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Effect of Grafting Tomato on Different Rootstocks on Growth and Productivity under Glasshouse Conditions

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Abstract: The aim of this study was to determine the effect of growing tomato on different root stocks on its growth and yield. In this study, tube grafting method was adopted since it has been widely used with high percentage of success. Tomato (*Lycopersicon esculentum* Mill.) cultivar Cecilia F1 was grafted using tube grafting method on three rootstocks, Beaufort, He-man and local Syrian tomato which were grown under glasshouse and fertilized according to the routine fertilization program with macro and micronutrients in ASTRA farms, Tabuk, north-west of Saudi Arabia. Plants produced from grafting Cecilia F1 scion on Beaufort rootstock were the tallest (37.56 cm) and had the greatest number of leaves (7.22) and stem diameter (4.92 cm). Six weeks after of grafting seedling leaves contents of Ca, Na, Mg, Fe and K increased and while the roots contents were not affected. Chlorophyll a and carotenoids significantly increased. The productivity of grafted tomato planted in glasshouse increased significantly and had reached up to 21%. Grafting also increased Total Dissolved Solids (TDS) and decreased the amount of lycopene in all grafts but β-carotene increased in Cecilia on Beaufort (5.46 mg kg^{-1}) and decreased in both Cecilia on He-man and Cecilia on local Syrian tomato fruits. It is concluded from this study that grafting significantly affected tomato growth and yield depending on the different rootstocks utilized.

Key words: *Lycopersicon esculentum*, *Lycopersicon hirsutum*, grafting, rootstock, scion, tomato, chlorophyll, minerals, trace-elements

INTRODUCTION

Tomato is one of the most popular and widely used vegetable crops in the world according to FAO. Syria produced 923200 tons of tomato from an area of 17100 ha in 2003, 384000 tons of which were from covered area. Saudi Arabia produced 500000 tons of tomato in 2007 from 17000 ha (FAO, 2009). In 2002 Saudi Arabia produced 159048 tons of tomato from 1690 ha of covered area only.

Various research groups have conducted research on how to improve tomato production especially during off-season. Grafting is a common method for vegetative reproduction in fruits and ornamental plants. However, grafting of vegetables has been spreading in greenhouses and open fields (Pogonyi *et al*., 2005) and it is a common technique in tomato especially in Asia (Lee *et al*., 1998). Many researchers found interaction between rootstock

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and scion which led to vigorous root system and higher absorption of water and minerals resulting in improving fruit yield and quality (Lee, 1994; Oda, 1995; Bersi, 2002; Leoni *et al*., 1990) from lower plant population (Core, 2005; Yetisir and Sari, 2003). Also grafting on suitable rootstock improves the resistance to salt stress (Romero *et al*., 1997), resistance to low root temperatures (Bulder *et al*., 1991) and heat stress (Rivero *et al*., 2003), synthesis of endogenous hormones and production of aerial parts (Zijlstra *et al*., 1994), resistance to soil-borne diseases (Bersi, 2002; Augustin *et al*., 2002) and also involved in the utilization and metabolism of macronutrients (Ruiz *et al*., 1996; Ruiz and Romero, 1999). There are a few reports on vegetables grafting under Saudi Arabia and Syria conditions due to the limited use of this technique in commercial production which is attributed to the high cost of rootstocks and labor. Since grafting is considered an important technique for the sustainable production of fruit bearing vegetables in Korea, Japan and some European countries (Lee, 1994; Oda, 1995), the cultivation of grafted fruit-bearing vegetables has increased greatly nowadays.

The objective of this investigation is to study the effect of grafting tomato on different rootstocks on growth and production under covered condition.

