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EFFECT OF GRAFTING AND DIFFERENT EC LEVELS OF SALINE IRRIGATION WATER ON GROWTH, YIELD AND FRUIT QUALITY OF TOMATO (*LYCOPERSICON ESCULENTUM*) IN GREENHOUSE

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Abstract

Tomato is one of the most important *Solaneaceae's* species worldwide. While, irrigation water salinity restricts the commercial production of tomato in arid and semi-arid zones. Therefore, grafting is one of the innovative techniques that can be used to overcome the problem of salinity of soil or water. This work was undertaken to study the efficiency of salt tolerant rootstocks to improve grafted tomato against saline irrigation water and investigate their impacts on fruit yield and quality. Therefore, factorial greenhouse experiment was arranged in two growing seasons with three replicates in sand soil. The commercial tomato cultivar "Galila" was grafted on Edkawi and Maxifort rootstocks, while non-grafted plants were used as control. Drip irrigation nutrient solution with two electrical conductivity (EC) levels (2 and 4 $dS.m^{-1}$) was used to irrigate all the grafted and non-grafted tomato plants. Results show that decreasing EC level of the applied nutrient solution from 4 to 2 $dS.m^{-1}$ significantly increased vegetative growth of non-grafted plants. The maximum total yield was obtained with grafted plants on Edkawi and Maxifort rootstocks at EC level of 2 $dS.m^{-1}$ followed by 4 $dS.m^{-1}$ compared to non-grafted plants. Further more, significant increases in Na^+ and proline in tomato leaves as well as a significant improvement in vitamin C and β carotene in fruits of non-grafted plants were noticed with 4 $dS.m^{-1}$ compare to 2 $dS.m^{-1}$. On contrast, grafting improved the dry biomasses and yield component with both EC levels, plus increasing the accumulation of potassium and K^+/Na^+ ratio in leaves at 4 $dS.m^{-1}$ than non-grafted plants. Our data indicate that Maxifort and Edkawi are appropriate rootstocks that can be used for reducing the adverse effects of saline water irrigation.

Key word: Fruit quality, *Lycopersicon esculentum,* Salinity, Yield

Introduction

Tomato is a popular vegetable crop cultivated for its nutritional value, especially in tropical and subtropical areas, where salinity of soil and water increases problem of plant stress (Al-Harbi *et al.,* 2017). Indeed, salinity is considered among the most important abiotic factors that cause significant losses in plant growth and production (Farooq *et al.*, 2017). Current assessments refer that more than 7% of arable area and 20% of worldwide-irrigated soils are affected by salinity (Peleg *et al.*, 2011). Several agricultural lands are becoming saline due to over using the low quality water and synthetic chemical fertilizers (Ferreira-Silva *et al.,* 2010; Voogt and Van Os, 2012). Deeply, continuous salt accumulation in soil causes series morphological, biochemical and physiological alterations, which impact plant performance and productivity (Shanker and Venkateswarlu, 2011; Munns and Gilliham, 2015). High salt concentrations reduce water absorption, nutrient uptake, photosynthetic activities, stomata opening and transpiration rate due to disturbing of plant osmotic balance (Munns and Tester, 2008, Chavarria and dos Santos, 2012). Several strategies are applied to improve salt tolerance in economic crops like utilizing the modern irrigation methods (Zhang *et al.,* 2018), sowing salt tolerance plants (Roy *et al.,* 2014), seed priming (Jisha and Puthur, 2014), plant growth regulators (Gong *et al.,* 2014; Yuan *et al.,* 2015), application of nutrients (Kafi *et al.,* 2012) and grafting on salt tolerant root stocks (Penella *et al.,* 2017; Yanyan *et al.,* 2018). One of the most modernization techniques that using to overcome salt stress problem is grafting. This technique is utilized widely in commercial scale with

