G51	55NE01
Winter squash	G8	BLHO
	G9	K4
	G10	K25
	G11	Gode
	G12	K6
	G13	K13
	G19	MAE 2
	G20	MAE 3
	G21	MAE 4
	G23	55 ÇA 06
	G24	55 ÇA 15
	G25	55 BA 03
	G26	57 Sİ 21
	G47	05 AM 08
	G48	05 AM 02
	G49	57 AY 01
	G50	57 Sİ 03
Bottle gourd	G36	55BA01
Interspecific hybrids (*C. maxima* x *C. moschata*)	G14	9X14 I
	G15	3X14
	G39	M12XEXC
	G40	07XSE
	G41	NSUX09
	G42	BOX02
	G43	UNRX04
Rootstock cultivars	G32	Shintoza F_1
	G33	Obez F_1
Pumpkin cultivar	G38	Titan

Table 2. Changes in plant height, leaf number and stem diameter of Cucurbit genotypes under salt stress.

Genotype	Plant height (cm)			Leaf number (unit)			Stem diameter (mm)		
	0 dS m^{-1}	16 dS m^{-1}	Diff. (%)	0 dS m^{-1}	16 dS m^{-1}	Diff. (%)	0 dS m^{-1}	16 dS m^{-1}	Diff.(%)
G1	68.33 g-k[a]	18.67 f-j	-72,7	12.33 g-o	7.33 b-g	-40,6	6.36 klm	5.18 fgh	-18,6
G2	120.67 bc	40.67 abc	-66,3	13.67 d-l	12.00 a	-12,2	6.09 l-o	5.84 efg	-4,1
G3	98.00 b-g	31.00 b-f	-68,4	14.00 d-k	12.67 a	-9,5	6.55 j-m	5.82 efg	-11,2
G4	90.00 c-h	28.00 c-f	-68,9	13.00 f-n	8.67 bc	-33,3	10.43 b-e	6.25 def	-40,1
G5	97.67 b-g	45.00 a	-53,9	13.67 d-l	8.67 bc	-36,6	6.89 i-m	5.84 efg	-15,2
G6	99.00 b-g	41.33 ab	-58,3	17.33 b-e	13.66 a	-21,2	6.24 lmn	5.86 efg	-6,1
G7	57.33 i-n	30.00 b-f	-47,7	10.33 k-q	9.00 b	-12,9	8.89 d-g	6.62 c-f	-25,5
G8	34.67 l-q	20.33 e-i	-41,4	11.66 i-o	7.33 b-g	-37,1	10.45 b-e	9.32 a	-10,8
G9	66.00 h-l	46.00 a	-30,3	9.66 l-q	8.00 b-e	-17,2	9.95 c-f	8.13 abc	-18,3
G10	55.00 i-o	27.33 def	-50,3	11.33 j-p	6.67 c-i	-41,1	7.50 g-l	6.32 def	-15,7
G11	53.00 j-o	25.67 d-h	-51,6	14.00 d-k	9.00 b	-35,7	9.04 d-g	5.86 efg	-35,2
G12	77.67 e-j	29.67 b-f	-61,8	8.33 opq	8.33 bcd	0,0	9.74 c-f	7.15 b-e	-26,6
G13	85.67 d-i	34.67 a-d	-59,5	9.00 n-q	7.33 b-g	-18,6	8.85 e-h	7.68 a-d	-13,2
G14	79.67 e-j	33.00 a-e	-58,6	9.33 m-q	6.00 e-k	-35,7	10.66 b-e	7.16 b-e	-32,8
G15	74.67 f-j	42.07 ab	-43,7	10.00 k-q	7.11 b-h	-28,9	12.53 a	8.45 ab	-32,6
G16	76.67 f-j	3.67 k	-95,2	16.00 c-h	3.67 lm	-77,1	7.06 h-m	3.67 h-k	-48,0
G17	101.00 b-f	4.67 k	-95,4	27.00 a	5.33 g-l	-80,3	8.34 f-j	2.92 i-n	-65,0
G18	27.00 n-q	3.33 k	-87,7	13.33 e-m	4.00 klm	-70,0	6.66 i-m	2.46 k-o	-63,1
G19	113.33 bcd	6.67 jk	-94,1	16.33 c-g	7.63 b-f	-53,3	7.54 g-l	2.03 k-p	-73,1
G20	78.67 e-j	4.33 k	-94,5	11.33 j-p	4.00 klm	-64,7	9.50 c-f	2.57 j-o	-73,0
G21	118.33 bc	7.50 ijk	-93,7	12.00 h-o	4.33 j-m	-63,9	9.50 c-f	2.63 j-o	-72,3
G22	9.33 q	3.97 k	-57,5	12.00 h-o	5.67 f-l	-52,8	6.17 lmn	1.64 m-p	-73,4
G23	91.00 c-h	5.67 jk	-93,8	11.33 j-p	4.67 i-m	-58,8	9.25 c-g	3.24 i-m	-65,0
G24	101.00 b-f	7.00 jk	-93,1	11.67 i-o	4.00 klm	-65,7	10.71 a-d	2.14 k-p	-80,0
G25	99.33 b-g	7.17 jk	-92,8	13.00 f-n	5.33 g-l	-59,0	10.41 b-e	1.47 nop	-85,9