MATERIALS AND METHODS

Seeds of three rootstocks of tomato were sown 10 days before the planting of the scion Cecilia F1 in May, 2007. That was to ensure similar stem diameters at the grafting time. The three rootstocks used in this study were Beaufort (*Lycopersicon esculentum*×*Lycopersicon hirsutum*) from De Ruiter seeds, He-man (*L. esculentum*×*L. hirsutum*) from Syngenta Seeds B.V. and local Syrian tomato seeds from Syrian farmers in As-Suwayda located Southwestern of Syria which is known for its low temperatures that these tomato seedlings can tolerate. Cecilia F1 seeds were obtained from GSN French Company. All scion seeds were sown in a peat moss substrate in 96 holes trays inside a fiberglass greenhouse in ASTRA Farms at Tabuk, Kingdom of Saudi Arabia. Grafting was done using tube grafting technique 18 days after sowing of scion seeds. The grafted plants were kept under a transparent plastic cover at 28°C and around 90% relative humidity. The grafted seedlings were established nine days after grafting. Then 60 grafted seedlings of each of the three grafts indicated above, in addition to Cecilia (non-grafted), were planted in a randomized block design with three replications each of which was consisting of 20 plants in a glass house, four weeks after grafting. The spacing between plants was 20 cm and that between rows was 60 cm (i.e., the plant density was 2.6 m^{-2}). Routine cultural practices were followed for irrigation, fertilizer and pesticide application. The plants were removed from the glasshouse after 186 days.

The productivity of the grafted tomato plants as measured by compatibility, height, stem diameter and the number of leaves at 3, 4, 5 and 6 weeks post grafting was recorded for 60 seedlings from each treatment. Five seedlings of each graft were then used to measure the leaf area (cm^2) by AAC-400 (Hayashi Denkoh Co.) and the fresh and dry weight of leaves and roots, at week six after grafting. Cations and trace elements in seedlings were measured by using AAS (Atomic Absorption Spectrophotometer) 2380 Perkin-Elmer after digestion with nitric/perchloric acid. Spectrophotometer was used to measure chlorophyll a, b, total chlorophyll and carotenoids at week six according to the following equations:

$$\text{mg chlorophyll a/g tissue} = 12.7(\text{O.D.})_{663}\text{-}2.69(\text{O.D.})_{645}\text{* v/w*100}$$

$$\text{mg chlorophyll b/g tissue} = 22.9(\text{O.D.})_{645}\text{-}4.68(\text{O.D.})_{6663}\text{* v/w*100}$$

$$\text{mg total chlorophyll/g tissue} = 20.2(O.D.)_{645}-8.02(O.D.)_{663} * v/w*100$$

$$\text{mg carotenoids/g tissue} = 4.695(O.D.)_{440.5}-0.268(O.D.)_{645}(\text{chlorophyll "a+b"} *v/ w*100$$

Where:
W : Fresh weight in g of plant tissue
V : Final volume of extract in Acetone
(OD): Optical Density at specific wave length (Smith and Benitez, 1955)

Tomato fruits were picked and weighed at intervals throughout the growing season and total yield (kg plant^{-1}) was determined at the end of experiment. Yield of five randomly selected plants from each treatment harvested at day 186 were used for determination of tomato fruit quality properties which include sugar which was determined by HPLC system for sugars (Model 2003, Shimadzu, Japan), soluble solids (measured by refractometer), lycopene concentration which was determined by HPLC system for lycopene analysis (Model 2003 from Shimadzu, Japan) and the pH.

Data were analyzed using the statistical analysis SPSS 16 for Windows. One-way ANOVA was used to determine differences between treatments. Duncan's multiple range test was used and LSD at 5% level of significance was utilized to distinguish between means (Steel and Torrie, 1980).

RESULTS

The success percentage of grafting Cecilia F1 scion on either of Beaufort or He-man rootstocks in this investigation was 99% whereas the success percentage of grafting Cecilia scion on Syrian tomato rootstock was 98%, four weeks post grafting.

The three tomato grafts had variable heights at the early stages of growth, However there was no significant differences observed between their heights and diameters six weeks after grafting (Table 1). The three grafts were also variable with regard to the number of leaves during the course of the six weeks experiment and no much differences were observed between the grafts in that parameter. It is obvious that Cecilia was the best when grafted on Beaufort six weeks after grafting (Fig. 1).

Significant differences were found in the leaf area of all grafted tomato plants compared to the control (Table 2).

There were significant differences among treatments as for fresh and dry weight of leaves of all tomato grafts compared with the control as shown in Table 2. The grafted tomato plants were also more vigorous than the control.

