Turk J Agric For
33 (2009) 65-77
© TÜBİTAK
doi:10.3906/tar-0805-23

Plant Growth and Mineral Element Content of Different Gourd Species and Watermelon under Salinity Stress

Halit YETİŞİR[1], Veli UYGUR[2]

[1]Department of Horticulture, Faculty of Agriculture, Mustafa Kemal University, Hatay - TURKEY

[2]Department of Soil Science, Faculty of Agriculture, Mustafa Kemal University, Hatay - TURKEY

Received: 20.05.2008

Abstract: The watermelon [*Citrullus lanatus* (Thunb.) Matsum. and Nakai] cultivar Crimson Tide and 7 different gourd genotypes [*Cucurbita maxima, C. moschata, Luffa cylindrica, Benincasa hispida, Lagenaria siceraria* landraces (Skp and Birecik), and *L. siceraria* hybrid (FRGold)] with rootstock potential for watermelon were grown under saline conditions (0, 4, 8, 12, and 16 dS m^{-1}) to investigate the responses of the gourd genotypes and watermelon to 30 days of salt stress. Plant main stem length, shoot dry weight, root dry weight, reduction in shoot dry weight, concentration of Na^+, Ca^{2+}, and K^+ in the leaves of the genotypes, and Ca^{2+}/Na^+ and K^+/Na^+ ratios were investigated. Plant length, and shoot and root dry weight of the plants significantly decreased as salinity stress increased. Gourd genotypes responded significantly differently to all investigated parameters under saline conditions. All genotypes had better growth performance than watermelon, except for *L. cylindrica* and *B. hispida*. The gourd genotypes and watermelon showed significant differences under saline conditions, with respect to ion regulation. Sodium concentration in the leaves of all the genotypes increased in response to salt application. There was a remarkable increase in Na^+ concentration in the leaves of *L. cylindrica*, whereas the lowest Na^+ concentration was observed in Birecik, and *C. maxima*, *B. hispida*, and *L. cylindrica* accumulated more Na^+ than watermelon and the other gourd genotypes did under saline conditions. Ca^{2+}/Na^+ and K^+/Na^+ ratios were significantly reduced by salt treatment and the degree of decrease was dependent on genotype. Genotypes with higher Ca^{2+}/Na^+ and K^+/Na^+ ratios produced more dry weight. Significant positive correlations were observed between plant biomass parameters, and Ca^{2+}/Na^+ and K^+/Na^+ ratios, whereas strong negative correlations were observed between Na^+ concentrations and shoot and root dry weight of the genotypes. *Cucurbita* and *Lagenaria* species were more tolerant to salinity stress than *L. cylindrica, B. hispida*, and watermelon.

Key Words: Gourd genotypes, watermelon, salinity tolerance, dry weight, ion regulation

Farklı Kabak Türlerinin ve Karpuzun Tuz Stresi Altında Bitki Gelişimi ve Element İçerikleri

Özet: Crimson Tide karpuz [Citrullus lanatus (Thunb.) Matsum. and Nakai] çeşidi ve karpuza anaçlık potansiyeli olan 7 farklı kabak genotipi [*Cucurbita maxima, C. moschata, Luffa cylindrica, Benincasa hispida, Lagenaria siceraria* (Skp ve Birecik) köy çeşidi ve *L. siceraria* melezi (FRGold)] 30 gün tuzlu (0, 4, 8, 12 ve 16 dS m^{-1}) koşullarda yetiştirilerek tuz stresine tepkileri belirlenmiştir. Bitki ana gövde uzunluğu, kök kuru ağırlığı, yaprak ve gövde kuru ağırlığı, bitki kuru ağırlığındaki azalma, yapraklardaki Na^+, Ca^{2+} ve K^+ konsantrasyonu, Ca^{2+}/Na^+ ve K^+/Na^+ oranları belirlenmiştir. Kabak genotipleri tuzlu koşullarda incelenen bütün parametrelere farklı tepkiler vermişlerdir. *L. cylindrica* ve *B. hispida* hariç bütün kabak genotipleri tuz stresinden karpuza göre bitki gelişimi açısından daha az etkilenmişlerdir. İyon regülasyonu bakımından kabak genotipleri ve karpuz arasında önemli farklılıklar tespit edilmiştir. Tuz uygulaması ile birlikte yapraktaki Na^+ konsantrasyonu yükselmiştir. *L. cylindrica*'nın yapraklarında Na^+ birikimi önemli bir artış gösterirken, en düşük Na^+ içeriği Birecik ve *C. maxima*'da belirlenmiştir. Tuz stresi altında, *B. hispida* ve *L. cylindrica,* karpuz ve diğer kabak genotiplerinden daha fazla Na^+ biriktirmişlerdir. Ca^{2+}/Na^+ and K^+/Na^+ oranları tuz uygulaması ile birlikte önemli derecede azalmıştır. Azalma genotipe göre değişmiştir. Yüksek bitki kuru ağırlığına sahip olan genotipler, yüksek Ca^{2+}/Na^+ ve K^+/Na^+ oranlarına sahip olmuşlardır. Bitki büyüme parametreleri ile Ca^{2+}/Na^+ ve K^+/Na^+ oranları arasında önemli pozitif korelasyonlar bulunurken, Na^+ içeriği ile önemli negatif korelasyon tespit edilmiştir. *Cucurbita* ve *Lagenaria* türleri tuz stresine, *L. cylindrica*, *B. hispida* ve karpuza göre daha yüksek tolerans göstermiştir.

Anahtar Sözcükler: Kabak genotipleri, karpuz, tuza tolerans, kuru ağırlık, iyon regülasyonu

* Correspondence to: yetisir1@yahoo.com, yetisir1@mku.edu.tr

Introduction

Salinity stress, which usually occurs in arid and semi-arid regions, is an important environmental constraint limiting crop productivity. The progressive salinization of irrigated land threatens the future of agriculture in most productive agricultural areas of the world. Low-level rainfall, saline irrigation water, native rock, high-level evaporation, and poor water management practices can cause salinity problems in agricultural areas. Under high saline conditions, majority of crop plants are not able to survive or are able to survive only with little growth and yield. The general effect of salinity is a reduced growth rate, resulting in a reduction in the number and size of leaves, and shorter plant stature. The initial and primary effect of salinity is due to its osmotic effect, leading to low water potential of the root medium. Two other effects of salinity are toxicity of ions, mainly Na^+ and Cl^-, and nutrient imbalance due to a decrease in uptake and/or transport (Jacoby, 1994; Marschner, 1995). Solving salinity problems will have a positive effect on crop production. Salinity management through reclamation or improved irrigation techniques is often prohibitively expensive and provides only short-term solutions for overcoming salinity problems in arid and semi-arid regions in which severe irrigation water shortages exist (Singh and Singh, 2000). Breeding cultivars that can grow and produce economic yields under saline conditions is a more permanent solution for minimizing the deleterious effects of salinity (Fooland, 1996). Numerous attempts have been made to improve salt-tolerant crops by traditional breeding programs, but commercial success has been quite limited. Although salt-tolerant species exist in gene pools, cultivar development has been tedious (Cuartero and Fernandez-Munoz, 1999). Recently, research has been directed towards developing transgenic salt-tolerant plants. Although improvement in salt tolerance is possible by the expression of a single gene in some cases (Rus et al., 2001), the transfer of more genes is required due to the polygenic character of this abiotic stress (Bonhert and Jensen, 1996). The demand from growers for cultivars with high yield and quality is high, even though they are susceptible to salinity; therefore, research focused on alleviating the deleterious effects of salt stress continues to be an important objective. One possible way to reduce the detrimental effects of salt stress on high-yielding cultivars might be to graft these genotypes onto rootstocks with the capability of inducing salt tolerance to the scion.