Continuing table 2

Genotype	Plant height (cm)			Leaf number (unit)			Stem diameter (mm)		
	0 dS m-1	16 dS m-1	Diff. (%)	0 dS m-1	16 dS m-1	Diff. (%)	0 dS m-1	16 dS m-1	Diff.(%)
G26	103.67 b-f	8.00 ijk	-92,3	14.00 d-k	5.00 h-m	-64,3	11.81 ab	1.43 nop	-87,9
G27	119.33 bc	8.17 ijk	-93,2	11.67 i-o	4.00 klm	-65,7	9.39 c-f	1.43 nop	-84,8
G28	109.00 b-e	7.33 ijk	-93,3	14.00 d-k	4.00 klm	-71,4	9.99 b-f	1.41 nop	-85,9
G29	113.67 bcd	14.00 g-k	-87,7	14.67 c-j	5.00 h-m	-65,9	9.62 c-f	1.94 m-p	-79,8
G30	10.00 q	5.33 k	-46,7	11.00 j-q	4.67 i-m	-57,6	6.52 j-m	2.18 k-p	-66,6
G31	128.00 b	26.33 d-g	-79,4	16.33 c-g	5.33 g-l	-67,4	10.93 abc	6.40 def	-41,5
G32	163.00 a	27.67 c-f	-83,0	18.33 bc	4.67 i-m	-74,5	8.96 d-g	4.43 ghi	-50,6
G33	117.00 bcd	12.67 h-k	-89,2	10.67 j-q	3.00 m	-71,9	8.17 f-k	3.01 i-n	-63,2
G36	42.80 k-p	5.33 k	-87,6	13.83 d-k	3.67 lm	-73,5	8.38 f-i	2.47 k-o	-70,5
G38	189.00 a	8.00 ijk	-95,8	15.67 c-i	4.67 i-m	-70,2	9.08d-g	1.72 m-p	-81,1
G39	24.60 opq	3.10 k	-87,4	16.67 c-f	5.50 f-l	-67,0	5.88 l-o	1.47 nop	-75,0
G40	81.60 e-j	3.00 k	-96,3	18.33 bc	5.33 g-l	-70,9	6.75 i-m	1.41 nop	-79,1
G41	27.60 n-q	3.67 k	-86,7	12.00 h-o	5.00 h-m	-58,3	4.45 no	0.78 p	-82,5
G42	34.50 l-q	3.33 k	-90,4	17.67 bcd	6.67 c-i	-62,3	6.51 j-m	1.47 nop	-77,4
G43	35.67 l-q	3.33 k	-90,7	21.00 b	6.00 e-k	-71,4	5.45 mno	2.02 k-p	-62,9
G44	60.00 h-m	5.33 k	-91,1	15.67 c-i	7.00 b-h	-55,3	5.48 mno	1.15 op	-79,0
G45	7.33 q	2.50 k	-65,9	10.33 k-q	5.00 h-m	-51,6	5.40 mno	1.08 op	-80,0
G46	8.33 q	4.33 k	-48,0	7.00 q	3.67 lm	-47,6	5.28 mno	1.99 l-p	-62,3
G47	53.60 j-o	5.50 k	-89,7	9.00 n-q	5.00 h-m	-44,4	6.05 l-o	3.63 h-l	-40,0
G48	29.70 m-q	7.33 ijk	-75,3	11.00 j-q	6.33 d-j	-42,5	5.98 l-o	4.14 hij	-30,8
G49	15.33 p-q	6.00 jk	-60,9	8.67 opq	4.00 klm	-53,9	5.95 l-o	1.73 m-p	-70,9
G50	29.17 m-q	7.33 ijk	-74,9	7.33 pq	4.00 klm	-45,4	5.80 l-o	2.42 k-p	-58,3
G51	8.33 q	4.00 k	-52,0	10.00 k-q	3.67 lm	-63,3	4.33 o	1.01 op	-76,7
cv	0.27	0.53	-	0.19	0.21	-	0.14	0.28	-

[a]Different letters in the same column indicate significant differences P<0.05.

Table 3. Changes in some plant vegetative growth parameters and scale scores of Cucurbit genotypes based on the leaf damage under salt stress (16 dS m^{-1}).