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various vegetable crops in many Mediterranean countries (Leonardi and Romano, 2004). Main objectives of vegetable grafting is enhancing crop tolerance to biotic and abiotic stresses (including soil borne diseases, drought, salinity, flooding, low and high temperatures) as well as improving of water use efficiency, water absorption and nutrient translocation and delaying plant senescence (Zhao and Simonne, 2008; Colla *et al*., 2010; Semiz and Yurtseven, 2010; Sánchez-Rodríguez *et al.,* 2013). Numerous studies confirmed that grafting economical vegetables crops on salt tolerant rootstocks is an effective strategy has been utilized with many vegetable crops, including cucumber (Zhen *et al*., 2010), tomato (Fan *et al.,* 2011), pepper (Penella *et al.,* 2013) and potato (Etehadnin *et al.,* 2010). Earlier studies have indicated that salinity adaptation of rootstocks are associated with different mechanisms such as exclusion of toxic ions, particularly Na^+ and Cl^- by rootstock roots and reduce their transport into shoots (Estan *et al.,* 2004). Other reports reveal that vigorous rootstocks root architecture adjust stomatal apertures (changes in stomatal regulation and water relations); preserving photosynthesis; by absorbing more water and nutrients (Penella *et al.,* 2017). In other cases, such elevated tolerance has been elucidated by increasing the accumulation of metabolic compounds *i.e.* proline, carbohydrates, betaine, enzymatic and non-enzymatic antioxidants (Kukreja *et al.,* 2005). Therefore, the aim of this research work is study the effectiveness of grafting process on tomato growth and fruit quality under saline condition.

Materials and Methods

Two experiments were carried out in sand soil greenhouse at private farm located in El-Taef, Mecca, Saudi Arabia during 2013 and 2014 seasons. The greenhousedaily temperature ranged between 25-30 ºC at day-light and 15±2ºC at night, with 85% relative humidity. The commercial tomato cultivar "Galila" (GA, Takamul National Agricultural Co., SA) was grafted on two different salt tolerance rootstocks "Maxifort" (GA/MF) and "Edcawi" (GA/ED) using the method of 'cleft grafting' as defined by Lee (1994). Seedlings were transplanted at density $3.5.m^{-2}$ on October of 2013 and 2014, respectively. Two weeks after transplanting, the available irrigation water, with 4 $dS.m^{-1}$ that adjusted to 2 $dS.m^{-1}$ by mixing the saline water with fresh water and applied for one month, was mixed with the chemical fertilizer 20-20-20 and applied with the drip irrigation system. Later, the nutrient solution was applied to grafted and non-grafted tomato plants at two different EC levels, 2 and 4 $dS.m^{-1}$. The experimental design was arranged in two-ways randomized plots with 3 replicates. One month post saline irrigation treatment, ten plants were selected randomly to determined plant height, number of leaves and number of branches. Also, samples were dried at 75ºC in forced air-oven to estimate the dry biomasses. The dried leaf samples were powdered and used to determinate the Na^+/K^+ ratio. The total K^+ and Na^+ concentrations were evaluated in digested acidic solution using flame photometer according to the method described by Brown and Lilliland (1964). The free proline was assessed in fresh leaf using colorimetric procedure according to Claussen method (2005). The average tomato fruit weight and fruit number were recorded through whole harvest times to calculate total yield per plant. Six fruits were collected from each treatment then grounded in blender for juice extraction. The homogenized juice was used to measure total soluble solid using digital refractmeter, Vitamin C according to the method described by A.O.A.C. (1990). Lycopene and carotene were estimated according to the method of Fish *et al.* (2002) and Jung (2004), respectively.

Statistical analysis

Test of normality distribution was performed according to Shapiro and Wilk, method (1965), by using SPSS v. 17.0 (2008) computer package. Combined analysis of variance of a randomized complete block design RCBD across the two seasons was computed after running Bartelet test according to Snedecor and Cochran (1994) for all tested parameters except plant height, number of branches, yield component and fruit lycopene content. The obtained data from combined analysis were subjected to the statistically analysis of variance and means were compared at 0.05 level according to Duncan's test using Statistica 7 program.

