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Impact of Salt-tolerant Rootstock on the Enhancement of Sensitive Tomato Plant Responses to Salinity

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Abstract. **In the present study, salt-tolerant (Tom 174) and sensitive (Tom 121) tomato genotypes were grafted onto their own roots (174/174 and 121/121), and a susceptible genotype was also grafted onto tolerant genotype 121/174. The grafted plants were grown under 50 mM NaCl and control conditions in a greenhouse. Plant physiological parameters, fruit yield, and physical measurements of fruit (e.g., weight, height, diameter, volume), and chemical analysis of fruit (e.g., vitamin C, pH, and total dry matter content) were investigated. When the sensitive genotype was grafted onto tolerant genotype 121/174, the tolerant genotype Tom 174 reduced the yield loss of susceptible genotype from 44% to 3%. Also, fruit size, total dry matter content, and vitamin C increased, while pH decreased under saline conditions. The rootstock Tom 174 seemed to be able to control sensitive scions' stomatal openness and closure for transpiration and CO_2 transition on photosynthesis because dry matter content was increased. It was found that the tolerant genotype played a role in ameliorating leaf osmotic adjustment of the sensitive genotype in grafting under salt stress. The combination 121/174 had the lowest Na^+ concentration in young leaves. Thus, the tolerant rootstock Tom 174 decreased the transport of accumulation of Na^+ ions to young leaves in this grafting combination.**

Many crops worldwide are exposed to cultivation under suboptimal conditions with the effects of climate change (Luterbacher et al., 2006). These effects create environmental stresses, which are the primary cause of crop losses, and this is will be of increasing importance given proposed climate change scenarios (Ray, 2015). Adverse climate conditions (e.g., low rainfall, high evaporation) and inappropriate agronomic management (e.g., poor water management and indiscriminate use of chemical fertilizers) have increased the rhizosphere concentration of salts in recent decades (Mahjan and Tuteja, 2005). In this respect, salinity is one of the abiotic stress factors that cause reduced crop productivity, plant growth, fruit quality, and fruit yield in tomato. Although cultivated tomato (*Solanum lycopersicum*) has a high ability to adapt to various climate conditions, it is sensitive to moderate levels of salt in soil or irrigation water. The adverse effects of salinity stress on crops are related to two main factors (Dasgan et al., 2002). First, osmotic stress occurs through the accumulation of high solute concentrations (Na^+ and Cl^-) in the rooting zone; thus, plant water uptake is decreased, and openness of stomatal and transpiration rate is also affected. The second factor is ion toxicity due to high ion concentrations in solution (Na^+ and Cl^-). Some wild tomato species have been used to improve and characterize salt tolerance in traditional breeding programs, but because the genetic complexity of the salt tolerance mechanism is complicated, alternative strategies are necessary (Cuartero et al., 2006; Foolad, 2007). Grafting is a potentially useful and desirable tool to preserve tomato productivity under adverse conditions (Colla et al., 2010; Estañ et al., 2005; Fernández-Garcia et al., 2004). Grafting tomato provides advantages by combining genotypes that have high yield or high quality but are sensitive to salinity stress with rootstocks that have higher plant vigor and are able to ameliorate salt stress (Bolarin et al., 1991; Estañ et al., 2009; Ghanem et al., 2011). The use of salt-tolerant genotypes as rootstock has been suggested as a useful approach to enhance salt tolerance in tomato (Cuartero et al., 2006).

In this work, two tomato genotypes, one salt tolerant and the other salt sensitive, were selected and tested in a grafting combination of tolerant rootstock and sensitive scion under saline conditions to attempt to alleviate salt damage in susceptible tomato.

Materials and Methods

Plant material. This study included two tomato genotypes: Tom 174, which is tolerant of salt stress, and Tom 121, which is sensitive to salt stress. Their responses to salinity stress are known from previous studies (Dasgan et al., 2010, 2018). Both of the genotypes were grafted onto their own roots (174/174, 121/121), and Tom 121 was grafted onto Tom 174 (121/174).