Genotype	Leaf area (cm^2)			Shoot dry weight (g)			Root dry weight (g)			SCORE 16 dS m^{-1}
	0 dS m^{-1}	16 dS m^{-1}	Diff. (%)	0 dS m^{-1}	16 dS m^{-1}	Diff. (%)	0 dS m^{-1}	16 dS m^{-1}	Diff. (%)	
G1	67.50 n-s[a]	19.10 l-p	-71,7	4.40 m-s	2.26 e-m	-48,6	1.70 a-e	0.53 fg	-68,8	4.35 bc
G2	67.90 n-s	29.03 g-p	-57,3	7.40 j-m	2.87 c-j	-61,2	1.38 d-j	0.87 cde	-37,0	4.00 cde
G3	87.00 m-q	27.47 g-p	-68,4	5.90 l-r	2.80 c-k	-52,5	1.30 d-k	0.90 cde	-30,8	3.75 de
G4	88.00 m-q	38.40 f-n	-56,4	7.20 k-n	2.50 d-l	-65,3	2.40 abc	0.37 gh	-84,6	2.50 e
G5	78.10 m-r	37.35 f-n	-52,2	9.60 h-k	4.15 a-d	-56,8	2.60 a	0.80 c-f	-69,2	4.50 abc
G6	78.70 m-r	23.80 i-p	-69,8	5.90 l-r	3.56 b-f	-39,7	1.20 d-m	0.60 efg	-50,0	4.25 bcd
G7	80.83 m-r	54.20 ef	-33,0	5.80 l-r	3.90 a-e	-32,8	2.50 ab	1.47 a	-41,2	4.00 cde
G8	96.30 m-p	23.17 f-o	-75,9	8.00 jkl	4.20 abc	-47,5	1.23 d-m	1.10 hi	-10,6	4.25 bcd
G9	123.00 j-n	46.60 e-j	-62,1	8.60 i-l	4.70 ab	-45,4	1.60 b-f	0.93 bcd	-41,9	4.00 cde
G10	112.60 k-o	20.32 k-p	-82,0	7.10 k-o	3.23 b-h	-54,5	1.00 d-o	0.50 fg	-50,0	4.75 ab
G11	57.90 o-s	21.76 j-p	-62,4	6.30 l-p	4.70 ab	-25,4	1.20 d-m	0.70 def	-41,7	4.25 bcd
G12	332.40 a-d	80.22 bcd	-75,9	6.30 l-p	4.63 ab	-26,5	1.90 a-d	0.63 d-g	-66,8	4.00 cde
G13	166.70 h-k	117.20 a	-29,7	11.70 f-i	4.00 a-d	-65,8	1.00 d-o	0.63 d-g	-37,0	2.00 f
G14	97.60 m-p	54.62 ef	-44,0	9.60 h-k	4.63 ab	-51,8	2.50 ab	1.03 bc	-58,8	3.75 de
G15	99.60 m-p	44.11 e-k	-55,7	8.10 jkl	5.50 a	-32,1	1.70 a-e	0.80 c-f	-52,9	3.75 de
G16	122.50 j-n	8.70 op	-92,9	6.16 l-q	0.33 opq	-94,6	0.79 e-o	0.06 i	-92,4	5.00 a
G17	158.33 h-l	14.63 m-p	-90,8	8.45 jkl	0.63 m-q	-92,5	0.77 e-o	0.11 hi	-85,7	5.00 a
G18	74.77 n-s	10.93 op	-85,4	2.22 stu	0.25 pq	-88,7	0.51 h-o	0.08 hi	-84,3	5.00 a
G19	257.03 ef	49.91 e-h	-80,6	17.27 abc	2.07 f-n	-88,0	1.15 d-m	0.16 hi	-86,1	5.00 a
G20	236.93 fg	18.13 l-p	-92,4	10.47 g-j	0.80 m-q	-92,4	0.60 g-o	0.07 hi	-88,3	5.00 a
G21	376.83 a	52.00 efg	-86,2	15.92 bcd	1.85 g-p	-88,4	1.06 d-n	0.14 hi	-86,8	5.00 a
G22	37.20 qrs	10.92 op	-70,7	2.85 r-u	0.08 q	-97,2	0.37 k-o	0.08 hi	-78,4	5.00 a
G23	314.20 b-e	82.21 bc	-73,8	13.26 d-g	1.36 j-q	-89,7	1.04 d-o	0.08 hi	-92,3	5.00 a
G24	294.50 de	37.40 f-n	-87,3	15.44 b-e	1.37 j-q	-91,1	1.38 d-j	0.07 hi	-94,9	5.00 a
G25	308.37 b-e	39.13 f-m	-87,3	18.59 ab	1.62 h-q	-91,3	1.48 c-g	0.15 hi	-89,9	5.00 a

Continuing table 3

Genotype	Leaf area (cm²)			Shoot dry weight (g)			Root dry weight (g)			SCORE 16 dS m⁻¹
	0 dS m⁻¹	16 dS m⁻¹	Diff. (%)	0 dS m⁻¹	16 dS m⁻¹	Diff. (%)	0 dS m⁻¹	16 dS m⁻¹	Diff. (%)	
G26	353.40 abc	56.97 def	-83,9	15.06 cde	2.10 f-n	-86,1	1.38 d-j	0.11 hi	-92,0	5.00 a
G27	298.63 cde	51.82 efg	-82,7	16.06 bcd	2.00 f-n	-87,6	1.27 d-l	0.16 hi	-87,4	5.00 a
G28	235.17 fg	38.73 f-n	-83,5	12.39 e-h	1.71 g-q	-86,2	1.62 b-f	0.20 hi	-87,7	5.00 a
G29	362.46 ab	66.93 cde	-81,5	19.46 a	3.31 b-g	-83,0	1.40 d-i	0.20 hi	-85,7	4.00 cde
G30	61.87 o-s	8.62 op	-86,1	2.83 r-u	0.72 m-q	-74,6	0.60 g-o	0.12 hi	-80,0	4.00 cde
G31	379.60 a	93.77 ab	-75,3	17.30 abc	4.01 a-d	-76,8	1.30 d-k	0.16 hi	-87,7	4.00 cde
G32	359.60 ab	97.28 ab	-73,0	13.95 def	3.10 b-i	-77,8	1.13 d-m	0.13 hi	-88,5	5.00 a
G33	210.07 fgh	39.73 f-l	-81,1	7.25 k-n	1.55 i-q	-78,6	0.94 d-o	0.07 hi	-92,6	-
G36	232.50 fg	46.67 e-i	-79,9	7.80 jkl	1.52 i-q	-80,5	0.67 f-o	0.09 hi	-86,6	5.00 a
G38	262.53 ef	45.87 e-j	-82,5	14.41 c-f	1.99 f-o	-86,2	1.43 d-h	0.10 hi	-93,0	5.00 a
G39	88.17 m-q	13.93 nop	-84,2	2.52 stu	0.56 n-q	-77,8	0.29 mno	0.01 i	-96,6	5.00 a
G40	188.40 ghi	15.88 l-p	-91,6	8.49 jkl	1.17 k-q	-86,2	0.55 g-o	0.07 hi	-87,3	4.00 cde
G41	51.10 p-s	9.13 op	-82,1	1.10 tu	0.47 n-q	-57,3	0.09 o	0.03 i	-66,7	5.00 a
G42	57.52 o-s	15.00 l-p	-73,9	3.59 p-u	0.91 l-q	-74,7	0.42 j-o	0.05 i	-88,1	5.00 a
G43	132.27 i-m	11.35 op	-91,4	4.28 m-s	1.02 l-q	-76,2	0.32 l-o	0.05 i	-84,4	5.00 a
G44	120.20 j-n	18.07 l-p	-85,0	4.13 n-t	0.98 l-q	-76,3	0.25 mno	0.04 i	-84,0	5.00 a
G45	18.23 s	5.75 p	-68,5	0.58 u	0.61 m-q	5,2	0.09 o	0.01 i	-88,9	5.00 a
G46	35.60 qrs	11.75 op	-67,0	1.10 tu	0.52 n-q	-52,7	0.13 no	0.03 i	-76,9	5.00 a
G47	172.40 hij	25.40 h-p	-85,3	5.80 l-r	1.15 k-q	-80,2	0.29 mno	0.05 i	-82,8	5.00 a
G48	72.20 n-s	20.37 k-p	-71,8	2.35 stu	1.23 j-q	-47,7	0.27 mno	0.08 hi	-70,4	4.50 abc
G49	108.07 l-p	19.45 k-p	-82,0	3.04 q-u	1.21 j-q	-60,2	0.24 mno	0.05 i	-79,2	5.00 a
G50	173.80 hij	22.75 i-p	-86,9	4.00 o-t	1.30 j-q	-67,5	0.46 i-o	0.13 hi	-71,7	5.00 a
G51	25.77 rs	7.92 op	-69,3	1.30 stu	0.61 m-q	-53,1	0.13 no	0.05 i	-61,5	5.00 a
cv	0.22	0.43	-	0.24	0.49	-	0.58	0.24	-	0.08