Table 1: Height, diameter and number of leaves of grafted tomato seedlings 3, 4, 5 and 6 weeks after grafting

	After 3 weeks from grafting			After 4 weeks from grafting			After 5 weeks from grafting			After 6 weeks from grafting		
Treatment	Height (cm)	Leaves (No.)	Diameter (cm)	Height (cm)	Leaves (No.)	Diameter (cm)	Height (cm)	Leaves (No.)	Diameter (cm)	Height (cm)	Leaves (No.)	Diameter (cm)
Cecilia on Beaufort	9.10^{a}	2.14^{a}	1.86^{a}	13.81^{a}	2.56^{a}	1.84^{a}	27.44^{c}	4.01^{c}	3.63^{a}	37.56^{a}	7.22^{a}	4.92^{c}
Cecilia on He-man	9.53^{b}	2.09^{a}	1.92^{b}	14.05^{a}	2.70^{a}	2.23^{b}	25.40^{ab}	4.15^{ab}	3.80^{a}	33.50^{a}	6.29^{a}	4.82^{ab}
Cecilia on Syrian	11.03^{c}	2.20^{a}	1.95^{b}	15.37^{b}	2.74^{a}	2.09^{b}	24.34^{a}	3.82^{a}	3.66^{a}	31.16^{a}	6.20^{a}	4.53^{a}

Means in the same column followed by the same superscript letter are not significantly different (p = 0.05) according to Duncan's multiple range test

The fresh and dry weights of roots of grafted tomato plants on Beaufort and He-man increased significantly than the control, Cecilia F1, (Table 2), whereas no significant differences were found between Cecilia on Syrian tomato and the control.

Significant difference existed in leaf content of Ca, Mg, Na, K and Fe for seedlings of all tomato grafts. Significant differences of Zn also existed in the leaf content of Beaufort and He-man grafts only and were not significant in Syria graft, however significant difference of Mn were detected in Syria grafts only (Table 3). Cu content of all three tomato grafts leaves were not significant, whereas Mn content were not significant in Beaufort and He-man.

The root contents of the minerals and trace-elements for Beaufort, He-man and Syrian tomato grafts were variable. Whereas significant differences existed in the root content of Na for Beaufort and of K and Cu for He-man compared with control, no significant differences existed in roots content for any of the minerals and trace- elements for Syrian tomato (Table 4).

Table 2: Leaf area (cm^2) and fresh and dry weight of leaves and roots (g) of grafted tomato plants

		Fresh weight (g)		Dry weight (g)	
Treatment	Leaf area (cm^2)	Leaves	Roots	Leaves	Roots
Cecilia F1	21.8233^{a}	1.50^{a}	0.266^{a}	0.30^{a}	0.1063^{a}
Cecilia on beaufort	138.5567^{c}	6.00^{b}	0.9552^{b}	1.00^{b}	0.3534^{b}
Cecilia on He-man	115.52^{bc}	6.700^{b}	1.1492^{b}	1.067^{b}	0.3936^{b}
Cecilia on Syrian	89.86^{b}	4.433^{b}	0.2808^{a}	0.40^{b}	0.1058^{a}

Means in the same column followed by the same superscript letter are not significantly different (p = 0.05) according to Duncan's multiple range test

Table 3: Minerals and trace-elements in seedlings of grafted tomato leaves

	Ca	Mg	Na	K	Fe	Zn	Mn	Cu
Treatment	(%)				(ppm)			
Cecilia F1	0.71^{a}	0.05^{a}	0.50^{a}	0.50^{a}	52.00^{a}	3.33^{a}	10.33^{a}	2.00^{a}
Cecilia on Beaufort	2.40^{c}	0.29^{c}	0.24^{c}	0.85^{b}	113.00^{b}	48.00^{d}	15.00^{ab}	1.33^{a}
Cecilia on He-man	2.88^{c}	0.40^{d}	0.31^{b}	0.85^{b}	105.67^{b}	25.00^{c}	15.00^{ab}	1.67^{a}
Cecilia on Syrian	1.27^{b}	0.12^{b}	0.90^{b}	0.64^{b}	110.00^{b}	13.33^{ab}	20.67^{c}	2.67^{a}

Means in the same column followed by the same superscript letter are not significantly different (p = 0.05) according to Duncan's multiple range test

Fig. 1: Growth of the three tomato grafts compared to their control six weeks after grafting

As shown in Fig. 1, chlorophyll a and carotenoids significantly increased in the seedlings leaves of Beaufort and He-man tomato grafts five weeks after grafting. Syrian tomato showed significant increase in carotenoids only.