Grafting conditions. Seeds of the genotypes were sown into a mixture of perlite and peatmoss (1:2) in a growth chamber under optimal growth conditions; day/night temperature 23 °C/18 °C, relative humidity 65%/70%, 16-h photoperiod, and photon flux density 300 $\mu mol \cdot m^{-2} \cdot s^{-1}$. Thirty days after germination, two genotypes were grafted with the splice-tube method, and grafting polyester slips were used to hold rootstocks and scions together. In the growth chamber, grafted tomato plants were placed under a transparent plastic cover for 10 days to increase the relative humidity and avoid the water loss from leaves. Sixteen days after grafting, plants of three graft combinations were transplanted to cocopeat, which is an organically grown medium of soilless culture for a glass greenhouse.

Plant growing in the greenhouse. The experiment was carried out in greenhouse soilless culture conditions during the spring to early summer season (February to June) in the research fields of the Department of Horticulture, Agricultural Faculty, Cukurova University, in Adana, Turkey.

The experiment was set in a randomized complete block design with four replicates, and 10 plants for each replicate were grown to analyze tomato yield and fruit quality.

Nutrient solution and saline conditions. The greenhouse was equipped with an automatically regulated irrigation and fertilization system. For the control nutrient solution (0 mM NaCl), macronutrient concentrations ($mg \cdot L^{-1}$) of irrigation water were 150 nitrogen, 50 phosphorus, 300 potassium, 50 magnesium, and 120 calcium. The micronutrient concentrations ($mg \cdot L^{-1}$) were 5 iron, 2 manganese, 0.25 zinc, 0.7 boron, 0.07 copper, and

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0.05 molybdenum. Salt treatment had the same nutrient solution with the addition of 50 mM NaCl. The electrical conductivity (EC) of the control nutrient solution was between 1.8 and 2.4 $dS \cdot m^{-1}$, and EC of the saline nutrient solution was between 5.0 and 5.5 $dS \cdot m^{-1}$. The pH of both nutrient solutions was ≈5.5–6.0. Salt treatment was applied to the grafted plants 43 d after transplantation until the end of the experiment, and thus the plants were exposed to salinity over 68 d.

Fruit harvest and yield. Tomato fruits that were sufficiently red and ripe were harvested four times during ≈2 months (May and June). The first harvest was on 20 May (82 d after transplanting), the second harvest was on 26 May (88 d after transplanting), the third harvest was on 8 June (100 d after transplanting), and the experiment was completed with the last harvest on 16 June (108 d after transplanting). The weight and the total number of harvested fruits were recorded on each harvest to calculate for the mean weight of fruits (g) and total fruit yield (kg/plant). Ten tomato fruits from each replication were collected for pomology and analyzed during the second harvest.

Fruit quality analysis. Fruit height (mm), fruit diameter (mm), and fruit volume (cm^3) were measured for 10 fruits per replicate per treatment in each graft combination. A digital compass (500-181-30; Mitutoyo, Kanagawa, Japan), which was sensitive to ±0.1 mm, was used to measure fruit height and diameter of tomatoes, and the mean values were calculated. For fruit volume, the fruit was put in a container that was measured and filled with water; the overflowing water was recorded. Fruit fresh weight was taken to calculate the total dry matter content of tomatoes. After weighing, the fruits were divided into four pieces and put in a 65 °C oven until the dry weight reached a constant weight. When the fruits were completely dried, they were weighed with the balance (BG802-S; Mettler Toledo, Greifensee, Switzerland) that was sensitive ±0.01 g. Fruit fresh and dry weight data were used to calculate the % dry matter content of 100 g of fresh tomato fruit. Vitamin C of fruits was measured by using the spectrophotometric method (520 nm) as milligrams ascorbic acid/100 mL (Ozdemir and Dundar, 2006) (Lambda EZ201; Spectrophtometer Perkin Elmer, Shelton, CT). The fruits were pulped in a blender, and 1 g of pulp was sampled from each fruit. Forty-five milliliters of oxalic acid, at 0.4% concentration, was added to the pulp, mixed, and filtered, and then 9 mL of dye solution was mixed with 1 mL of filtered solution. The resulting solution was used to determine vitamin C content. The pH content of fruit juice was measured from ≈100 mL tomato juice by using a digital pH meter (Profline pH 3110; WTW, Weilheim, Germany).