[a]Different letters in the same column indicate significant differences P<0.05.

Figure 1. Sodium accumulation in leaves of different Cucurbit genotypes grown in salt treatment (16 dS m^{-1}) and control medium.

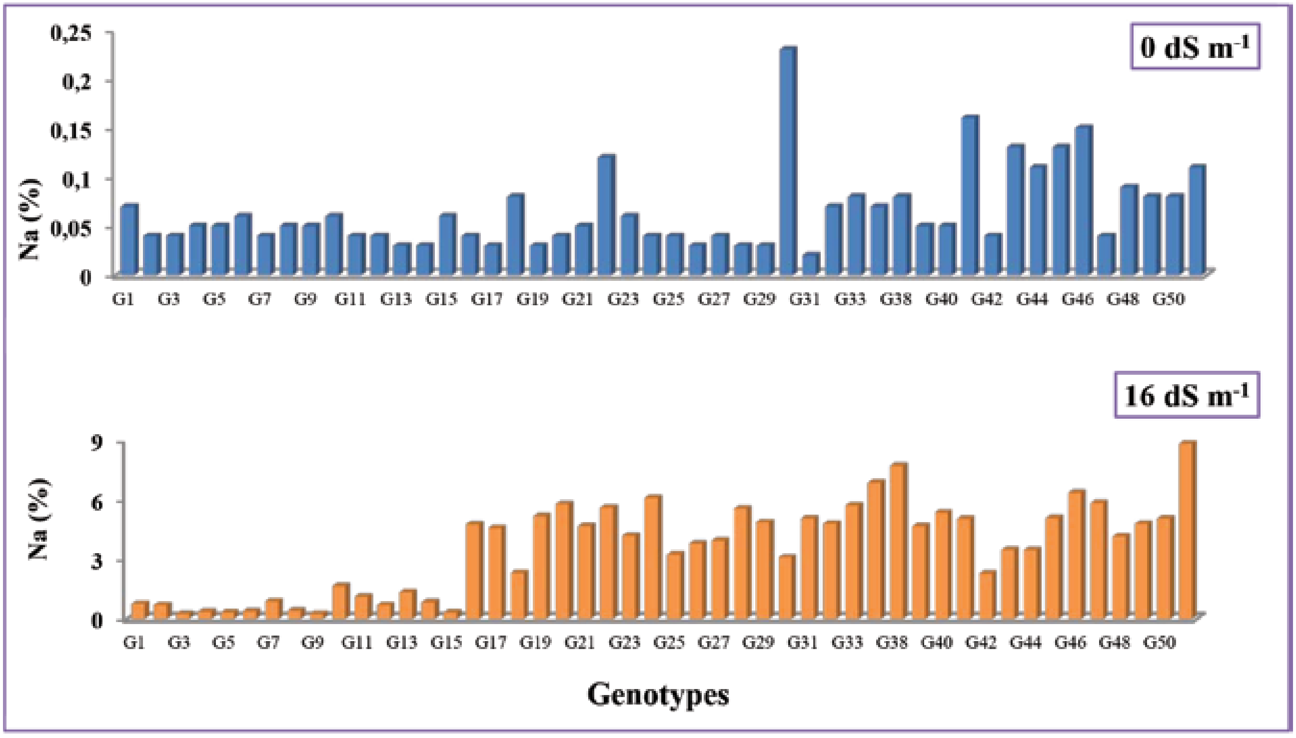


Figure 2. Potassium accumulation in leaves of different Cucurbit genotypes grown in salt treatment (16 dS m^{-1}) and control medium.