Results and discussion

Effect of grafting and saline water on tomato growth

Results show that growth of tomato plants were significantly affected by increasing levels of EC and grafting on salt tolerant rootstocks (Fig. 1). Elevating the level of EC led to significant decline in plant height, number of leaves, and number of branches of non-grafted rootstock tomato plants (Fig. 1). Notably, grafted tomato plants in the two growing seasons achieved the highest plant height, leaves number and number of branches more than non-grafted tomato plants (Fig 1. A, B, C), under both EC levels (2 and 4 $dS.\ m^{-1}$). The number of leaves was 15.5% and 20% higher when Edkawi and Maxfort rootstock were used at 2 $dS.m^{-1}$, besides 18.4 % and 15.8% higher with 4 $dS.m^{-1}$ level, respectively, as compared to non-grafted plants (Fig. 1 C). Moreover, maximum values of dry biomass were achieved by grafting onto Edkawi and Maxfort rootstocks at 2 dS.m^{-1} than 4 dS.m^{-1} levels if compared to non-grafted tomato plants at both EC levels. The dry weight of section part reached 12.2% and 8.02% higher with Edkawi and Maxfort rootstocks at 2 dS.m^{-1}, and 32.3% and 31.15% higher at 4 dS.m^{-1} level, as compared to non-grafted plants (Fig. 1 D). Several researchers reported that grafting tomato plants onto salt tolerant rootstock have improved plant vigor than non-grafted plants (Karaca *et al.* 2012). However, the maximum vegetative growth characters were noted when the grafted tomato plants onto Maxfort and Edkawi at 2 dS.m^{-1} level than 4 dS.m^{-1} (Fig. 1). These results were confirmed according to Al-Harbi *et al.* (2017) who found significant improves in tomato growth under combination of high salinity stress application and grafting technique.

Effect of grafting and saline water on yield and fruit quality

Grafting and different EC levels have significantly affected fruit quantity of tomato grown in the two growing seasons (Fig. 2). The maximum total yield was obtained with grafted plants on Edkawi and Maxifort rootstocks at EC level of 2 dS.m^{-1} followed by 4 dS.m^{-1} compared to non-grafted plants (Fig. 2 A). In terms of average tomato fruit weight, data in Fig. 2 B shows that grafted plants were much superior to produce better fruit weight if compared to non-grafted plants with both EC levels of saline irrigated water. Similar trend was observed in term of number of produced fruits except that control plants presented significant decrease with higher EC level than the lower one (Fig. 2 D). Similar findings were obtained by Turhan *et al.* (2011) and Echevarria *et al.* (2012) whom indicated that grafting ameliorated yield quantity of grafted tomato plants and its components. These enhancements in total yield of grafted tomato plants might be associated to the strength of plant growth (Yanyan *et al.*, 2018).

According to the effect of grafting and saline irrigation water on fruit quality of treated tomato plants, data in fig. 3 (A, B) reveal that vitamin C and β carotene were significantly increased in control plants (GA) at EC level of 4 dS.m^{-1}. The highest value of vitamin C was observed with non-grafted plants (26.8 mg.100 g^{-1} FW) in 4 dS.m^{-1} than grafted plants on Edkawi (23.95 100 g^{-1} FW) and