Significant differences were observed in the amount of chlorophyll a and carotenoids of Cecilia on Beaufort and Cecilia on He-man, however that was not the case for Cecilia on Syria except for carotenoids. No. significant increase was observed in chlorophyll b and total chlorophyll in all tomato grafts (Fig. 2).

The productivity of grafted tomato increased by 21% (11.25 kg) for He-man 15% (10.73 kg) for Syrian tomato and 6% (9.81 kg) for Beaufort (Table 5). However the fruit size of the grafted tomato was not greater than the fruit size of the control plants.

Sugar in tomato fruits was significantly greater in plants grafted on Beaufort and on Syrian tomato (4.01 and 4.00, respectively Table 6) and significantly lowers in plants grafted

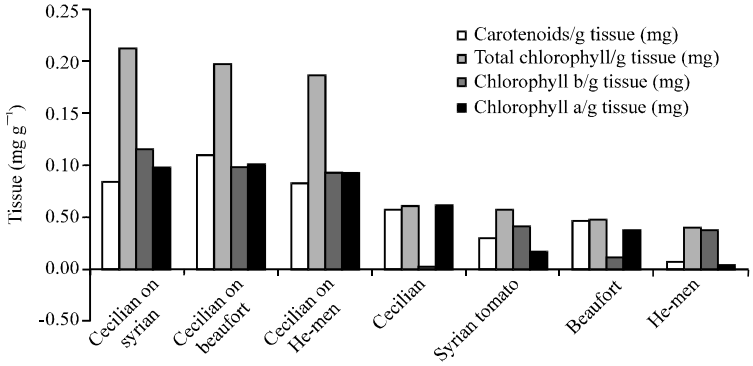

Fig. 2: The leaves contents of chlorophyll a, b, total chlorophyll and carotenoids in the grafted tomato seedlings and rootstocks

Table 4: Minerals and trace-elements in seedlings roots of grafted tomato

Treatment	Ca	Mg	Na	K	Fe	Zn	Mn	Cu
	(%)				(ppm)			
Cecilia F1	0.37^{a}	0.03^{a}	0.02^{a}	0.14^{ab}	34.00^{ab}	0.33^{a}	2.33^{a}	2.67^{a}
Cecilia on Beaufort	0.19^{a}	0.093^{a}	0.09^{b}	0.26^{bc}	62.67^{b}	7.00^{a}	2.00^{ab}	2.67^{a}
Cecilia on He-man	0.33^{a}	0.09^{a}	0.05^{ab}	0.32^{c}	92.67^{b}	7.00^{a}	1.33^{ab}	16.67^{b}
Cecilia on Syrian	0.14^{a}	0.01^{a}	0.00^{a}	0.10^{a}	0.14^{a}	0.01^{a}	0.00^{a}	0.10^{a}

Means in the same column followed by the same superscript letter are not significantly different (p = 0.05) according to Duncan's multiple range test

Table 5: Yield of tomato (kg) and fruit diameter (cm), 186 days from planting in the greenhouse

Treatment	Yield (kg)	Fruit diameter (cm)
Cecilia F1	9.30^{a}	5.40^{b}
Cecilia on Beaufort	9.81^{b}	4.46^{ab}
Cecilia on He-man	11.25^{d}	5.10^{ab}
Cecilia on Syrian	10.73^{c}	4.90^{a}

Means in the same column followed by the same superscript letter are not significantly different (p = 0.05) according to Duncan's multiple range test

Table 6: Acidity, sugar, TDS, lycopene and B-carotene in fruits of tomato four days after fruit picking