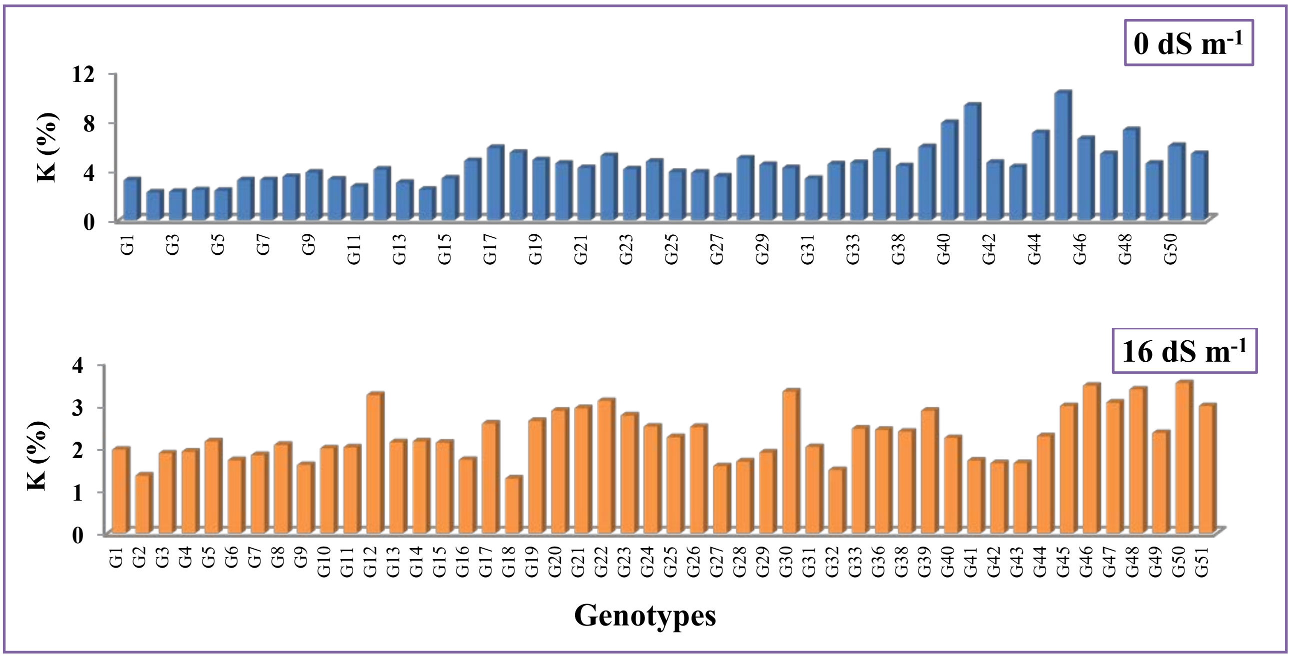


Figure 3. Calcium accumulation in leaves of different Cucurbit genotypes grown in salt treatment (16 dS m^{-1}) and control medium.

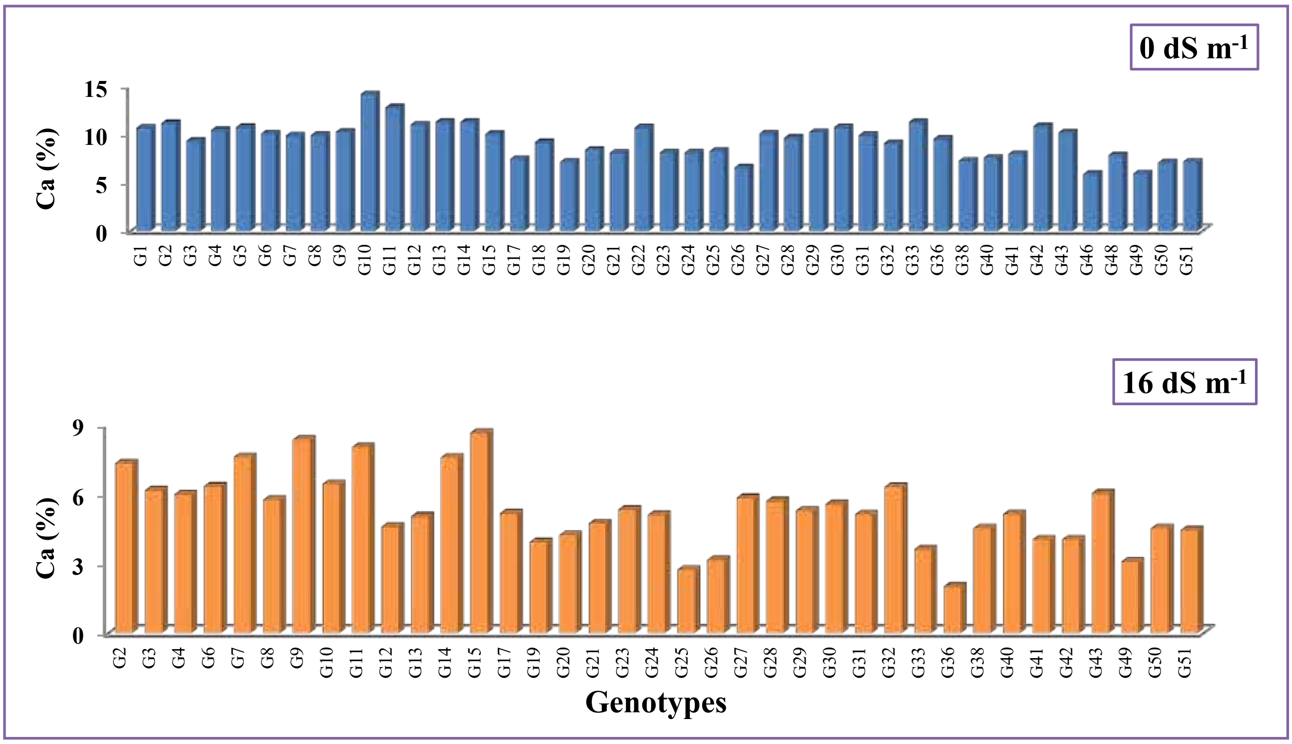


Figure 4. K/Na ion contents of different Cucurbit genotypes grown in salt treatment (16 dS m^{-1}) and control medium.