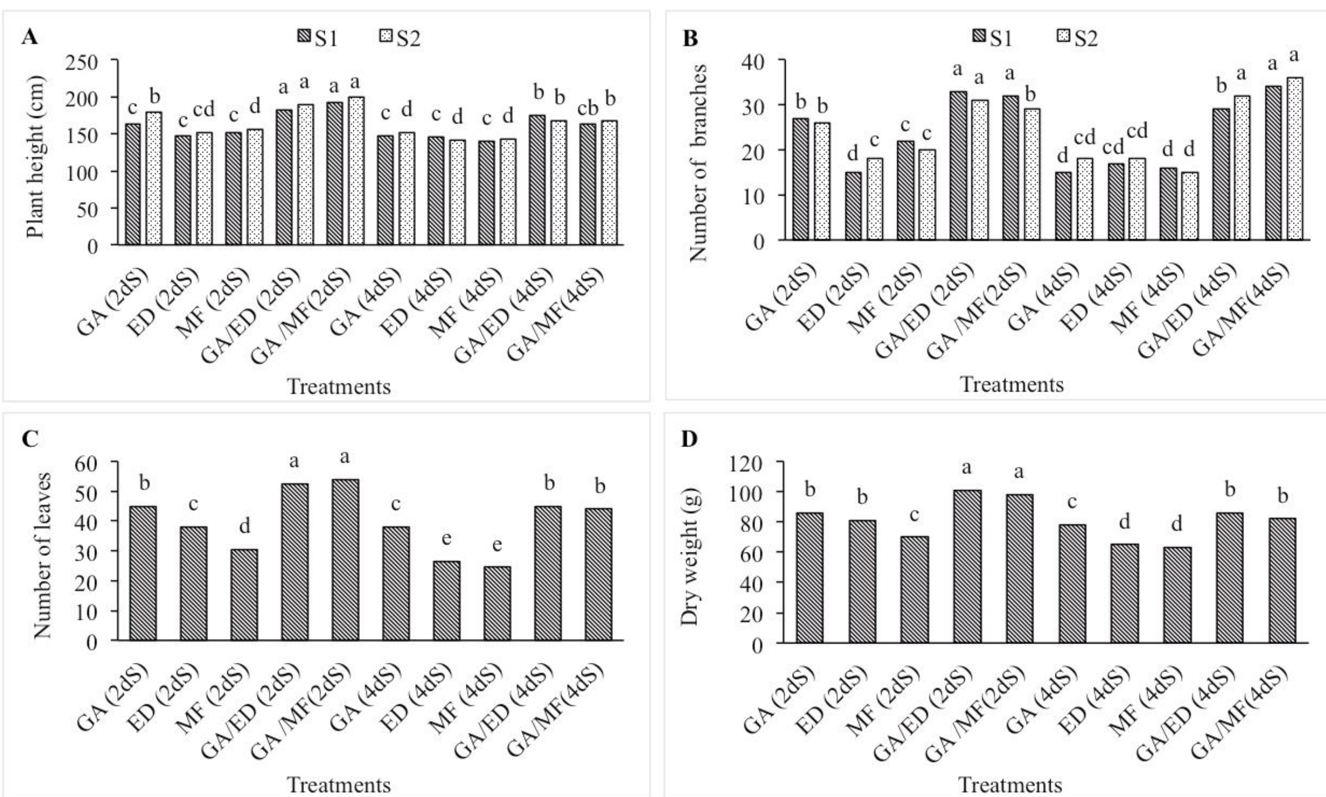

Fig. 1: Effect of two EC levels (2 and 4 dS.m^{-1}) and grafting on (A) plant height, (B) Number of branches, (C) Number of leaves and (D) Dry weight of grafted and non-grafted tomato plants in the 2013-2014 seasons. Different letters indicate significant differences at P = 0.05 by Duncan's multiple range test. GA= Galila cultivar, ED= Edkawi rootstock, MF=Maxifort rootstock, S1=Season1, S2=Season2, 2dS= 2dS.m^{-1},4dS= 4dS.m^{-1}