Stomatal conductance. Stomatal conductance (g_S) in leaves of tomato plants was measured by using a portable porometer (AP4; Delta-T, Cambridge, UK). The measurement was done the day before the last harvest from the top third to fourth leaves of plants. The water vapor that enters through the stomata and total CO_2 gases were read as mmol. The data observed with the instrument were recorded in $mmol \cdot m^{-2} \cdot s^{-1}$.

Osmotic potential. Osmotic potential (ψ_S) was measured from the top fourth to fifth leaves of the plants. To determine the osmolality (c), 1 g of fresh weight from fully expanded leaves was homogenized in a mortar and mixed with distilled water to reach a final volume of 20 mL. After extraction using a millipore filter, the sap was used to determine the osmolality using a freezing point osmometer (Osmomat 030; Gonotec, Berlin, Germany) (Akhoundnejad and Dasgan, 2018; Dasgan et al., 2018). The ψ_S was determined using the formula: ψ_S (MPa) = –c ($mOsmol \cdot kg^{-1}$) × 2.58 × 10^{-3}, according to the Van't Hoff equation (Silva et al., 2010).

Na^+ and Cl^- ion analysis of leaves and roots. Three plants were chosen randomly to conduct an ion analysis of young and old leaves and roots for both control and salt treatments. The leaves were washed three times with deionized water and put in a 65 °C oven for 48 h. Ground dried leaves weighing 200 mg were placed in glass bottles and burned at 550 °C for 5 h, and 3.3% of HCl acid was added to the resulting ashes. The solution was then filtered by using blue band filter papers. The Atomic absorption spectrophotometer (FS220; Varian, Santa Clara, CA) measured sodium (Na^+) ion content in the emission mode (Dasgan et al., 2018; Jones, 2001). The Cl concentration in tissue samples was determined using titrimetric analysis with silver nitrate ($AgNO_3$) with the Mohr method. Fifty milligrams of ground plant leaves were put into centrifuge tubes, 12.5 mL deionized water was added to the samples to centrifuge at 180 cycles for 45 min. Ten milliliters were taken from the solution after centrifuging and mixed with 0.5 mL potassium chromate (K_2CrO_4). The new solution was titrated with silver nitrate ($AgNO_3$). When the total Cl was settled as $AgCl_2$ and the color of the solution was light brown, titration was ended. Cl concentration was calculated with the following formula (Dasgan et al., 2018):

$$\text{Chloride}\,(\%) = (N - B)/A \times 100,$$

where N is the quantity of used silver nitrate in titration (mL), B is the quantity of used blank titration (mL), and A is the quantity of the plant sample used for analysis (g).

Statistical analysis of data obtained at the end of the experiment was conducted using the SAS-JMP/7 program. The averages were compared with the least significant difference test. Percentage changes in salinity stress relative to control were calculated.