To date, many studies have been carried out to determine the response of grafted trees to saline conditions (Walker, 1986; Sykes, 1992); however, only a limited number have investigated vegetable grafting and salinity. Santa-Cruz et al. (2002) reported that root characteristics determine, at least partially, the salinity response of tomato and, therefore, grafting is a valid strategy for the alleviation of the deleterious effects of salt stress on shoot growth. Similarly, melon root characteristics have a primary role in determining the response to salt stress (Romero et al., 1997).

Grafting is an important technique for the suitable cultivation of fruit-bearing vegetables in Japan, Korea, and some other Asian and European countries where intensive and continuous cultivation is performed. Grafting vegetables was first performed in Korea and Japan in the late 1920s by grafting watermelon onto gourd rootstocks (Lee, 1994; Oda, 1995). Watermelon was grafted to control *Fusarium* wilt, to increase low temperature tolerance, and to increase yield by enhancing water and plant nutrient uptake (Lee, 1994; Oda, 1995). For these purposes, watermelon was grafted onto *Cucurbita moschata, C. maxima, Benincasa hispida,* and *Lagenaria siceraria. L. siceraria* is a species widely used as rootstock for watermelon (Lee, 1994). Responses of pumpkin and squash to salt stress were reported in previous studies, and they are more tolerant than watermelon (Kotuby-Amacher et al., 2000); however, to the best of our knowledge information about the response of *B. hispida, L. siceraria,* and *Luffa cylindrica* species to different levels of salt stress has not been reported. Therefore, the aim of the present study was to determine the response of different gourd species with rootstock potential for watermelon to salt stress, as compared to watermelon. Plant growth parameters and ion regulation were compared between gourd species, and between the gourd species and watermelon.

Materials and Methods

The watermelon [C*itrullus lanatus* (Thunb.) Matsum. and Nakai] cultivar Crimson Tide (Ct) and 7 different gourd species were used as plant materials. The name, definition, and source of the gourd genotypes are presented in Table 1. The experiment was carried out in a greenhouse (temperature regime: 28 °C (day) and 20 °C (night); relative humidity: 60%-70%). Seeds were

Table 1. Name, definition, and source of gourd genotypes.

Gourd genotypes	Abbreviation	Definition	Source
Luffa cylindrica (L.) Roem.	(Lcy)	Landrace	Hatay, Turkey
Lagenaria siceraria (Mol.) Standl Birecik	(Br)	Landrace	Şanlıurfa, Turkey
Lagenaria siceraria (Mol.) Standl Skopje	(Skp)	Landrace	Adana, Turkey
Cucurbita maxima Duchense	(Cma)	Landrace	Hatay, Turkey
Cucurbita moschata Duchense ex Poir.	(Cmo)	Landrace	Hatay, Turkey
FR Gold	(Frg)	*Lagenaria* hybrid	Korea
Benincasa hispida (Thunb.) Cogn.	(Bh)	Landrace	Ankara, Turkey

sown in a mixture of peat (EC: 0.36 dS m^{-1}, pH: 6.0-6.5) and perlite in a 2:1 ratio. The Birecik and Skp *L. siceraria* landraces used in this study have performed well with regard to potential use as rootstock for watermelon (Yetisir and Sarı, 2003). Seeds of *Luffa cylindrica* and *Benincasa hispida* were sown 7 days earlier than seeds of the other gourd species and watermelon because they require more time for germination and emergence (Yetişir and Sarı, 2004). Seedlings at the 2-true-leaf stage were transplanted to 3-l pots filled with a mixture of peat and perlite in a 1:1 ratio, and were amended with 0.4 g N l^{-1}, 0.175 g P l^{-1}, 0.332 g K l^{-1}, and 0.4 g Ca l^{-1}. Seedlings were irrigated with tap water (EC: 0.5 dS m^{-1} and pH 7.0-7.4) for 1 week and then salt application began. Plants were irrigated every 2 days with 5 different saline treatments that were made from tap water and NaCl. Electrical conductivity at 25 °C of the 5 salinity treatments was 0.5 (control), 4.0, 8.0, 12.0, and 16.0 dS m^{-1}. In the first week of salt application, half of the dosage (control, 2.0, 4.0, 6.0, and 8 dS m^{-1}) was used. Surplus water drained naturally from the bottom of pots to avoid excessive accumulation of salt in the growth medium. A plate was put under each pot to collect the drainage water. EC of the drainage water was measured with a hand EC meter after irrigation and EC of the growth medium was kept at the same level with the applied salt concentrations. The experiment was in a split plot design. The main plots were salinity levels and the subplots were gourd genotypes. Each treatment was replicated 3 times with 3 plants. At the end of 4 weeks (beginning of the flowering stage in the control treatment) plants were harvested and evaluated for their response to salinity. Plant main stem length was measured. Roots and shoots of the plants were separated from the growth medium surface. Plant roots were cleaned of growth medium under running water. In order to determine shoot and root dry weight, plant materials were dried for 48 h at 70 °C. Na^+, K^+, and Ca^{2+} concentrations in the leaves were determined by ICP-AES (Varian Series II) after nitric acid digestion (Zarcinas et al., 1987). Ca^{2+}/Na^+ and K^+/Na^+ ratios, and percent reduction in dry weight, as compared to the control treatment, were calculated.

The data were subjected to ANOVA and means were compared using Tukey's test at 0.05 and 0.01 significance levels. The correlation coefficients between Ca^{2+}/Na^+ and K^+/Na^+ ratios, and Na^+ concentration and total dry weight were calculated for each salt treatment with SPSS.

Results

Plant growth significantly decreased as the NaCl concentration in irrigation water increased. The inhibitory effects of salt on growth were observed in all the measured growth parameters. Growth performance of the genotypes was dependent on genotype and level of salinity. The effect of salinity level and genotype, and their interaction were significant (Table 2). The effect of NaCl on main stem length was greater in Lcy, Bh, and Birecik than in watermelon and the other gourd species used in this study. The longest plant main stem length was measured in Skp, while the shortest was measured in Bh, at each salt level. Watermelon had an intermediate value with regard to main stem length. Reduction in main stem length was more pronounced in each genotype in response to salt treatments over 12 dS m^{-1} salinity (Figures 1 and 2).

Regarding shoot dry weight, the gourd species and watermelon were significantly different in their responses to salinity (Figure 3). Shoot dry weight decreased as salt

Table 2. Analysis of variance summaries of the data for shoot dry weight, root dry weight, and different ions of the leaves of various gourd species and watermelon grown under salinity stress for 30 days.