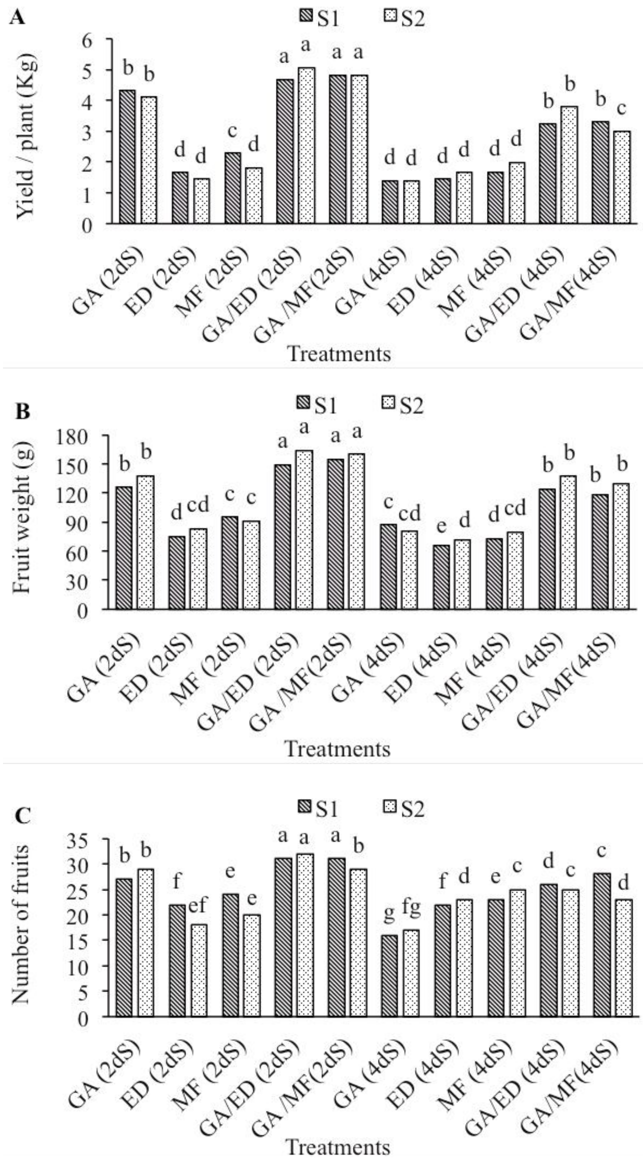

Fig. 2: Effect of two EC levels (2 and 4 dS.m^{-1}) and grafting on (A) total yield, (B) fruit weight and (C) number of fruit of grafted and non-grafted tomato plants in the 2013-2014 seasons. Different letters indicate significant differences at P = 0.05 by Duncan's multiple range test. GA= Galila cultivar, ED= Edkawi rootstock, MF=Maxifort rootstock, S1=Season1, S2=Season2, 2dS= 2dS.m^{-1},4dS= 4dS.m^{-1}

Maxfort (22.5 100 g^{-1} FW) as shown in figure (Fig. 4 A). Furthermore, grafted tomato plants on Edkawi and Maxfort caused 11% and 16 % reduction in vitamin C content, as compared to non-grafted plants in 4 dS.m^{-1}. Similar result was recorded with β carotene content. In consequence, β carotene content was 11% and 17 % in 4 dS.m^{-1} when use Edkawi and Maxfort, respectively, as compared to non-grafted tomato plants (Fig. 4 B). Similar result was reported by Al-Harbi *et* al. (2017) who found a reduction in fruit quality of grafted tomato plants under excessing of salt stress. Over the two growing seasons, concentration of lycopene in tomato fruit tends to increase with grafted plants than non-grafted plants ($p \leq 0.05$, Fig. 4 C) at both applied EC levels. The value of lycopene concentration in tomato fruits increased by 52.3% and 54% at the first season, and 47% and 44% at the second one under 4 dS.m^{-1} with Edkawi and Maxfort rootstocks, as compared to non-grafted plants. Notably, no significant differences were observed on total soluble solid (TSS) between grafted and non-grafted tomato at both levels of salt concentrations as shown in Fig. 4 (D), similar trend was reported by (Fernández-Garcí *et al*., 2004) who stated that fruit quality and quantity of grafted tomato plants exposed to 30 and 60 mM NaCl, significantly improved comparing with non-grafted plants.

Effect of grafting and saline water on proline content

The accumulation of leaf proline was increased significantly with increasing EC of the saline irrigation water ($P \leq 0.05$). The maximum content of leaf proline was obtained from grafted tomato at the EC level of 4 dS.m^{-1} followed by EC level of 2 dS.m^{-1} (Fig. 4A). Similar tendency was observed in non-grafted tomato plants. At the EC level of 4 dS.m^{-1}, the highest content of leaf proline was achieved in leaves of non-grafted plants than grafted tomato plants. On contrary, no significant difference was noted in leaf proline among grafted and non-grafted plants at EC level of 2 dS.m^{-1}. Such results was reported by Yanyan *et al*. (2018) who found that proline increased with increasing salinity levels in tested tomato plants. These results could be attributed to role of rootstocks in decreasing the adverse effects of salinity by reducing the Na^+ uptake from plant roots (Ferreira-Silva *et al.,* 2010). In this respect, it could be mentioned that proline contributes to membrane stability (Gadallah, 1999) and alleviates the destructive effect of NaCl on cell membrane interruption (Mansour, 1998) thus improves plant developments under saline conditions (Lone *et al.,* 1987).

Effect of grafting and saline water on leaf K^+/Na^+ ratio

Generally, leaf Na^+ concent in grafted and non-grafted tomato plants was increased gradually with increasing EC level of 4 dS.m^{-1} in comparison to 2 dS.m^{-1} (Fig. 4 B). Lower concentration of leaf Na^+ was observed in plant grafted onto Edkawi and Maxifort rootstock at the EC level of 4 dS.m^{-1}. Notably, leaf Na^+ content reduced by 50% with Edkawi and 36% with Maxfort rootstocks at 4 dS.m^{-1}. Reducing Na^+ content in grafted tomato plants was also described by Martinez-Rodriguez *et al.* (2002).