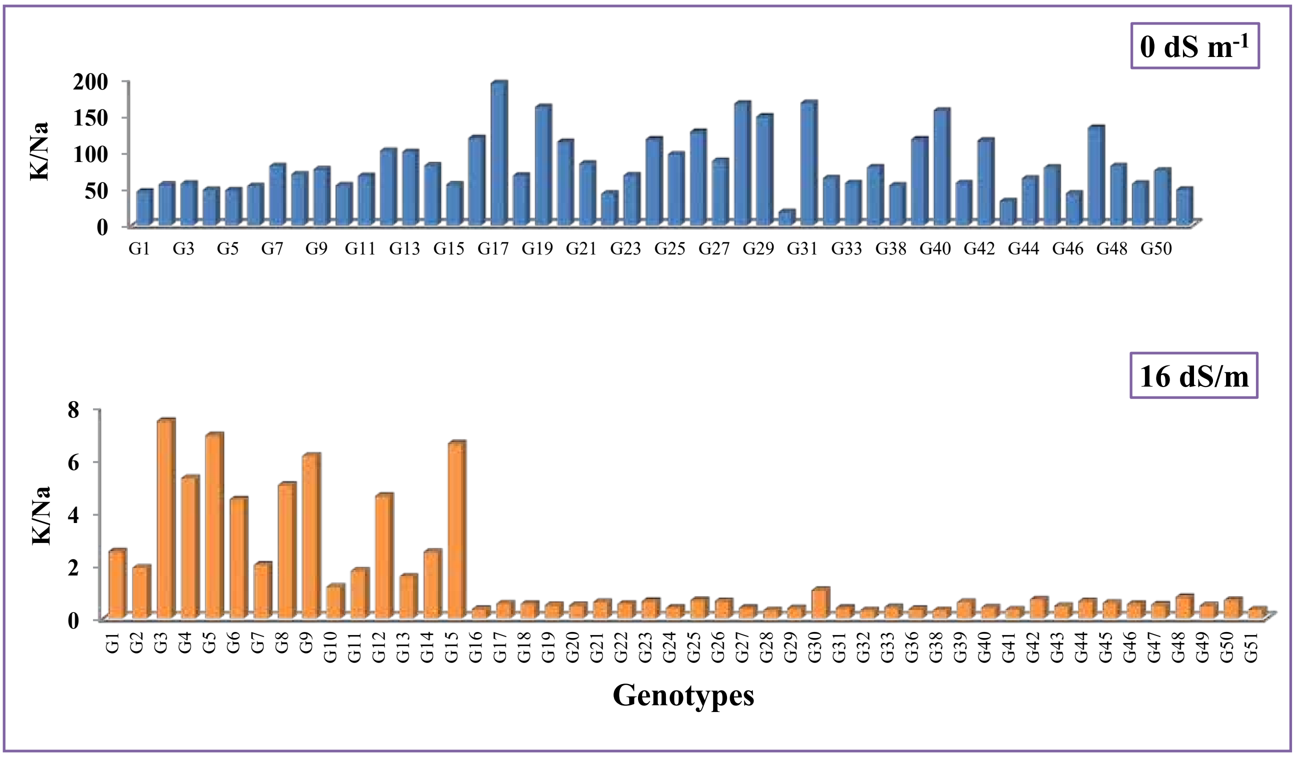
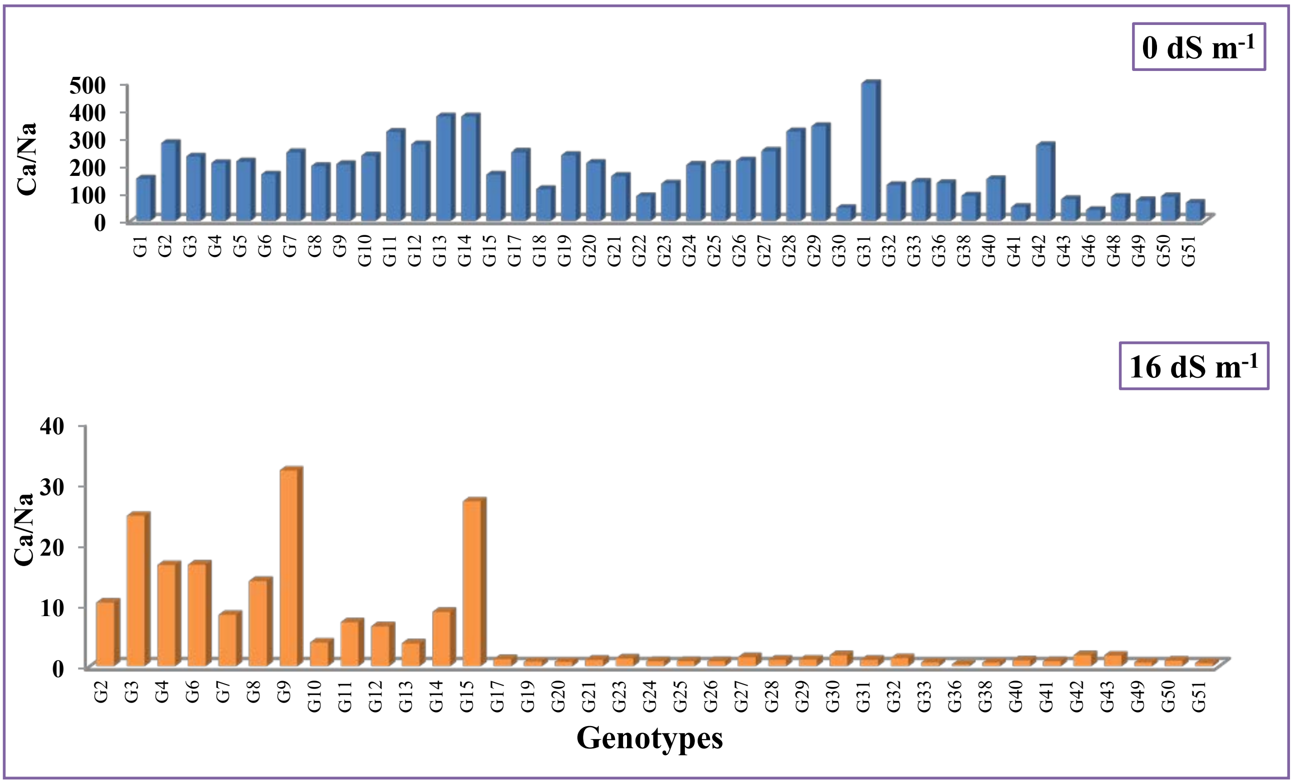


Figure 5. Ca/Na ion contents of different Cucurbita genotypes grown in salt treatment (16 dS m^{-1}) and control medium.



