African Journal of Agricultural Research Vol. 7(41), pp. 5553-5557, 29 October, 2012
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.2448
ISSN 1991-637X © 2012 Academic Journals

Full Length Research Paper

The effect of grafting of five different rootstocks on plant growth and yield of tomato plants cultivated outdoors and indoors under salinity stress

Sotiria Voutsela[1], Garip Yarsi[2]*, Spyridon A. Petropoulos[1] and Ebrahim M. Khan[1]

[1]Department of Agriculture, Crop Production and Rural environment, School of Agricultural Sciences, University of Thessaly, Fytokou Street, N. Ionia, Volos 384 46, Greece.
[2]Department of Plant and animal Production, University of Adiyaman, Kahta-Adıyaman, Turkey, TR-02400.

Accepted 18 June, 2012

The effect of grafting technique on plant growth of tomato plants (*Lycopersicon esculentum* L. cv. Despina) cultivated under salinity stress, either self-rooted (P7) or grafted on to themselves (P6) and five different rootstocks (P1, P2, P3, P4 and P5) was examined. Plants were grown both indoors (heated glasshouse) and outdoors, whereas salinity stress was simulated by applying three levels of salinity [Contol (0.69 mS/cm), 3 and 6 mS/cm) on growth medium. The results of the study showed that grafted plants formed more fruit in total and had a higher total yield than self-rooted plants at the level of 6 mS/cm when grown indoors, whereas mean fruit weight was higher for P2, P5 and P6 combinations. For outdoor cultivation, scion × P1 and P2 combinations were superior to others at the level of 6 mS/cm, regarding total number of fruit and total yield, whereas mean fruit weight was higher for P5 combination. In conclusion, implementing grafting technique on tomato plants results in the formation of more internodes and therefore flowers, especially, for outdoor cultivation, whereas significant effects were observed on both total number and total weight of fruit for indoor cultivation. In addition, rootstock × scion combination has a significant effect on plant growth and yield and could be used as a useful means in order to alleviate problems that arise from salinity stress due to either lack of water or high salinity of irrigation water.

Key words: *Lycopersicon esculentum* L., grafting, salinity stress, rootstock, scion.

INTRODUCTION

Shortage of water for agricultural use is an ever-growing problem in many areas of the world, mainly due to increased consumption for industrial and urban use, as well as, deterioration of water quality through increase in salinity levels which is induced mostly from the activities of man. In addition, high soil salinity renders the cultivation of vegetables in many areas prohibitive, with almost 20% of the total arable land and 50% of irrigated land to be deteriorated by salinity problems (McBride, 1994; Zhu, 2001; Arzani, 2008), caused either by irrigation water or underground water of low quality. More than 800 million hectares of land throughout the world are salt-affected (including both saline and sodic soils), corresponding to more than 6% of the world's total land area (FAO, 2009). High concentration of salts in root environment increases osmotic potential of soil and therefore decreases water availability for plants due to osmotic stress (Barbour et al., 1998; Bauder and Brock, 2001). Salinity levels of 4 mmhos/cm resulted in a 10% decrease for tomato yield, whereas increasing electrical conductivity up to 8 mmhos/cm decreased yield by 50%

*Corresponding author. E-mail: ggyarsi@gmail.com.Tel: +90 416 7258150. Fax: +90 416 7257792.

(Bernstein, 1964). Fruit yield decrease is reported in various studies; however, the decrease rate is affected by growing medium and salinity level (Demir et al., 1999; Chartzoulakis, 1995), composition of salts (Trajkova et al., 2006) and scion-rootstock combination (Huang et al., 2009a, b). Sharaf and Hobson (1986), Drew et al. (1990) and Trajkova et al. (2006) also reported that yield reduction resulted mainly from a decrease in fruit size and not in fruit number and in turn in higher percentage of unmarketable fruit. One way of reducing decrease in yield caused by salinity is by using high-yielding genotypes of rootstocks capable of reducing the effect of external salt on the scion. For this, the plant breeder should investigate the possibility of combining good scion characters with good rootstock characters, and of studying the contribution of genes transcribed in the roots towards the performance of the scion. Apart from yield, high salinity affects plant physiology by preventing seed germination, reducing root biomass, delaying shoot development and plant height (Cuartero and Fernandez, 1999; Kerkides et al., 1997; Khah et al., 2007), as well as, by reducing total leaf area (Perez-Alfocea et al., 1993; Khah et al., 2011). However, Allan et al. (2000) and Turhan et al. (2009) reported that there are significant differences among the various tomato genotypes in regards to high salinity tolerance. Besides, the growth stage of tomato plants is of major importance, with younger plants being more salt sensitive than the older ones (Olympios et al., 2003).