Source	df	Main stem length	Shoot dry weight	Root dry weight	Ca^{2+}	K^+	Na^+	Ca^{2+}/Na^+	K^+/Na^+	df	Reduction (%)
Salt treatment (T)	4	53,298**	1014**	3.82**	11.25**	1.01**	1.34**	66,847**	17,231**	3	5409**
Rep/T	10	16	1	0.04	0.01	0.00	0.00	6	3	8	2
Genotype (G)	7	12,583**	358**	9.49**	2.20**	0.14**	2.42**	3335**	987**	7	704**
T × G	28	500**	14**	0.14**	1.28**	0.09**	0.33**	6894**	1419**	21	74**
Error	70	11	1	0.04	0.01	0.02	0.00	63	18	56	2

**Significant at P = 0.01.

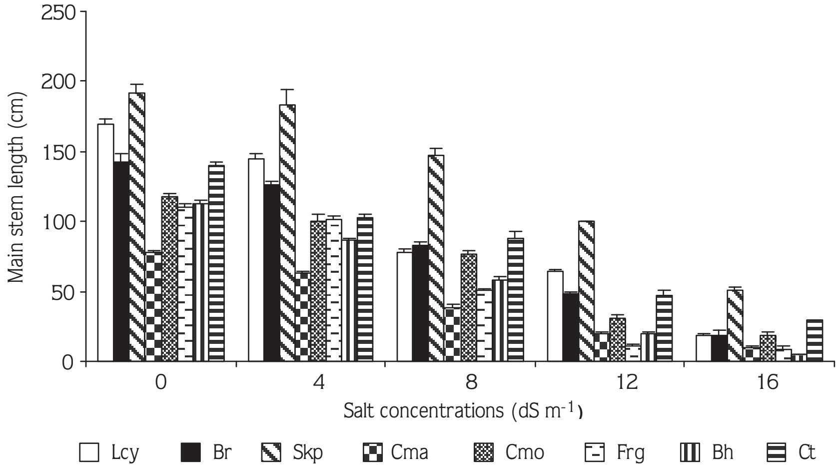

Figure 1. Plant main stem length of watermelon and different gourd species grown under saline conditions for 30 days (significant at 0.01 level).

concentration increased in all the genotypes. The highest shoot dry weight was measured in Cmo and Cma, while the lowest was recorded in Lcy and Bh. Ct accumulated less dry matter than Cmo, Cma, Skp, Birecik, and Frg, while having more shoot dry weight than Lcy and Bh (Figure 3). The 4 dS m^{-1} salinity treatment did not affect shoot dry weight in Lcy, Cma, or Cmo, whereas it significantly reduced shoot dry weight in Ct, Birecik, Skp, and Bh. The lowest reduction in shoot dry weight was observed in Cma, while the reduction in shoot dry weight ranged from 10% to 40% in Ct and other the gourd genotypes in response to the 4 dS m^{-1} salt treatment. The genotypes most affected by the 4 dS m^{-1} salt treatment were Bh and Ct. The effect of salinity treatment on shoot dry weight was significant in all the genotypes with treatments over 8 dS m^{-1}, and it was severely pronounced in response to the 12 and 16 dS m^{-1} salt treatments. The reduction in shoot dry weight in Lcy significantly increased and reached about 70%. Reduction in shoot dry weight in the other genotypes was about 50% in response to the 8 dS m^{-1} salt treatment. Reduction in shoot dry weight in response to the 12 dS m^{-1} salt treatment reached 60% or more in all the genotypes, except for Cma (about 35%). Shoot dry weight decreased by 60%-90% in all the genotypes in response to the 16 dS m^{-1} salt treatment. The smallest reduction in response to the 16 dS m^{-1} salt treatment was recorded in Cma (Figure 4).

The salinity treatments decreased root dry weight in Lcy, Skp, Frg, Bh, and Ct, while it increased root dry weight in Cma, Cmo, and Birecik in response to the 4 dS m^{-1} salt treatment, as compared to the control plants (0 dS m^{-1}) (Figure 5). Similarly, root dry weight increased in Cma, Cmo, and Ct, while it decreased in Lcy, Birecik, Skp, Frg, and Bh in response to the 8 dS m^{-1} salt treatment. Root dry weight of each gourd genotype and Ct

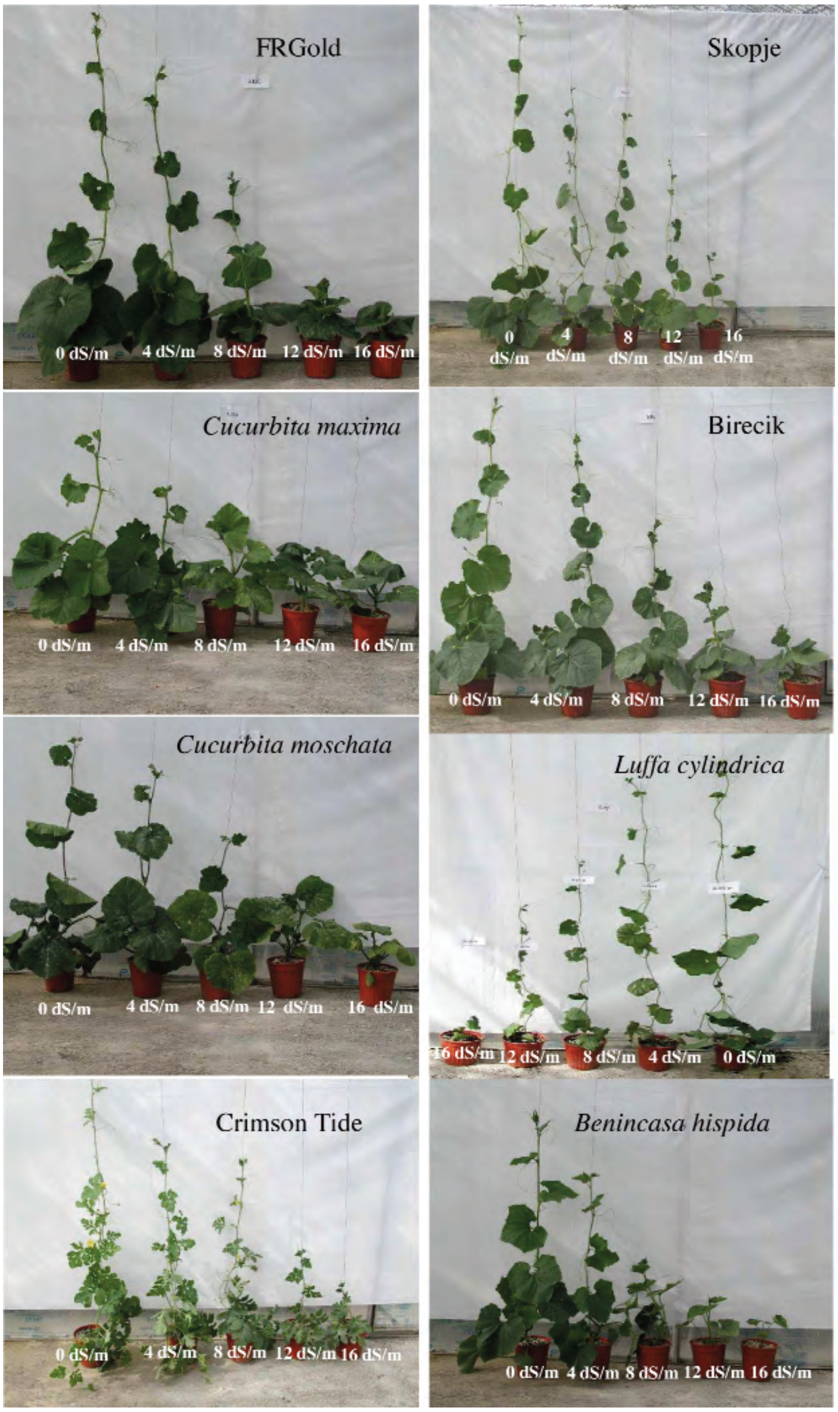

Figure 2. Watermelon and different gourd species grown under NaCl salinity conditions for 30 days.

continually decreased in response to the 12 and 16 dS m^{-1} salt treatments, except for Skp (in response to the 16 dS m^{-1} salt treatment). In terms of root dry weight, the gourd species most affected were Lcy and Bh, whereas Cma and Cmo were the least affected. With regard to root dry weight, Birecik, Skp, and Frg had more tolerance to salinity than Ct, Bh, and Lcy, but they had less tolerance to salinity than Cma and Cmo.