Results and Discussion

The effects of rootstock on fruit yield. A significant difference in tomato fruit yield was observed between self-grafted plants of the two genotypes and the plants in combination (grafted 121 onto 174). Whereas self-grafted plants of salt-tolerant genotype 174 grown at 50 mM NaCl had an increase in fruit yield (16.6%) compared with the same graft combination plants grown at 0 mM NaCl, self-grafted plants of salt-sensitive genotype 121 had a decrease in fruit yield (44.4%) under the same salt level and control conditions compared with its own graft combination (Table 1). In contrast, when the salt-tolerant genotype was used as rootstock and the salt-sensitive genotype was used as a scion (121/174), the fruit yield was decreased by only 2.5% under saline conditions compared with control treatment plants. These results show that grafting contributed to an improvement in fruit yield under salt stress conditions. However, genotype 174, a salt-tolerant cherry tomato, reduced the fruit size of the 121 genotypes, probably because it is not a vigorous rootstock (Table 2). Grafted plants under saline conditions often showed better photosynthesis and higher leaf water content, higher accumulation of compatible compounds, and lower accumulation of Na^+ and Cl^- than ungrafted or self-grafted plants (Colla et al., 2010). Because of these alleviating effects, salt-sensitive tomato 121 was less affected when grafted onto the tolerant 174 than when grafted onto its own roots. Romano and Paratore (2001) stated that the dry weight of the above-ground vegetative organs of the grafted plants was higher than that of self-rooted plants. Di Giogia et al. (2013) investigated ungrafted tomato plants grafted onto two interspecific hybrids for 2-year experiments; it was shown that the yield was higher when the cultivar was grafted onto rootstocks. Savvas et al. (2011) also reported that the yield change is related to rootstock and salt stress levels. Estañ et al. (2005), who worked with different tomato grafting combinations (different scion/rootstock), reported that salt tolerance changed at different salt levels. In their study, they used commercial hybrid cultivar Jaguar as scion

Table 1. Fruit yield of grafting combinations: a salt-sensitive tomato genotype (121) was grafted onto a tolerant genotype (174) and their own roots. Plants were grown for 108 d in the greenhouse and exposed to salinity during the last 68 d. Tom 174 was a cherry tomato genotype.

Grafting combination	Control (g/plant)	Salt stress (g/plant)	Change (%)[z]
121/174	4057 b	3954 a	–2.5
174/174	1304[y] c	1520[y] b	16.6[y]
121/121	7332 a	4078 a	–44.4
$LSD_{0.05}$	694.25	634.91	—

[z]Changes relative to control, 121/174 (scion/rootstock). 121: salt susceptible 174: salt tolerant.
[y]Cherry tomato.
Data show means of four independent replications, and each replicate contained 10 plants. Values with the same letter are not significantly different. LSD = least significant difference.

Table 2. Tomato fruit physical parameters of grafting combinations and change percentages under salt stress relative to control.

	Fruit wt (g)			Fruit ht (mm)			Fruit diam (mm)			Fruit vol (cm^3)		
Grafting combination	Control	Salt	Change[z]	Control	Salt	Change[z]	Control	Salt	Change[z]	Control	Salt	Change[z]
121/174	62.3 b	64.4 b	3.4	38 b	44 a	16	50 b	48 b	–4.0	51 b	67 a	31
174/174	24.3[y] c	16.6[y] c	–32	28[y] c	23[y] b	–18	39[y] c	30[y] c	–23	38[y] b	22[y] b	–42
121/121	106.3 a	85.3 a	–20	51 a	43 a	–16	61 a	54 a	–11	123 a	91 a	–26
$LSD_{0.05}$	8.63	14.67	—	7.40	4.99	—	7.10	4.88		41.51	23.92	—

[z]Changes in salinity relative to control (%), 121/174 (scion/rootstock); 121 = salt susceptible, 174 = salt tolerant.
[y]Cherry tomato.
Data show means of four independent replications, and each replicate contained 10 fruits. Values with the same letter are not significantly different. LSD = least significant difference.

Table 3. Tomato fruit chemical parameters for grafting combinations and change percentages under salt stress relative to control.

	Dry matter content (%)			Vitamin C (mg/100 g)			pH		
Grafting combination	Control	Salt	Change[z]	Control	Salt	Change[z]	Control	Salt	Change[z]
121/174	5.74 b	8.41 b	47	20.17 c	22.42	11	4.23 b	4.31 b	1.9
174/174	8.12 a	11.07 a	36	21.70 b	22.57	4.0	4.52 a	4.46 a	–1.3
121/121	6.24 ab	7.38 c	18	23.66 a	22.71	–4.0	4.30 b	4.28 b	–0.5
$LSD_{0.05}$	1.97	0.51	—	1.08	NS	—	0.06	0.06	—