Recently, grafting is being applied as a means of alleviating the negative effects of high salinity being simultaneously an environmental-friendly technique, by using rootstocks capable of getting over the problems induced by high concentration of salts in root environment (Zhu et al., 2008a, b; He et al., 2009; Huang et al., 2009a, b, c, 2010; Uygur and Yetisir, 2009; Yetisir and Uygur, 2010; Zhen et al., 2010). In addition, recent work on cucumber suggested that the salt tolerance of grafted cucumber seedlings is related to the scion genotype (Zhu et al., 2008a, b), whereas Chen et al. (2003) and Santa-Cruz et al. (2002) reported similar results for tomato plants.

The aim of the present study was to examine the effect of grafting and rootstock × scion interaction on the growth, development and yield of tomato plants grafted on to five rootstocks and themselves and grown in pots under salt stress both at indoors and outdoors environmental conditions.

MATERIALS AND METHODS

Location and plant material

The experiment was conducted in a heated glasshouse at the University of Thessaly (Velestino, Greece). Tomato plants (*Lycopersicon esculentum* L. cv. Despina) were provided by Agrosystem S.A. (Ierapetra, Greece) on 20th April, 2010 and transferred in a glasshouse until transplantation. Tomato plants were either self-rooted (P7), or grafted on to themselves (P6) or five experimental rootstocks (P1 to P5). Transplantation took place on 29^{th} April, 2010 in 10 L plastic pots containing peat (Agrosystem S.A. Ierapetra, Greece) and perlite (Perloflor Company, Athens, Greece) in a ratio of 1: 1 (one plant per pot × 7 grafting treatments × 3 salinity stress levels × 5 replicates = 105 plants in total for each cultivation condition). Irrigation was applied via a fully automated drip system, whereas application of water stress treatment started 28 days after transplantation (DAT).

Field experiment

A standard nutrient solution for tomato with an electrochemical coefficient (EC) of 0.67 mS/cm (bore water) was used as control and compared with two salinity treatments, namely 3.0 and 6.0 mS/cm, which were obtained by adding 1165 and 2330 g of NaCl in 850 L of water respectively. The three salinity treatments were combined with seven combinations of rootstocks and scions in a two factorial experimental design. During cultivation, EC of nutrient solution was recorded regularly and the appropriate adjustments were applied. Immediately after trans-plantation, Kelp 100 (Farma-Chem S.A., Thessaloniki, Greece) was applied directly to the roots via watering cans (1ml per plant), whereas fertilization was applied 49 DAT via irrigation system using 100 ml per plant of 20-20-20 (N-P-K) for the first 18 days and 100 ml per plant of 20-10-30 (N-P-K) until the end of the experiment. Plants were trained as single stems in both indoors and outdoors experiments, whereas supporting was carried out on vertical cordons and wooden sticks for indoors and outdoors cultivation respectively. During cultivation of plant height, number of flowers, numbers of green and mature fruit were recorded at regular intervals starting from 15 DAT until 89 DAT. Fruits were harvested at commercial maturity (fully red colored) by hand. For fresh and dry weight evaluation, samples were taken at 69, 83 and 95 DAT. Fresh samples of plant tissues were chopped and oven-dried at 72°C to constant weight.

Statistical analysis

The experiment was laid out in a split-plot design, each plot consisting of one irrigation regime with fully randomized sub-plots comprising the water stress levels. Statistical analysis was performed with the aid of the SPSS 14 for Windows statistical package (IBM Corp., New York, USA) and Microsoft Office Excel, 2003. Data were evaluated by analysis of variance for the main effects and the means of values were compared by the Duncan Multiple Range Test (DMRT) at p=0.05.

RESULTS AND DISCUSSION

High salinity increased the osmotic potential of nutrient solution resulting in water stress conditions for plant grown in the environment. The results of our study showed that grafted plants grown outdoors formed more internodes than self-rooted plants, regardless of the salinity stress level, whereas for plants grown indoors, there were differences only at the level of 3 mS/cm, where scion × P2 combination plants formed less internodes than the others (Table 1). However, when highest salinity level was applied, no significant differences were observed among the treatments. Number of internodes reduced when salinity increased,

Table 1. The effect of salinity level and grafting × scion combination on the number of internodes measured at the stage of 82 days after transplantation (indoors cultivation).