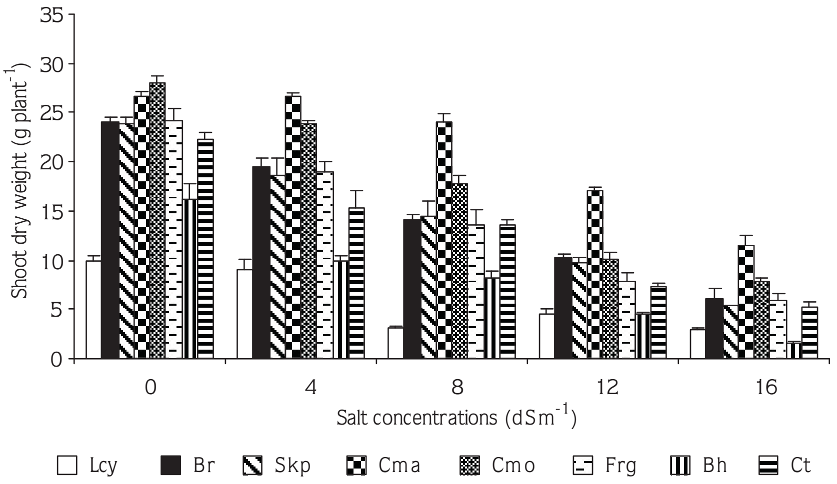

Figure 3. Shoot dry weight of watermelon and different gourd species grown under saline conditions for 30 days (significant at 0.01 level).

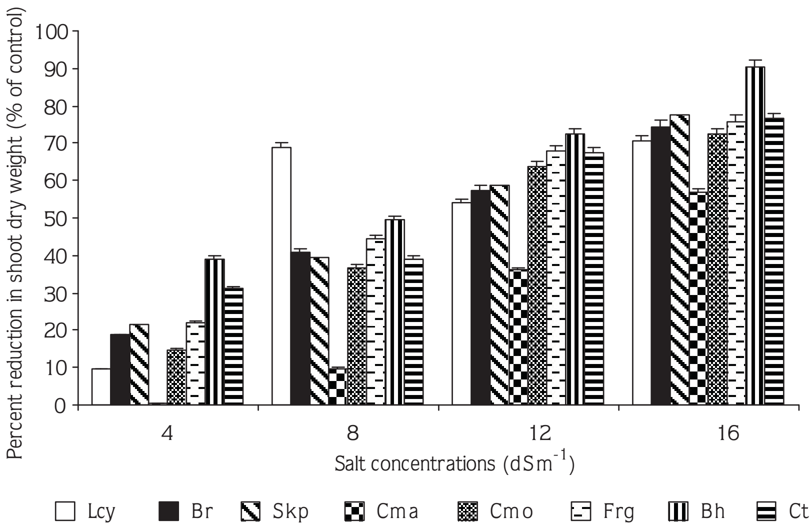

Figure 4. Percent reduction in shoot dry weight of watermelon and different gourd species grown under saline conditions for 30 days (significant at 0.01 level).

Sodium accumulation was significantly affected by the genotypes and salinity level (Figure 6). The salinity treatments generally increased leaf Na^+ concentration, particularly in Lcy. The lowest Na^+ concentration was observed in the leaves of Lcy, while the highest Na^+ concentration was in the leaves of Ct control plants. Other genotypes had similar Na^+ concentration levels under control conditions. Sodium concentration increased in response to salt treatment. The highest increase in leaf Na^+ concentration was observed in Lcy and Ct, whereas the smallest increase was in Birecik and Cma, in response to the 4 dS m^{-1} salt treatment. With the 8 dS m^{-1} salt treatment, the highest Na^+ concentration was observed in Lcy, followed by Bh, Ct, and Cmo, whereas the lowest Na^+ concentration was recorded in Frg, Cma, and Birecik. Sodium concentration continued to increase in each genotype, particularly in Lcy, in response to the 12 dS m^{-1} and 16 dS m^{-1} salt treatments.

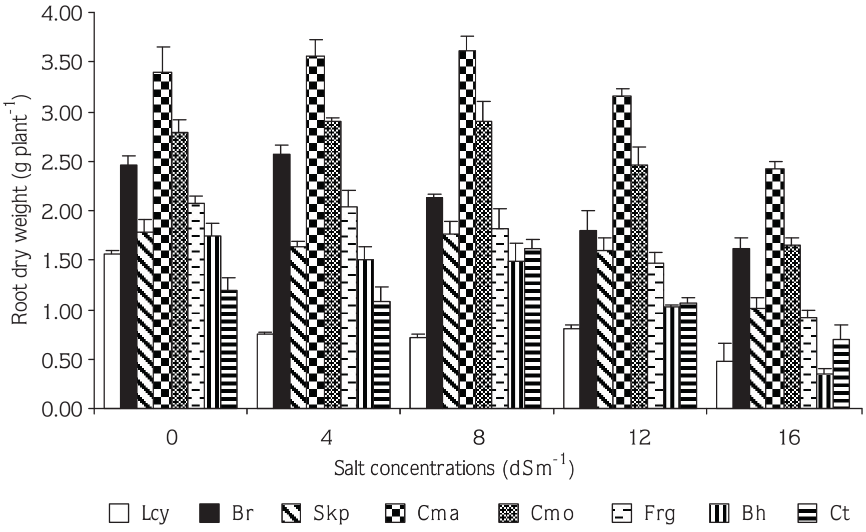

Figure 5. Root dry weight of watermelon and different gourd species grown under saline conditions for 30 days (significant at 0.01 level).

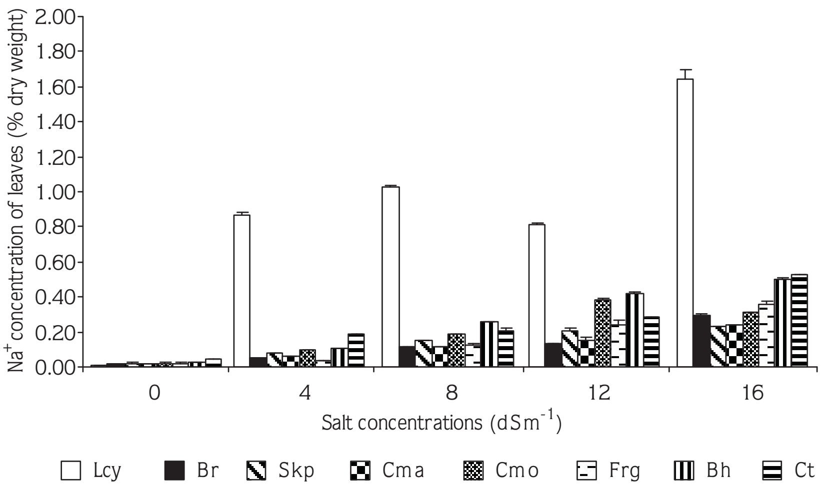

Figure 6. The effect of NaCl salinity on Na^+ concentration in the leaves of watermelon and different gourd species (significant at 0.01 level).