[z]Changes in salinity relative to control (%), 121/174 (scion/rootstock); 121 = salt susceptible, 174 = salt tolerant.
Data show means of four independent replications, and each replicate contained five fruits. Values with the same letter are not significantly different. NS = nonsignificant; LSD = least significant difference.

and salt-tolerant genotype Radja (excluder) and Pera (ion includer) at 0, 25, 50, and 75 mM NaCl levels. They demonstrated that fruit yield is higher at high salt stress levels, and it is affected by rootstock. It was observed that grafting influences sensitive tomato fruit yield. Thus, we may conclude that grafting can be an alternative method to improve plant productivity under salt stress conditions. In this study, although the yield loss was 44.4% for the self-grafted genotype 121, yield loss was only 2.5% for 121 grafted onto 174 under saline conditions. This means that the use of tolerant rootstock may improve the productivity of sensitive genotypes when plants are exposed to salinity.

Fruit quality. Mean fruit weight was affected negatively by salinity on self-grafted plants of both tolerant and sensitive genotypes. Weight loss of 174/174 and 121/121 was 32% and 20%, respectively; in contrast, 121 grafted onto 174 plants had an increase of 3.4% under the same salt level compared with control treatment plants. Because the tolerant genotype 174 is a cherry tomato that has small fruits, the fruit weight decrease was higher than the self-grafted genotype 121, but it was observed that the rootstock enhanced the fruit weight of the scion (Table 2). Salt stress influenced tomato fruit height, fruit diameter, and fruit volume (Table 2). Fruit height was increased by 16% when 121 was grafted onto 174. However, the height of fruits was decreased by 18% and 16% for two fruits of self-grafted combinations, which are 174/174 and 121/121, respectively. Under salt treatment, fruit diameter was decreased for all three graft combinations. The highest decrease of 23% was seen in the fruits of 174/174 self-grafted plants (Table 2). Even when the highest reduction was observed for the genotype 174 with its rootstock, a positive effect induced by rootstock 174 alleviated the 11% decline of the scion 121 to a 4% decline in the combination of 121/174 (Table 2). For fruit volume, prominent differences were found between self-grafted plants of both genotypes and 121 grafted onto 174. Salinity affected fruit volume of self grafted 174 and 121 negatively by 42% and 26%, respectively, yet there was an increase of 31% on 121/174 (Table 2). Wahb-Allah (2014) investigated the influence of grafting on salt and drought tolerance of tomato. Experiments over two seasons were carried out with two hybrid cultivars, Farida and Unifort; results showed that mean total fruit weight and total yield were increased from 13.1% to 17.4% under abiotic stress conditions. Other studies are in agreement with the positive effect of grafting on fruit size, number (Echevarrira et al., 2012; Turhan et al., 2011), and weight (Rouphael et al., 2010).

Total dry matter content was significantly increased under salinity stress conditions in all graft combination fruits. The highest increased percentage compared with plants that were grown under the control condition was 47% in the fruits of 121 grafted onto 174. In addition, the total dry matter content of self-grafted plants was also increased although at a lower percentage by 36% and 18%, respectively (Table 3). Plaut et al. (2004) investigated the effects of drought and salt stresses on tomato fruits and showed that total dry weight increased by 10% to 15% under saline conditions; this increase resulted from less water transport to the fruits. Bertin et al. (2000) found that total tomato dry matter content and volume were produced independently; for instance, whereas fruit size was influenced by fruit number, it was unaffected by total dry matter content. However, Guichard et al. (2001) reported that the change of total dry matter content might not be explained by fruit size and climate conditions alone. An effect of using tolerant genotype 174 as a rootstock was found on vitamin C content of fruit when sensitive genotype was grafted onto tolerant genotype. The graft combination 121/174 showed the highest content, increasing by 11% under saline conditions (Table 3). The fruits of self-grafted 174 plants had a 4% increase in vitamin C content; in contrast, self-grafted 121 plants had a 4% decrease (Table 3). These results are in agreement with Veit-Köhler et al. (1999), who reported that sugar, titratable acidity, and vitamin C content were increased under water-deficit conditions. Nair et al. (2008) showed that drought stress affected the quantity of ascorbic acid in black-eyed pea, and it has emerged in a tolerant genotype. Salinity also affected the pH of tomato fruit juice differently among graft combinations. The combination of the sensitive genotype grafted onto the tolerant genotype showed an increase in pH by 1.9% under the saline condition, whereas self-grafted 174 and 121 plants decreased by 1.3% and 0.5%, respectively (Table 3).