References

Balkaya A and Kandemir D (2015). An overview of winter squash (*Cucurbita maxima* Duch.) and pumpkin (*Cucurbita moschata* Duch.) growing in Turkey. Azarian Journal of Agriculture2(3):57-64.

Balkaya A, Kurtar ES, Yanmaz R and Ozbakir M (2011). The promising winter squash cultivars candidate developed by selection breeding from the Black Sea Region, Turkey. Türkiye IV. Tohumculuk Kongresi. Bildiriler Kitabı-1 17-22 (in Turkish).

Balkaya A, Ozbakir M and Karaagac O (2010). Evaluation of variation and fruit characterization of pumpkin (*Cucurbita moschata* Duch.) populations collected from Black Sea Region. Journal of Agricultural Sciences 16 (1):17-25 (in Turkish).

Balkaya A, Yanmaz R and Ozbakir M (2009). Evaluation of variation in seed characters in Turkish winter squash (*Cucurbita maxima* Duch.) populations. New Zealand Journal of Crop and Horticultural Science 37 (3): 167-178.

Belkhodja R, Morales F, Abadia A, Gomez Aparisi J and Abadia J (1994). Chlorophyll fluorescence as a possible tool for salinity tolerance screening in barley (*Hordeum vulgare* L.). Plant Physiology 104: 667-673.

Bergmann W (1992). Nutrition disorders of plants-development, visual and analytical diagnosis. Gustav Fischer Verlag, Jena, Stuttgart 333-371.

Colla G, Rouphael Y, Cardarelli M, Salerno A and Rea E (2010). The effectiveness of grafting to improve alkalinity tolerance in watermelon. Environmental and Experimental Botany 68: 283-291.

Cramer GR, Lauchli A and Epstein E (1986). Effects of NaCl and $CaCl_2$ on ion activities in complex nutrient solutions and root growth of cotton. Plant Physiology 81: 792-797.

Curuk S, Dasgan HY, Mansuroglu S, Kurt S, Mazmanoglu M, Antaklı O and Tarla G (2009). Grafted eggplant yield, quality and growth in infested soil with *Verticillium dahlia* and *Meloidogyne incognita*. Pesquisa Agropecuária Brasileira 44(12): 1663-1681.

Dasgan HY and Koc S (2009). Evulation of salt tolerance in common bean genotypes by ion regulation and searching for screening parameters. Journal of Food Agriculture and Environment 7: 363-372.

Dasgan HY, Balacheva E, Yetisir H, Yarsi G, Altuntas O, Akhoundnejad Y and Coban A (2015). The effectiveness grafting to improve salt tolerance of sensitive melon when the tolerant melon is use as rootstock. Procedia Environmental Sciences 29, 268.

Davis AR, Perkins Veazie P, Sakata Y, López Galarza S, Maroto JV, Lee SG, Huh YC, Sun Z, Miguel A, King SR, Cohen R and Lee JM (2008). Cucurbit grafting. Critical Reviews in Plant Sciences 27: 50-74.

Demir S (2009). Investigation on salt tolerance of the local melon populations grown in salt lake region. Master Thesis (Unpublished). Graduate School of Natural and Applied Sciences, Ankara University, Ankara, Turkey, 97p (in Turkish).

Edelstein M, Ben Hur M, Cohen R, Burger Y and Ravina I (2005). Boron and salinity effects on grafted and non-grafted melon plants. Plant and Soil 269: 273-284.

El Shraiy AM, Mostafa MA, Zaghlool SA and Shehata SAM (2011). Physiological aspect of NaCl-salt stress tolerant among Cucurbitaceous cultivars. Australian Journal of Basic and Applied Sciences 5(11): 62-71.

Ertekin F (2010). A research on the possibilities of using ion distribution in the plant parts for determining of salt tolerance on squash. Master Thesis (Unpublished). Graduate School of Natural and Applied Sciences, Ankara University, Ankara, Turkey, 98p (in Turkish).

Estan MT, Martinez Rodriguez MM, Francisco Perez Alfocea F, Flowers TJ and Bolarin MC (2005). Grafting raises the salt tolerance of tomato through limiting the transport of sodium and chloride to the shoot. Journal of Experimental Botany 56(412): 703–712.

Franco JA, Esteban C and Rodriguez C (1993). Effect of salinity on various growth stages of muskmelon cv.Revigal. Journal of Horticultural Science 68: 899-904.

Greenway H and Munns R (1980). Mechanisms of salt tolerance in nonhallophytes. Annual Review of Plant Physiology 31: 149-190.

Gungor B and Balkaya A (2016). The quantitative effects of local pumpkin rootstock candidates on the vegetative growth of grafted mini watermelon. Bahçe 2:21-26(in Turkish).

Huang J and Redman RE (1995). Solute adjustment to salinity and calcium supply in cultivated and wild barley. Journal Plant Nutrition18: 1371-1389.

Kacar B (1984). Practice Guide of Plant Nutrition. Ankara University, Publications of Agricultural Faculty No. 900 Practice Guides No. 214, Ankara (in Turkish).

Kachout SS, Bouraoui NK, Jaffel K, Rejeb MN, Leclere JC and Ouerghi Z (2012). Water deficit-induced oxidative stress in leaves of garden orach (*Atriplex hortensis*). Research Journal of Biotechnology 7(4): 45-52.