Regarding Ca^{2+} concentration, all the genotypes had a different response to increasing salinity (Figure 7). Ca^{2+} concentration significantly increased in each gourd genotype and Ct as the level of salinity increased, except Lcy. Ca^{2+} concentration was lower in Lcy compared to the control. Ca^{2+} accumulation as salinity level increased was greater in Birecik, Skp, and Frg than in Cmo, Cma, and Bh.

Under salinity stress, K^+ concentration increased with increasing salt level, except in Lcy (Figure 8). Potassium concentration in Lcy decreased with increasing salinity. The effect of salinity on K^+ accumulation in the genotypes was significant; however, with the 12 dS m^{-1} salt treatment, all the gourd genotypes and Ct had a similar response to salinity, in terms of K^+ concentration in leaves. Bh and Ct, which had the lowest K^+ concentration

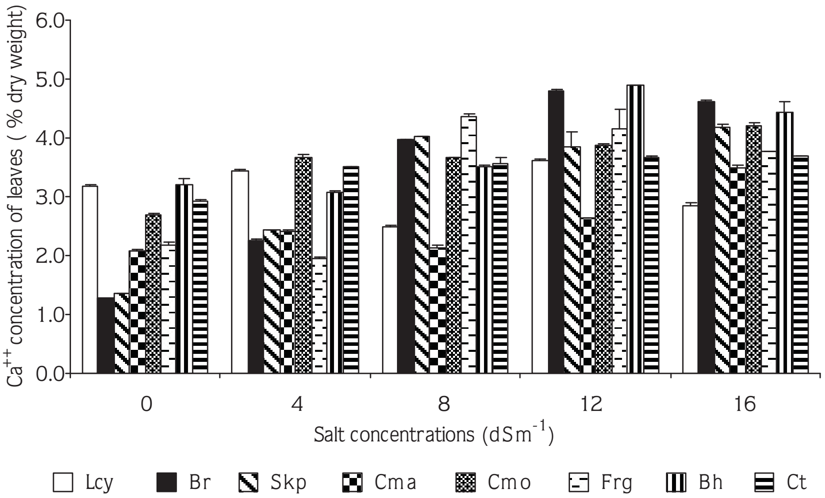

Figure 7. The effect of NaCl salinity on Ca^{++} concentration in the leaves of watermelon and different gourd species (significant at 0.01 level).

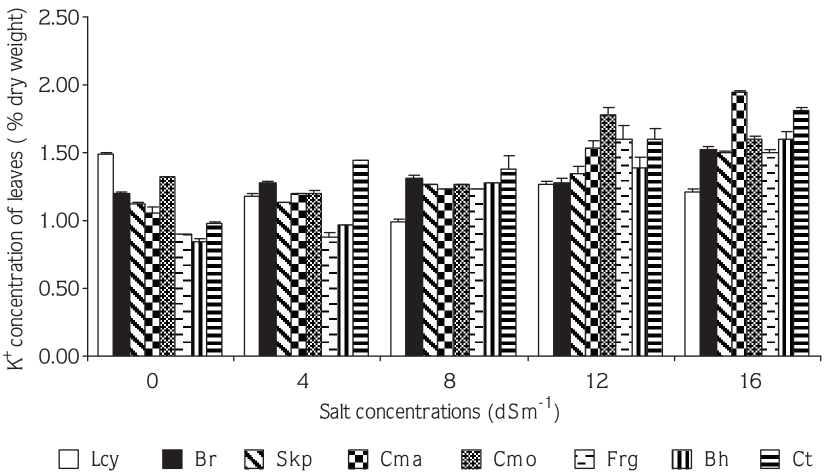

Figure 8. The effect of NaCl salinity on K^+ concentration in the leaves of watermelon and different gourd species (significant at 0.01 level).

under control conditions, had the highest K^+ concentration under saline conditions.

The effects of salt treatment on Ca^{2+}/Na^+ and K^+/Na^+ ratios in the leaves of watermelon and the gourd species after 30 days of salt application are presented in Table 3. Under control conditions the highest Ca^{2+}/Na^+ ratio was observed in Lcy, while the lowest was in Ct and Skp. The gourd species and Ct were significantly different with regard to Ca^{2+}/Na^+ ratio under saline conditions. The Ca^{2+}/Na^+ ratio linearly decreased by increasing the salinity level in all the gourd genotypes and Ct, except Lcy. The Ca^{2+}/Na^+ ratio in Lcy significantly decreased in response to the 4 dS m^{-1}, 8 dS m^{-1}, and 16 dS m^{-1} salt treatments, while it increased in response to the 12 dS m^{-1} salt treatment. The gourd genotypes and Ct were also significantly different in terms of the K^+/Na^+ ratio. In control plants, as with the Ca^{2+}/Na^+ ratio, Lcy had the highest K^+/Na^+ ratio, while Ct had the lowest K^+/Na^+ ratio. The K^+/Na^+ ratio decreased in each genotype with salt treatment. The greatest reduction was observed in

Table 3. The effect of salt treatment on Ca^{2+}/Na^{+} and K^{+}/Na^{+} ratios in the leaves of watermelon and different gourd species after 30 days of salt application.

Genotypes	Ca^{2+}/Na^{+}					K^{+}/Na^{+}				
	Salt concentrations (ds m^{-1})									
	0	4	8	12	16	0	4	8	12	16
Lcy	369.6 a*	4.0 f	2.4 e	4.5 b	1.7 d	172.7 a	1.4 e	1.0 g	1.6 b	0.7 e
Birecik	75.9 cd	45.9 b	35.0 a	35.4 a	15.9 a	71.0 bc	25.9 a	11.5 a	9.4 ab	5.2 bc
Skp	65.0 d	29.0 d	27.0 b	18.7 ab	17.9 a	53.9 bcd	13.4 c	8.5 d	6.6 ab	6.4 b
Cma	138.6 b	38.4 c	19.1 c	17.5 ab	14.6 ab	71.0 b	19.1 b b	11.0 b	10.2 a	8.1 a
Cmo	129.0 b	36.7 c	19.6 c	10.0 b	13.6 ab	63.2 bc	12.0 c	6.8 e	4.6 ab	5.2 bc
Frg	107.7 bc	54.4 a	34.2 a	17.3 ab	10.5 bc	44.6 cd	24.5 a	9.7 a	6.6 ab	4.2 cd
Bh	135.1 b	28.5 d	13.6 d	11.6 ab	8.8 bc	35.6 de	8.9 d	4.9 d	3.3 ab	3.2 d
Ct	62.2 d	19.0 e	17.3 c	13.0 ab	7.0 c	20.7 e	7.8 d	6.7 e	5.6 a	3.5 d
Significance level	***	***	***	***	***	***	***	***	**	***

*Values not associated with the same letter are significantly different.
**$P < 0.05$
***$P < 0.01$

transition from the control to 4 dS m^{-1} salt treatment. The greatest reduction in K^{+}/Na^{+} ratio was in Lcy, while the smallest reduction was observed in Skp. The reduction in the K^{+}/Na^{+} ratio was about 10-fold in all the gourd genotypes, except Lcy, while it was 6-fold in Ct. Watermelon had a higher K^{+}/Na^{+} ratio than Lcy and Bh, whereas it had a lower K^{+}/Na^{+} ratio than Cma, Cmo, Birecik, Skp, and Frg in response to the 4, 8, and 16 dS m^{-1} salt treatments. With the 12 dS m^{-1} salt treatment, Ct, Cmo, and Cma had a higher K^{+}/Na^{+} ratio than the other gourd genotypes.