Stomatal conductance. Significant differences in leaf g_S were observed between self-grafted genotypes and the sensitive genotype grafted onto the tolerant genotype. When genotype 174 was grafted onto its own root (174/174) and the susceptible genotype was grafted onto the tolerant genotype (121/174), g_S decreased by 68% and 31%, respectively, under salt stress (Table 4). The self-grafted plants of 121 had an increase of 37%. The biggest change in g_S relative to control, which is observed in the plants of genotype 174, may control stomatal openness and closure because it is a tolerant genotype under saline conditions. Whereas self-grafted plants of the sensitive genotype 121 showed an increase (37%) in g_S under salt stress, the plants of 121 grafted onto 174 (121/174) showed a decrease (31%) (Table 4). However, the increase of g_S may cause high water to be lost through transpiration.

In contrast, it seems that the decrease in g_S in 121/174 was lower than the self-grafted plants of 174. Thus, the rootstock 174 was able to control its stomatal openness and closure for transpiration and CO_2 transition on photosynthesis because the dry matter

Table 4. Stomatal conductance (g_S) and osmotic potential (ψ_S) in leaves of tomato genotypes grafted on their own root and salt sensitive genotype (121) grafted onto tolerant genotype (174). Plants were grown for 108 d in the greenhouse and they were exposed to salinity during last 68 d.

	g_S (mmol·m^{-2}·s^{-1})			ψ_S (MPa)		
Grafting combination	Control	Salt	Change[z]	Control	Salt	Change[z]
121/174	169.25 a	117.25 b	–31	–0.242 b	–0.317 b	–31
174/174	121.25 b	39.25 c	–68	–0.271 a	–0.432 a	–60
121/121	101.25 c	138.75 a	37	–0.242 b	–0.274 c	–13
$LSD_{0.05}$	17.12	9.70	—	0.009	0.018	—

[z]Changes in salinity relative to control (%), 121/174 (scion/rootstock); 121 = salt susceptible, 174 = salt tolerant.
Data show means of four independent replications, and each replicate contained four plants. Values with the same letter are not significantly different. NS = nonsignificant; LSD = least significant difference.

Table 5. Compartmentation of Na and Cl concentrations of grafted plants grown under salt stress in the different plant organs (%).

	Na concn (%)			Cl concn (%)		
Grafting combination	Old leaves	Young leaves	Roots	Old leaves	Young leaves	Roots
121/174[z]	5.02 b	3.28 b	3.22	5.51	4.26	2.87
174/174	4.11 b	3.62 b	1.62	4.98	5.14	2.16
121/121	9.67 a	5.77 a	2.06	5.89	4.43	2.60
$LSD_{0.05}$	1.07	1.55	NS	NS	NS	NS

[z]121/174 (scion/rootstock); 121 = salt susceptible, 174 = salt tolerant.
Data show means of four independent replications, and each replicate contained four plants. Values with the same letter are not significantly different. NS = nonsignificant; LSD = least significant difference.

content was increased. Some researchers have reported that under saline conditions in grafted plants compared with ungrafted plants, a significant increase is observed for g_S; this could be related to high plant biomass (Fernández-Garcia et al., 2004). Plants that have constant stomatal data under drought condition are more tolerant of stress (Moriana and Fereres, 2002). Some problems of stomatal regulation include decreased transpiration, insufficient CO_2 accumulation, reduced shoot production, and reduced root biomass, which are symptoms observed under water-deficit conditions (Hsiao, 1973; Schulze, 1986).