Karaagac O (2013). Determination of rootstock potential of winter squash (*Cucurbita maxima* Ducshesne) and pumpkin (*C. moschata* Ducshesne) genotypes selected from Black Sea Region for watermelon. Doctoral Thesis (Unpublished). Graduate School of Natural and Applied Sciences, Ondokuz Mayıs University, Samsun, Turkey, 240p (in Turkish).

Karaagac O and Balkaya A (2013). Interspecific hybridization and hybrid seed yield of winter squash (*Cucurbita maxima* Duch.) and pumpkin (*Cucurbita moschata* Duch.) lines for rootstock breeding. Scientia Horticulturae 149: 9-12.

Koc S (2005). Determination of genotipic variations for salinity tolerance at early plant growth stages in green beans. Master Thesis (Unpublished). Graduate School of Natural and Applied Sciences, Çukurova University, Adana, Turkey, 87p (in Turkish).

Kurtar ES, Balkaya A and Kandemir D (2016). Screening for salinity tolerance in developed winter squash (*Cucurbita maxima*) and pumpkin (*Cucurbita moschata*) lines. YuzuncuYil University Journal of Agricultural Sciences 26 (2): 183-195 (in Turkish).

Kusvuran S (2010). Relationships between physiological mechanisms of tolerances to drought and salinity in melons. Doctora Thesis (Unpublished), Graduate School of Natural and Applied Sciences, Çukurova Üniversitesi, Adana, Turkey, 356p (in Turkish).

Kusvuran S, Dasgan HY and Abak K (2011). Responses of different melon genotypes to drought stress. YuzuncuYil University Journal of Agricultural Sciences 21(3):209-219 (in Turkish).

Kusvuran S, Ellialtioglu S and Polat Z (2013). Applications of salt and drought stress on the antioxidative enzyme activities and malondialdehyde content in callus tissues of pumpkin genotypes. Journal of Food, Agriculture & Environment 11(2): 496-500.

Levitt J (1980). Responses of plants to environmental stresses. Vol.II, 2nd ed. Academic Press New York, 607.

Munns R (2002). Comparative physiology of salt and water stress. Plant Cell Environment 25: 239-250.

Ors S and Suarez DL (2016). Salt tolerance of spinach as related to seasonal climate. Horticultural Science (Prague) 1: 33-41

Paris HS and Brown RN (2005). The genes of pumpkin and squash. Horticultural Science 40: 1620-1630.

Robinson RW and Decker Walters DS (1997). Cucurbits. New York CAB International, 226p. (Crop Production Science in Horticulture).

Romero L, Belakbir A, Ragala L and Ruiz JM (1997). Response of plant yield and leaf pigments to saline conditions: effectiveness of different rootstocks in melon plants (*Cucumis melo* L.). Soil Science Plant Nutrition 43: 855–862.

Ruiz JM, Belakbir A, Lopez Cantarero I and Romero L (1997). Leaf macronutrient content and yield in grafted melon plants. A model to evaluate the influence of rootstock genotype. Scientia Horticulturae 71: 227-234.

Santa Cruz A, Martinez Rodriguez MM, Perez Alfocea F, Romero Aranda RC and Bolarin M (2002). The rootstock effect on the tomato salinity response depends on the shoot genotype. Plant Science 162(5): 825–831.

Sevengor S (2010). Investigations on antioxidant enzyme activities under in vitro and in vivo conditions to obtain salt tolerance in squash (*Cucurbita pepo* L.). Doctora Thesis (Unpublished). Graduate School of Natural and Applied Sciences, Ankara University, Ankara, Turkey, 179p (in Turkish).

Sevengor S, Yasar F, Kusvuran S and Ellialtioglu S, (2011). The effect of salt stress on growth, chlorophyll content, lipid peroxidation and antioxidative enzymes of pumpkin seedling. African Journal of Agricultural Research 6(21): 4920-4924.

Tipirdamaz R and Ellialtioglu S (1997). Some physiological and biochemical changes in *Solanum melongena* L. genotypes grown under salt conditions. Progress in Botanical Research (First Balkan Botanical Congress, Thessaloniki) 377-380.

Wei G, Zhu Y, Liu Z, Yang L and Zhang G (2007). Growth and ion distribution in grafted eggplant seedling under NaCl stress. Acta Botanica Boreali-OccidentaliaSinica27: 1172-1178.

Wu T, Zhou J, Zhang Y and Cao J (2007). Characterization and inheritance of a bush-type in tropical pumpkin (*Cucurbita moschata* Duchesne). Scientia Horticulturae 114: 1-4.

Yamamuro K and Marukawa S (1974). Studies on the selection of *Cucurbita* spp. as watermelon rootstocks. 3. Compatibility and yield in relation to differences in cultivation. Bulletin of Ibaraki-ken Horticultural Experiment Station 5: 123-149.

Yetisir H and Uygur V (2009). Plant growth and mineral element content of different gourd species and quality. Phytoparasitica 31: 163-169.

Yetişir H and Uygur V (2010). Responses of grafted watermelon onto different gourd species to salinity stress. Journal of Plant Nutrient33:315-327.

Yıldız S (2014). Determination of salinity tolerance levels of some winter squash and pumpkin (*Cucurbita* spp.) genetic resources as rootstocks for grafted cucumber seedling productıon. Master Thesis (Unpublished).Graduate School of Natural and Applied Sciences, Ondokuz Mayıs University, Samsun, Turkey, 240p (in Turkish).

Zhu J, Bie Z and Li Y (2008). Physiological and growth responses of two different salt-sensitive cucumber cultivars to NaCl stress. Soil Science and Plant Nutrition 54: 400-407.