Grafting treatment*	Control	3.0 mS/cm	6.0 mS/cm
P1 × Despina	31.0(a)	31.0a(a)	24.3(b)
P2 × Despina	28.7(a)	22,7b(b)	24.3(b)
P3 × Despina	28.0(abc)	32.0a(a)	25.0(c)
P4 × Despina	27.0(a)	28,7a(a)	26.0(a)
P5 × Despina	29.3(a)	29.0a(a)	28.0(a)
P6	31.0(a)	29.7a(ab)	27.3(b)
P7	33.0(a)	31.0a(a)	27.3(b)

*Grafting treatments refers to rootstock (P1-P5) × scion combination; P6: Despina × Despina; P7: Self rooted plants of cv. Despina. Mean values within the same row followed by different letters in parenthesis are significantly different by DMRT test at p=0.05. Mean values within the same column followed by different letters without parenthesis are significantly different by DMRT test at p=0.05.

Table 2. The effect of salinity level and grafting x scion combination on the total number of flowers (outdoors cultivation).

Grafting treatment*	Indoors	Outdoors
P1 × Despina	30.4b	22a
P2 × Despina	29.0b	21.6a
P3 × Despina	29.8b	21.0a
P4 × Despina	27.3bc	20.5b
P5 × Despina	29.0b	17.0c
P6	25.2c	22.0a
P7	39.4a	13.0d
Control	34.4a	17.57a
3.0 mS/cm	28.5b	20.33a
6.0 mS/cm	27.2b	20.95a

*Grafting treatments refers to rootstock (P1-P5) × scion combination; P6: Despina × Despina; P7: Self rooted plants of cv. Despina. Mean values within the same column followed by different letters are significantly different by DMRT test at p=0.05.

except for scion × P4 and P5 combinations where no differences were observed. The effect of salinity level and grafting treatment on plant height was similar to that on the internodes (data not shown). These results are in linewith the literature where salinity tolerance of the scion is suggested to be highly depended on the rootstock; however, the scion × rootstock combination may also affect the degree of salinity tolerance according to the exclusion ability of the genotype (Colla et al., 2010). Ruiz et al. (1997) also reported that grafting could result in an increased water and nutrient uptake by scion due to the enhanced vigor of the root system. Regarding the total number of flowers, self-rooted plants formed more flowers than grafted ones when grown indoors, regardless of the water stress level, whereas growing outdoors resulted in more flowers for grafted plants (Table 2). In addition, the number of flowers reduced when salinity increased, but only in the case of indoors cultivation.

Plants grafted on to rootstocks P4 and P5 had the best ratio of matured: green fruit than the other combinations, for indoor cultivation and the level of 6 mS/cm, though without significant differences among them, whereas for outdoor cultivation, scion × P1 combination showed the best results (Table 3). The effect of salinity level on the ratio of mature: green fruit was depended on the scion × grafting combination (data not shown). Fruit yield is previously reported by various studies to be affected by salinity level and salt composition (Bernstein, 1964; Chartzoulakis, 1995), whereas yield reduction may be attributed mainly to fruit size reduction (Sharaf and Hobson, 1986; Demir et al., 1999; Trajkova et al., 2006). Regarding fruit yield, grafted plants formed more fruit in total and had a higher total yield than self-rooted plants at the level of 6 mS/cm when grown indoors, whereas mean fruit weight was higher for P2, P5 and P6 combinations (Table 4). For outdoor cultivation, scion × P1 and P2 combinations were superior to others at the level of 6 mS/cm as regards the total number of fruit and total yield,

Table 3. The effect of grafting treatment on the ratio of green: mature fruit (expressed as percentage) at the level of 6.0 mS/cm for both indoors and outdoors cultivation.

Grafting treatment*	Indoors (%)	Outdoors (%)
P1 × Despina	17.3^{bc}	17.9^{a}
P2 × Despina	19.1^{b}	14.3^{b}
P3 × Despina	17.0^{c}	12.5^{c}
P4 × Despina	20.5^{a}	15.9^{b}
P5 × Despina	20.9^{a}	11.9^{c}
P6	16.9^{c}	11.9^{c}
P7	19.3^{b}	13.0^{c}

*Grafting treatments refers to rootstock (P1-P5) × scion combination; P6: Despina × Despina; P7: Self rooted plants of cv. Despina. Mean values within the same column followed by different letters are significantly different by DMRT test at p=0.05.

Table 4. The effect of grafting treatment on total yield and mean fruit weight per plant (g) at the level of 6.0 mS/cm for both indoors and outdoors cultivation.