Osmotic potential. Leaf ψ_S was decreased by salinity for all grafted plants. This may indicate that organic or inorganic matter was increased in cells for osmotic adjustment, which is essential for osmoregulation. The highest percentage decrease in ψ_S was 60% in leaves of self-grafted tolerant genotype plants, as expected (Table 4). Sensitive genotype 121 had the lowest percentage decrease by 13% in ψ_S; however, when 121 was grafted onto 174, which is tolerant to salinity, leaves showed a higher decrease percentage by 31%. It was found that the tolerant genotype played a role in enhancing leaf osmotic adjustment of the sensitive genotype. These data agree with Mugdal et al. (2010), who observed high soluble NaCl concentrations in soil and decreased the water uptake for plants. In this case, a typical response by plants is to reduce water potential and thereby increase soluble matter content; therefore, a balance occurs with decreasing in ψ_S under high salt levels. Martinez-Rodriguez et al. (2008) used a genotype that has an excluder character as a scion to investigate the effect of grafting under saline conditions. It was observed that the ψ_S was decreased by ≈60% when the genotype Moneymaker was grafted onto its roots and grafted onto genotype Radja (excluder). The Pera plant, which has ''includer'' character grafted onto Moneymaker, showed a higher decrease by 73%.

Mineral analysis. Na^+ and Cl^- concentrations were significantly increased in shoots and roots for all grafted plants under saline compared with control conditions. However, the combination 121/174 had the lowest Na^+ level in young leaves in all combinations. This indicates that the tolerant rootstock 174 decreased the transport of accumulation of Na^+ ions. Also, whereas Na^+ transport was highest in old leaves of self-grafted 121 plants, the transport was lower in 121/174 plants. The accumulation of Na^+ was higher in roots of 121/174 than other self-grafted plants. Therefore, it could be concluded that the plants controlled the transportation to the shoot and may be stored in the root (Table 5). The accumulation of Cl^- in young leaves of 121/174 was lowest in all graft combinations, even if the change percentage is high for all plants for osmoregulation (ion regulation) under saline conditions. The grafted plants of 121/121, which is the salt-sensitive genotype, had the highest accumulation in old leaves; the salt-tolerant genotype 174 decreased the Cl^- transport to the old leaves of 121/174 (Table 5). In the roots of 121/174, Na^+ was highest, and it may be an excellent option to prevent the ions from entering the shoot and thus reduce the effect of toxicity. Enhancing salt tolerance in grafted plants is based on including Na^+ in leaves and excluding Na^+ in cell vacuoles (Albacete et al., 2009; Edelstein et al., 2011). Some rootstocks under salinity stress exhibit an ability to control shoot Na^+ partitioning between younger and older leaves and ensure higher K^+ to Na^+, Mg^{2+} to Na^+, and Ca^{2+} to Na^+ ratios in fruits, tips, and younger leaves of grafted compared with ungrafted plants. The effect of rootstocks in amelioration of salt tolerance for grafted plants through regulation or alleviation of Cl^- ion concentration in leaves is less effective compared with the Na^+ ion (Colla et al., 2006; Edelstein et al., 2011; Savvas et al., 2011). These studies are in agreement with our research, which showed that the partitioning of Na^+ and Cl^- was considerably higher when the grafted plants were exposed to salinity. Na^+ accumulation was lower than Cl^- accumulation in various graft combinations.

Conclusion

When 121 was grafted onto 174 (121/174), the tolerant genotype 174 enhanced the sensitive scion yield, fruit size, and some quality properties of fruit under saline conditions. As a result, we obtained higher fruit quality from 121/174 than 121/121, with the goal of creating more flavorful tomato fruit and contributing to better human health through its consumption. Salt-tolerant rootstocks such as Tom174 could be important in the context of climate change in saline areas to improve plant production in the agriculture and fruit properties and quality of tomato. Future studies should focus on the development of salt-stress-tolerant rootstocks, as well as grafting compatibility and physiology with scion combinations.

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