Correlation coefficients between total dry weight and leaf Na^{+} concentration, and between Ca^{2+}/Na^{+} and K^{+}/Na^{+} ratios were separately calculated for each genotype under salinity stress conditions (Table 4). Total dry weight and Ca^{2+}/Na^{+} ratios were significantly correlated in all genotypes. The correlation coefficient was lower in Cma than in the other genotypes, and was significant at the 0.05 significance level. Similarly, significant positive correlations were observed between total dry weight and K^{+}/Na^{+} ratio. In contrast, a significant negative correlation was noted between leaf Na^{+} concentration and total dry weight of the genotypes. Total dry weight significantly decreased as leaf Na^{+} concentration increased.

Discussion

Gourd genotypes and watermelon with different growing characteristics were significantly affected by salt stress, and had different responses in terms of plant growth and ion regulation. Total dry weight decreased by different rates in each genotype with salt application. The genotypes most affected by salt treatment were Lcy and Bh, while the least affected were Cma and Cmo. *Cucurbita* and *Lagenaria* genotypes had better performance than watermelon under saline conditions, with regard to shoot dry weight. The results obtained with the *Cucurbita* genotypes are in agreement with previous work on crops under salt stress. Watermelon was reported to be more susceptible to salt stress than pumpkin and squash (Kotuby-Amacher et al., 2000). Furthermore, it was reported that *Lagenaria* species had higher tolerance to salinity stress than watermelon, while Lcy and Bh showed lower tolerance than watermelon in the present study. Salt stress had remarkable effects on plant growth parameters. High foliar concentration of Na^{+} is capable of reducing CO_2 assimilation because of ionic toxicity (Cachorro et al., 1993). Reduction in plant fresh and dry weights in response to salt stress has been reported for other crops, such as melon (Sivritepe et al., 2005),

Table 4. Correlation coefficients between total dry weight, and $Ca^{2+}/Na+$ and K^+/Na^+ ratios, and Na^+ concentration of the leaves of watermelon and different gourds after 30 days of different salt concentrations.

Genotypes	Ca^{2+}/Na^+	K^+/Na^+	Na^+
L. cylindrica	0.719***	0.718***	–0.766***
	0.003	0.000	0.000
Birecik	0.925***	0.866***	–0.913***
	0.000	0.000	0.000
Skp	0.806***	0.758***	–0.980***
	0.000	0.001	0.000
C. maxima	0.548**	0.538**	–0.840***
	0.035	0.039	0.000
C. moschata	0.777***	0.726***	–0.959***
	0.001	0.002	0.000
FRGold	0.910***	0.898***	–0.946***
	0.000	0.000	0.000
B. hispida	0.856***	0.827***	–0.919***
	0.000	0.000	0.000
Crimson Tide	0.856***	0.872***	–0.919***
	0.000	0.000	0.000

The first number in the cell is the correlation coefficient, the second number is the P value and significance level (**$P \leq 0.05$, ***$P \leq 0.01$, n= 15).

cucumber (van de Sanden and Veen, 1992), strawberry (Awang et al., 1993), tomato (Dasgan et al., 2002), eggplant (Chartzoulakis and Loupassaki, 1997), pepper (Chartzoulakis and Klapaki, 2000), and broad bean (de Pascale and Barbieri, 1997). As salt stress increases, plants show the following responses: a reduction in shoot and leaf dry mass, a decrease in leaf area and size, and a decrease in shoot length (de Pascale and Barbieri, 1997). It has been reported that salinity causes several kinds of injury, such as growth inhibition (Carvajal et al., 1998), metabolic disturbances (del Amor et al., 2000), and reduction in yield and quality (del Amor et al., 1999); however, the severity of salt damage has been reported to be dependent on cultivars, level of salinity, duration of salinity stress, and plant developmental stage (Botia et al., 1998; Carvajal et al., 1998; del Amor et al., 1999). Results of the present study agree with those of previous studies in that the effects of salinity on plant growth parameters differed according to plant genotype and salt concentration.

Root dry weight was significantly affected by genotypes and salinity levels. It has been widely reported that shoot growth of non-halophytes is generally more sensitive to salinity than root growth (Lauchli and Epstein, 1990). There was an increase in root dry weight in Cma and Cmo up to the 8 dS m^{-1} salt treatment, and in Br only at the 4 dS m^{-1} treatment, whereas the other gourd genotypes and watermelon had reduced root dry weight in response to all salinity levels, as compared to the control treatment. The observed reductions in root dry weight were not as severe as those seen in shoot dry weight. The slight increase in root dry weight in Cma, Cmo, and Birecik in response to moderate salinity could be thought of as an adaptation mechanism of the plants that alleviated the deleterious effects of salinity by increasing the water absorbing root surface area. The absorption capacity of roots is a significant factor related to salt tolerance, as it depends on the capability of roots to uptake water, and to restrict Na^+ and Cl^- transport to shoots or to control Na^+ concentration in the xylem sap (Durand and Lacan, 1994).

Na^+ concentration showed a remarkable increase in all the genotypes with salt application. Increased Na^+ concentration in plant tissues is one of the primary plant responses to salinity (Shachtman and Munns, 1992; Sivritepe et al., 2005). It is evident that salt tolerance is associated with low uptake of Na^+ (Santa-Maria and Epstein, 2001; Tester and Davenport, 2003), partial exclusion (Shachtman et al., 1989; Tester Davenport, 2003), and compartmentalization of salt in plant cells (Flowers and Yeo, 1986). Na^+ concentrations in the genotypes were significantly different in the present study. The highest Na^+ concentration was observed in Lcy, which was the genotype most susceptible to salinity. The only toxic effect of salt observed in Lcy was scorching of leaves. A strong negative correlation was observed between Na^+ concentration and plant growth parameters in all the gourd genotypes. The *Cucurbita* and *Lagenaria* genotypes used in the present study accumulated less Na^+ in leaves than Lcy, Bh, and watermelon in response to the 4 and 8 dS m^{-1} salt treatments, but Na^+ accumulation also increased in *Cucurbita* and *Lagenaria* genotypes above the 8 dS m^{-1} salinity level. It may be concluded that *Cucurbita* and *Lagenaria* were able to restrict Na^+ uptake, as compared to watermelon, Lcy, and Bh, at moderate salinity levels. A strong negative correlation was observed between Na^+ concentration and plant growth parameters in response to all treatments.