Here, we suggest that occurrence of salt tolerance

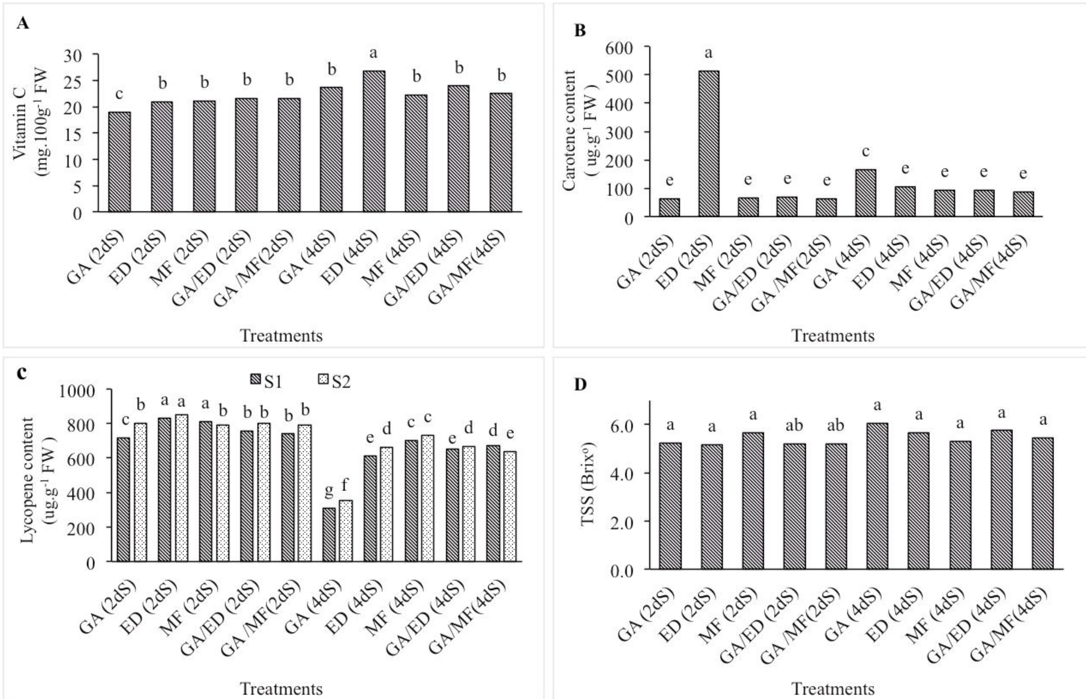

Fig. 3: Effect of two EC levels (2 and 4 dS.m^{-1}) and grafting on (A) Vitamin C, (B) Carotene, (C) Lycopene and (D) T.S.S of grafted and non-grafted tomato plants in the 2013-2014 seasons. Different letters indicate significant differences at P = 0.05 by Duncan's multiple range test. GA= Galila cultivar, ED= Edkawi rootstock, MF=Maxifort rootstock, S1=Season1, S2=Season2, 2dS= 2dS.m^{-1},4dS= 4dS.m^{-1}