Grafting treatment*	Indoors		Outdoors	
	Total yield (g)	Mean fruit(g)	Total yield(g)	Mean fruit(g)
P1 × Despina	475.1^{b}	50.9^{c}	589.5^{a}	85.5^{c}
P2 × Despina	521.3^{a}	62.6^{a}	594.4^{a}	78.5^{d}
P3 × Despina	458.6^{b}	55.1^{b}	396.7^{c}	85.7^{c}
P4 × Despina	544.7^{a}	51.0^{c}	454.3^{b}	80.7^{c}
P5 × Despina	488.3^{b}	61.0^{a}	437.7^{b}	105.3^{a}
P6	438.1^{b}	59.8^{a}	443.7^{b}	93.0^{b}
P7	210.0^{c}	52.5^{c}	398.5^{c}	67.6^{e}

*Grafting treatments refers to rootstock (P1-P5) × scion combination; P6: Despina × Despina; P7: Self rooted plants of cv. Despina. Mean values within the same column followed by different letters are significantly different by DMRT test at p=0.05.

whereas mean fruit weight was higher for P5 combination (Table 4). Higher yield of grafted in comparison to self-rooted plants grown under salinity stress conditions, may be attributed to the improved water and nutrient uptake as well as, to a better control of stomata conductance of leaves (Holbrook et al., 2002). However, rootstock × scion combination affects scion performance and plant growth in general under water stress conditions, rendering the choice of rootstock of major importance for high yield (Huang et al., 2009a, b; Allan et al., 2000; Turhan et al., 2009).

Conclusions

In conclusion, implementing grafting technique on tomato affects significantly physiology of plants grown under salinity stress, resulting in the formation of more internodes and therefore flowers, especially for outdoor cultivation, whereas significant effects are observed on both total number and total weight of fruit for indoor cultivation. In addition, rootstock × scion combination has a significant effect on plant growth and yield and could be used as a useful means in order to alleviate problems that arise due to either lack of water or high salinity of irrigation water. The use of improved genotypes for rootstocks is required so as to improve yields under a variety of climatic and high salinity soil conditions. It is well known that the root system of the plants affects vegetative growth and yield and as such, the effects of grafting recorded in most research papers are obviously related to the differences in the root system between grafted and non-grafted plants, that is, to the efficiency of water and nutrient uptake by the roots, or even to the distribution of growth regulators. In Greece, where the vegetable cultivation is still carried out mostly by traditional methods and modern cultivated techniques are adopted slowly, the grafting technique could help in the solution of soil salinity problems by evaluating and screening new genotypes for their rootstocks tolerance to biotic and abiotic stresses occurring in intensive agro-systems.

REFERENCES

Allan A, Altman B, Heuer B (2000). Genotypic difference in salinity and water stress tolerance of fresh market tomato cultivars. Plant Sci. 152:59-65.

Arzani A (2008). Improving salinity tolerance in crop plants: a biotechnological review. In Vitro Cell. Dev. Biol. Plant 44:373-383.

Barbour MG, Burk JH, Pitts WD, Gillian FS, Schwartz MN (1998). Terrestrial Plant Ecology. Publisher Benjamin/Cummings, Menlo Park, California. pp. 46-58.

Bauder JW, Brock TA (2001). Irrigation water quality, soil amendment and crop effects on sodium leaching. Arid Land Res. Manage. 15:101-113.

Bernstein L (1964). Effect of salinity on mineral composition and growth of plants. Plant Anal. Fertil. Prob. 4:25-44.

Chartzoulakis KS (1995). Salinity effects on fruit quality of cucumber and eggplant. International Symposium on Quality of Fruit and Vegetables: Influence of Pre- and Post Harvest Factors and Technology. Acta Hortic. 379:187-192.

Chen G, Fu X, Lips SH, Sagi M (2003). Control of plant growth resides in the shoot, and not in the root, in reciprocal grafts of flacca and wild-type tomato (*LYcopersicon esculentum*), in the presence and absence of salinity stress. Plant Soil 256:205-215.

Colla G, Rouphael Y, Leonardini C, Bie Z, (2010). Role of grafting in vegetable crops grown under saline conditions. Sci. Hortic. 127:147-155.

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

Demir K, Gunes A, Inal A, Alpaslan M (1999). Effects of humic acids on the yield and mineral nutrition of cucumber grown in different salinity levels. I. Internationa Symposium of Cucurbits. Acta Hortic. 492:71-76.

Drew MC, Hole PS, Picchioni GA (1990). Inhibition by NaCl of net CO_2 fixation and yield of cucumber. J. Am. Soc. Hortic. Sci. 115:472-477.

FAO (2009). FAO land and plant nutrition management service. http://www.fao.org/ag/agl/agll/spush/http://www.fao.org/ag/agl/agll/spush/.