Calcium concentration increased as salt concentration increased in all the gourd genotypes and watermelon, except Lcy. Higher leaf Ca^{2+} concentration in the *Cucurbit* and *Lagenaria* genotypes, and watermelon grown under saline conditions exhibited similar patterns as those reported by Navarro et al. (2000). Ca^{2+} accumulation in plant tissues suggested that the higher Ca^{2+} concentration in the plants might be a factor involved in conferring salt tolerance. In addition, recent studies showed that increased Ca^{2+} concentration in melon plants challenged with salinity stress could ameliorate the inhibitory effects of salinity stress on plant growth (Navarro et al., 2000; Kaya et al., 2003).

The Ca^{2+}/Na^+ ratio also significantly decreased under salt stress and was affected by genotypes; all genotypes had higher ratios than watermelon, except Lcy and Bh, which were the 2 genotypes most susceptible to the salt treatments. It is well known that the toxic effects of Na^+ can be ameliorated by increasing the Ca^{2+} concentration of the growth medium. Although the effects of Ca^{2+} are likely to be more complex (Cramer, 2002), plants may be protected from Na^+ toxicity due to inhibition of excessive Na^+ accumulation into roots and shoots (Cachorro et al., 1994; Porcelli et al., 1995). This reduction in Na^+ accumulation is due to partial inhibition of the unidirectional influx of Na^+ into roots by Ca^{2+} (Tester and Davenport, 2003). The Ca^{2+}/Na^+ ratio and plant dry weight were significantly correlated in the present study.

Under salinity stress, K^+ concentration increased as the salt level increased, except in Lcy; K^+ concentration in Lcy decreased with increasing salinity. Gourd genotypes with higher dry matter values had higher concentrations of K^+ under saline conditions; therefore, maintenance of K^+ selectivity in gourd species with more dry matter could be a strategy used by those plants for improving their salt tolerance. Regarding K^+ selectivity in growing leaves, salt-tolerant tomato plants showed a similar strategy (Cayuela et al., 2001).

K^+/Na^+ ratios significantly decreased under saline conditions. Lcy and Bh had lower K^+/Na^+ ratios than watermelon and the other gourd genotypes. The K^+/Na^+ ratio was significantly correlated with plant dry weight. Similar findings were reported for tomato (Romero-Aranda et al., 2001), eggplant (Chartzoulakis and Loupassaki, 1997), bean (Bayuelo-Jiménez et al., 2003), melon (Botia et al., 1998), and pepper (Chartzoulakis and Klapaki, 2000) grown under different degrees of salinity stress. In fact, it is possible that a high K^+/Na^+ ratio is more important to many species than simply maintaining a low concentration of Na^+ and that much of Na toxicity is due to competition with K^+ (Tester and Davenport, 2003).

The results of the present study show that plant growth and ion regulation of the gourd genotypes and watermelon were significantly different under saline conditions. The most affected gourd genotypes were Lcy and Bh. They produced the lowest shoot and root dry weight, and had lower Ca^{+2}/Na^+ and K^+/Na^+ ratios. The *Lagenaria* and *Cucurbita* genotypes produced higher shoot and root dry weight than watermelon. The highest shoot and root dry weight was observed in Cma. In general, the *Lagenaria* and *Cucurbita* genotypes had a higher ratio of Ca^{+2}/Na^+ and K^+/Na^+ than watermelon. Previous studies showed that grafting onto salt-tolerant rootstocks improved salt tolerance-related characteristics in watermelon (Chung et al., 2003; Zhang et al., 2004; Yang et al., 2005, Colla et al., 2007), cucumber (Yang et al., 2006), tomato (Zhang et al., 2006), and eggplant (Wei et al., 2007). It may be concluded that Lcy and Bh might not have rootstock potential for watermelon under saline conditions. On the other hand, *Lagenaria* and *Cururbita* species seemed to have rootstock potential for improving salt-tolerance characteristics in watermelon. Future studies should investigate the responses of gourd genotypes that have more tolerance to salt stress as rootstocks for watermelon.

Acknowledgements

This study was supported by the Research Fund of Mustafa Kemal University.

References

Awang, Y.B., J.G. Atherton and A.J. Taylor. 1993. Salinity effects of strawberry plants grown in rockwool I. Growth and leaf water relations. J. Hort. Sci. 68: 783-790.

Bayuelo-Jiménez, J.S., D.G. Debouck and J.P. Lynch. 2003. Growth, gas exchange, water relations, and ion composition of *Phaseolus* species grown under saline conditions. Field Crop. Res. 80: 207-222.

Bonhert, H.J. and R.G. Jensen. 1996. Metabolic engineering for increased salt tolerance the next step. Aust. J. Plant Physiol. 23: 661-666.

Botia, P., M. Carvajal, A. Cerda and V. Martinez. 1998. Responses of eight *Cucumis mole* cultivars to salinity during germination and early vegetative growth. Agronomie 18: 503-513.

Cachorro, P., A. Ortiz and A. Cerda. 1993. Growth, water relations and solute compositions of *Phaseolus vulgaris* L. under saline conditions. Plant Sci. 95: 29-32.

Cachorro, P., A. Ortiz and A. Cerda. 1994. Implication of calcium nutrition on the response of *Phaseolus vulgaris* L. to salinity. Plant Soil. 159: 205-221.

Carvajal, E., F.M. del Amor, G. Fernandez-Ballester, V. Martinez and A. Cerda. 1998. Time course of solute accumulation and water relations in muskmelon plants exposed to salt during different growth stages. Plant Sci. 138: 103-112.

Cayuela, E., M.T. Estan, M. Parra, M. Caro and M.C. Bolarin. 2001. NaCl pre-treatment at the seedling stage enhances fruit yield of tomato plants irrigated with salt water. Plant Soil. 230: 231-138.

Chartzoulakis, K. and G. Klapaki. 2000. Response of two greenhouse pepper hybrids to NaCl salinity during different growth stages. Sci. Hortic. 86: 247-260.

Chartzoulakis K. and M.H. Loupassaki. 1997. Effects of NaCl salinity on germination, growth, gas exchange, and yield of greenhouse eggplant. Agric. Water Manage. 32: 214-225.

Chung, H., T. Ryu, Y. Choi. 2003. Selection of salt-tolerant bottle gourd (*Lagenaria siceraria*) rootstock for watermelon graft. J. Korean Soci. Hortic. Sci. 44: 588-594.

Colla, G., Y. Rouphael, M. Cardarelli, O. Temperini, S. Fanasca, F. Pierandrei, A. Salerno and E. Rea. 2007. Salt tolerance and mineral relations for grafted and ungrafted watermelon plants grown in NFT. Acta Hortic. 747: 243-247.

Cramer, G.R. 2002. Sodium-calcium interaction under saline stress. In: Salinity. Environment-Plants-Molecules. (Eds.: A. Lauchi and U. Lüttge) Dordrecht: Kluwer, pp. 205-227.

Cuartero, J. and R. Fernandez-Munoz. 1999. Tomato and salinity. Sci. Hortic. 78: 83-125.

Dasgan, H.Y., H. Aktas, K. Abak and I. Cakmak. 2002. Determination of screening techniques to salinity tolerance in tomato and investigation of genotypes responses. Plant Sci. 163: 695-703.

de Pascale, S. and G. Barbieri. 1997. Effects of salinity and top removal on growth and yield of broadbean as a green vegetable. Sci. Hortic. 71: 147-165.

del Amor, F.M., V. Martinez and A. Cerda. 1999. Salinity duration and concentration affect fruit yield and quality and growth and mineral composition of melon plants grown in perlite. HortScience 34: 1234-1237.

del Amor, F.M., M.C. Ruiz-Scanchez, V. Martinez and A. Cerda. 2000. Gas exchange, water relations, and ion concentrations of salt-stressed tomato and melon plants. J. Plant Nutr. 23: 1315-1325.