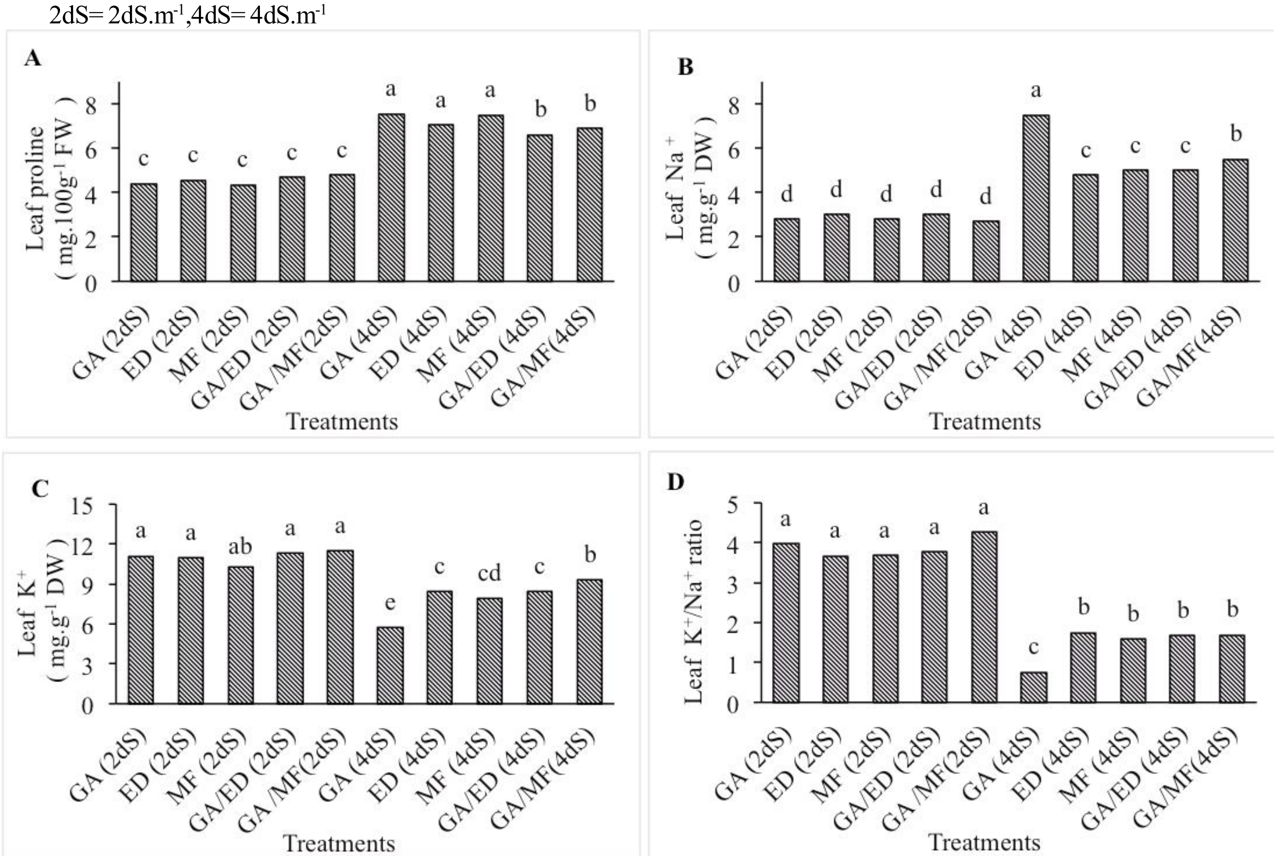

Fig. 4. Effect of two EC levels (2 and 4 dS.m^{-1}) and grafting on contents of leaf (A) Proline, (B) Na^+, (C) K^+ and (D) K^+/Na^+ ratio of grafted and non-grafted tomato plants in the 2013-2014 seasons. Different letters indicate significant differences at P = 0.05 by Duncan's multiple range test. GA= Galila cultivar, ED= Edkawi rootstock, MF=Maxifort rootstock, S1=Season1, S2=Season2, 2dS= 2dS.m^{-1},4dS= 4dS.m^{-1}

improvement of grafted plants has regularly been associated by lowering Na^+ contents in the section biomasses (Fig. 4B). Grafting plants onto appropriate rootstocks may be restricted the transport of Na^+ from root to scion vegetative growth (Zhu *et al.,* 2008). On the other hand, the accumulation of potassium in leaves of grafted tomato plants was greater than non-grafted plants at the EC level of 4 $dS.m^{-1}$ (Fig. 4C). Leaf K^+ content was 32% and 39% higher with Edkawi and Maxfort rootstocks, respectively. While, no significant differences among grafted and non-grafted plants were observed in terms of leaf K^+ under 2 $dS.m^{-1}$. According to K^+/Na^+ ratio, grafted plants revealed higher K^+/Na^+ ratiounder 2 $dS.m^{-1}$ if compared to 4 $dS.m^{-1}$ (Fig. 5 D). These results are in agreement with Yong *et al.* (2009) who found that accumulation of K^+ in tomato plants could be associated to the improvement of K^+/Na^+ ratio and thus increase salt tolerance in grafted plants. Commonly, improving K^+ absorption is known mechanism to decrease Na^+ accumulation in plant biomasses which reducing Na^+ toxicity (Blumwald, 2000). In addition, potassium plays a vital role in activation of many enzymes related to chlorophyll formation, photosynthesis activity and regulated the stomata opining to reduce water losses as well as improves the activation of antioxidant systems of stressed plants (Akram and Ashraf, 2011; Yanyan *et al.,* 2018), which modulating the adverse effect of salt condition. In this respect, it can be concluded that grafting tomato on salt tolerant rootstocks could be a successful tool to improve tomato growth and production in areas that straggle saline irrigation application in protected culture.

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