He Y, Zhu ZJ, Yang J, Ni XL, Zhu B (2009). Grafting increases the salt tolerance of tomato by improvement of photosynthesis and enhancement of antioxidant enzymes activity. Environ. Exp. Bot. 66:270-278.

Holbrook NM, Shashidhar VR, James RA, Munns R (2002). Stomata control in tomato with ABA deficient roots: response of grafted plants to soil drying. J. Exp. Bot. 53(373):1503-1514.

Huang Y, Bie ZL, Liu ZX, Zhen A, Wang WJ (2009c). Exogenous proline increases the salt tolerance of cucumber by enhancing water status and peroxidase enzyme activity. Soil Sci. Plant Nutr. 55:698-704.

Huang Y, Tang R, Cao QL, Bie ZL (2009b). Improving the fruit yield and quality of cucumber by grafting onto the salt tolerant rootstock under NaCl stress. Sci. Hortic. 122:26–31.

Huang Y, Zhu J, Zhen A, Chen L, Bie ZL (2009a). Organic and inorganic solutes accumulation in the leaves and roots of grafted and ungrafted cucumber plants in response to NaCl stress. J. Food Agric. Environ. 7:703–708.

Huang Y, Bie ZL, He SP, Hua B, Zhen A, Liu ZX 2010. Improving cucumber tolerance to major nutrients induced salinity by grafting onto *Cucurbita ficifolia*. Environ. Exp. Bot. 69, 32–38.

Kerkides P, Olympios C, Psychoyou M, Lagoudaki A (1997). The effect of saline irrigation water on crop growth and yield. Proc. Int. Conf. on water management, salinity and pollution control towards sustainable irrigation in the Mediterranean region. MAI Bari, Italy 4:1-17.

Khah EM, Katsoulas N, Tchamitchian M, Kittas C (2011). Effect of grafting on eggplant leaf gas exchanges under mediterranean greenhouse conditions. Int. J. Plant Prod. 5(2):121-134.

Khah EM, Koukoufikis K, Mavromatis AG, Chachalis D, Goulas CK (2007). The effect of different irrigation techniques on plant performance and seed quality in relation to fruit maturation and storage of different genotypes of pepper (*Capsicum annuum* var. *annuum L*.). J. Food Agric. Environ. 5(1):159-163.

McBride MB (1994). Environmental chemistry of soils. New USA York: Oxford University Press.. 416 pp.

Olympios CM, Karapanos IC, Lionoudakis K, Apidianakis I (2003). The growth, yield and quality of greenhouse tomatoes in relation to salinity applied at different stages of plant growth. ISHS Acta Hortic. 609:313-320.

Perez-Alfocea F, Estan MT, Caro M, Bolarin MC (1993). Response of tomato cultivars to salinity. Plant Soil 150:203-211.

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

Santa-Cruz A, Martinez-Rodriguez MM, Perez-Alfocea F, Romero-Aranda R, Bolarin MC (2002). The rootstock effect on the tomato salinity response depends on the shoot genotype. Plant Sci. 162:825-831.

Sharaf AR, Hobson GE (1986). Effect of salinity on the yield and quality of normal and non ripening mutant tomatoes. Acta Hortic. 190:175-181.

Trajkova F, Papandonakis N, Savvas D (2006). Comparative effects of NaCl and $CaCl_2$ salinity on cucumber grown in a closed hydroponic system. Hortscience 41(2):437-441.

Turhan A, Seniz V, Kuscu H (2009). Genotypic variation in the response of tomato to salinity. Afr. J. Biotechnol. 8(6):1062-1068.

Uygur V, Yetisir H (2009). Effects of rootstocks on some growth parameters, phosphorous and nitrogen uptake by watermelon under salt stress. J. Plant Nutr. 32:629-643.

Yetisir H, Uygur V (2010). Responses of grafted watermelon onto different gourd species to salinity stress. J. Plant Nutr. 33:315-327.

Zhen A, Bie ZL, Huang Y, Liu ZX, Li Q (2010). Effects of scion and rootstock genotypes on the antioxidant defense systems of grafted cucumber seedlings under NaCl stress. Soil Sci. Plant Nutr. 56:263-271.

Zhu J, Bie ZL, Huang Y, Han XY (2008a). Effect of grafting on the growth and ion contents of cucumber seedlings under NaCl stress. Soil Sci. Plant Nutr. 54:895-902.

Zhu JK (2001). Plant salt tolerance. Trends Plant Sci. 6:66-71.

Zhu SN, Guo SR, Zhang GH, Li J (2008b). Activities of antioxidant enzymes and photosynthetic characteristics in grafted watermelon seedlings under NaCl stress. Acta Bot. Boreal-Occident. Sin. 28:2285-2291.