Durand, M. and D. Lacan. 1994. Sodium partitioning within the shoot of soybean. Physiol. Plant. 91: 65-71.

Flowers, T.J. and A.R. Yeo. 1986. Ion regulation of plants under drought and salinity. J. Plant Physiol. 13: 75-91.

Fooland, M.R. 1996. Genetic analysis of salt tolerance during vegetative growth in tomato, *Lycopersicon esculentum* Mill. Plant Breeding. 115: 245-250.

Jacoby, B. 1994. Mechanisms involved in salt tolerance by plants. In: Pessarakli, M. (Ed), Handbook of plant and crop stress. Marcel Dekker, New York, pp, 97-123.

Kaya, C., D. Higgs, H. Kirnak and I. Tas. 2003. Ameliorative effects of calcium nitrate on cucumber and melon plants drip irrigated with saline water. J. Plant Nutr. 26: 1665-1681.

Kotuby-Amercher, J. Koing, R. and Kitchen, B. 2000. Salinity and plant tolerance, Utah State University Extension Publ. AG-SO-03, 1-8.

Lauchli, A. and E. Epstein. 1990. Plant responses to saline and sodic conditions. In: Agricultural Salinity Assessment and Management. (Ed.: K.K. Tanji). Vol. 71, *ASCE* Manuals and Reports on Engineering Practice, American Society of Civil Engineers, New York, pp. 113-137.

Lee, J.M. 1994. Cultivation of grafted vegetables I. Current status, grafting methods and benefits. HortScience. 29: 235-239.

Marschner, H. 1995. Saline soil in: mineral nutrition of higher plants, Academic Press, New York, 657-680 pp.

Navarro, J.M., M.A. Botella, A. Cerda and V. Martinez. 2000. Effect of salinity calcium interaction on cation balance in melon plants grown under two regimes of orthophosphate. J. Plant Nutr. 23: 991-1006.

Oda, M. 1995. New grafting methods for fruit-bearing vegetables in Japan. Jpn. Agr. Res. Q. 29: 187-198.

Porcelli, C.A., F.H. Gutierrez Boem, R.S. Lavado. 1995. The K/Na and Ca/Na ratios and rapeseed yield, under soil salinity and sodicity. Plant Soil. 175: 251-255.

Romero, L., A. Belakbir, L. Ragala and J.M. Ruiz. 1997. Responses of plant yield and leaf pigments to saline conditions: effectiveness of different rootstocks in melon plants (*Cucumis melo* L.). Soil Sci. Plant Nutr. 43: 855-862.

Romero-Aranda, R., T. Soria and J. Cuartero. 2001. Tomato plant-water relationship under saline growth conditions. Plant Sci. 160: 828-830.

Rus, A.M., M.T. Estan, C. Gisbert, B. Garcia-Sogo, R. Serrano, M. Caro, V. Moreno and M.C. Bolarin. 2001. Expressing the yeast Hal1 gene in tomato increases fruit yield and enhances K^+/Na^+ selectivity under salt stress. Plant Cell Environ. 24: 875-880.

Santa-Cruz, A., M.M. Martinez-Rodriguez, F. Perez-Alfocea, R. Romero-Aranda and M.C. Bolarin. 2002. The rootstocks effect on the tomato salinity response depends on the shoot genotype. Plant Sci. 162: 825-831.

Santa-Maria, G.E. and E. Epstein. 2001. Potassium/sodium selectivity in wheat and amphiploid cross wheat *Lophopyrum elongatum*. Plant Sci. 160: 523-534.

Shachtman, D.P. and R. Munns. 1992. Sodium accumulation in leaves of *Triticum* species that differ in salt tolerance. Aust. J. Plant Physiol. 9: 331-340.

Shachtman, D.P., A.J. Blum and J. Dovrak. 1989. Salt tolerant *Triticum Lophopyrum* derivatives limit the accumulation of sodium and chloride ions under saline stress. Plant Cell Environ. 12: 47-55.

Singh, S. and M. Singh. 2000. Genotypic basis of response to salinity in some crosses of spring wheat *Triticum aestivum* L. Euphytica. 115: 209-219.

Sivritepe, H.O., N. Sivritepe, A. Eris and E. Turhan. 2005. The effects of NaCl pre-treatments on salt tolerance of melons grown under long-term salinity. Sci. Hortic. 106: 568-581.

Sykes, S.R. 1992. The inheritance of salt exclusion in woody perennial fruit species. Plant Soil, 146: 123-129.

Tester, M. and R. Davenport. 2003. Na^+ tolerance and Na^+ transport in higher plants. Ann. Bot. 91: 503-527.

van der Sanden P.A.C.M. and B.W. Veen. 1992. Effects of air humidity and nutrient solution concentration on growth, water potential and stomatal conductance of cucumber seedlings. Sci. Hortic. 50: 173-186.

Walker, R.R. 1986. Sodium exclusion and potassium selectivity in salt treated Trifoliate orange (*Poncirus trifoliate*) and Cleopatra mandarin (*Citrus reticulate*) plants. Aust. J. Plant Physiol. 13: 193-303.

Wei, G., Y. Zhu, Z. Liu, L. Yang and G. Zhang. 2007. Growth and ion distribution in grafted eggplant seedling under NaCl stress. Acta Botanica Boreali-Occidentalia Sinica 27: 1172-1178.

Yang, L., Y. Zhu, C. Hu, G. Zhang and Z. Liu. 2005. Studies on growth trends, physiology and biochemical characteristics in hydroponically-grown grafted watermelon under NaCl stress. Southwest China J. Agric. Sci. 18: 439-443.

Yang, L., Y. Zhu, C. Hu, Z. Liu and G. Wei. 2006. Effects of salt stress on biomass formation and ion partition in hydroponically-cultured grafted cucumber. Acta Botanica Boreali-Occidentalia Sinica. 26: 2500-2505.

Yetisir, H. and N. Sari. 2003. Effect of rootstock on plant growth, yield and quality of watermelon. Aust. J. Exp. Agric. 43: 1269-1274.

Yetişir, H. and N. Sarı. 2004. Effect of hypocotyls morphology on survival rate and growth of watermelon seedling grafted on rootstocks with different emergence performance at various temperatures. Turk. J. Agric. For. 28: 231-237.

Zarcinas, B.A., B. Cartwright and L.P. Spouncer. 1987. Nitric acid digestion and multi-element analysis of plant material by inductively coupled argon plasma spectrometry. Commun. Soil. Sci. Plan. 18: 131-147.

Zhang, Y., S. Liu and H. Wang. 2004. Effect of salt-tolerant stock grafting on the salt-tolerant characteristics of watermelon. Acta Hortic. 20: 62-64.

Zhang, G., Y. Zhu, L. Yang, Z. Liu and C. Hu. 2006. Effect of NaCl stress on the biomass and ion contents in grafted tomato seedlings. Acta Botanica Boreali-Occidentalia Sinica. 26: 2069-2074.