Treatment	Sugar (%)	TDS (ppm)	pH	Lycopene (mg kg^{-1})	β-Carotene (mg kg^{-1})
Cecilia F1	3.90^{b}	1981^{a}	4.15^{c}	78.69^{d}	5.42^{c}
Cecilia on He-man	3.80^{a}	2643^{b}	4.15^{c}	49.22^{a}	4.69^{a}
Cecilia on Beaufort	4.01^{c}	2771^{c}	4.09^{a}	64.14^{b}	5.46^{d}
Cecilia on Syria	4.00^{c}	2643^{b}	4.10^{b}	76.69^{c}	4.88^{b}

Means in the same column followed by the same superscript letter are not significantly different (p=0.05) according to Duncan's multiple range test

on He-man (3.8). As for Total Dissolved Solids (TDS), they were found to increase significantly in grafted tomato plants as compared with the control. This may be due to the effect of grafting on fruit quality which is reflected in the main contents of the fruits (Augustin *et al.*, 2002; Pogonyi *et al.*, 2005).

It was also observed that the amount of lycopene in tomato fruits significantly decreased in all three grafts.

As for β-carotene, significant increase was found in Beaufort grafts (5.46) compared with significant decrease in He-man and Syria grafts.

DISCUSSION

Present results in the effect of grafting on the plant height, diameter and the number of leaves of the grafted plants agree with Lee (1994), that variable heights were observed during the early stages of growth, however, no significant differences were observed between the grafted and control tomato plants in both plant height, diameter and the number of leaves parameters six weeks post grafting. this finding agreed with Khah *et al.* (2006) and Pulgar *et al.* (1998), who found an increase in the number of leaves which was probably due to the absorption of water and minerals. Present results on the vigor of the grafted tomato plants agreed with what was reported by Khah *et al.* (2006) who found grafted plants were more vigorous than non-grafted ones.

Grafting increased Ca, Mg, Na, K and Fe contents in leaves of all tomato grafts, however the leaves contents of Zn and Mn was variable. The trace-elements existed in protoplasm of leaves such as Fe, Cu, Mn and Zn ions probably play a role in the enzymatic activity in the cell. Grafting had variable effects on the root contents of minerals and trace elements. It is important to know that the nutrient relationship between the rootstock and scion to prepare a nutrient program subsequent to the transfer of grafted plants to the field or greenhouse (Chaplin and Westwood, 1980).

The occurrence of both chlorophyll a and carotenoids in Beufort and He-man grafts and the occurrence of the later only in the Syrian graft along with lack of any significant differences in chlorophyll b and the total chlorophyll suggests the possible role of the scion/rootstocks interaction in the noticeable increase detected in these substances.

Grafting increased the yield of all tomato grafts which agreed with Khah *et al.* (2006) who attributed these findings to the adaptation of the grafted plants to the environmental conditions, but contradicted with what has been found by Ginoux (1974) and Tsouvaltzis *et al.* (2004) they attributed their results to the stress that plants were subjected to after grafting. Although, grafting increased the yield of the three tomato grafts, it does not seem to have any effect on the fruit size as none of the fruits diameter (Size for any of the three tomato grafts was significantly greater than the size of the control).

With the exception of plant height, diameter, number of leaves and fresh and dry weight of roots of Syrian tomato grafts, grafting seems to be generally involved in the increase of all other parameters such as leaf area, dry and fresh weight of leaves, minerals and trace-elements of leaves, chlorophyll a, b, total chlorophyll and carotenoids of leaves, yield and T.D.S of tomato fruits used in this study. It is interesting that grafting seem to have directly affected tomato fruit quality as it increased the sugar contents and decreased the pH in two of the tomato grafts and significantly decreased the lycopene and variably affected B-carotene contents. The decrease in lycopene agreed with Helyes *et al.* (2009) who found significant decrease in lycopene content of tomato fruits and concluded that the variety of tomato is one of the most important determinants of lycopene content and disagreed with

researcher, who found high lycopene content in tomato fruits. The high content of B-carotene in the Beaufort graft in this study contradicted what was reported by Khah *et al*. (2006). The variability in the results of these two investigations were probably due to the different tomato hybrids and the different grafting techniques used.

It can be concluded that grafting of tomato on suitable rootstocks has positive influence on the crop efficiency under greenhouse conditions. This study also demonstrated that the proper selection of rootstocks activates plant growth and increases the crop yield, hence there is a great potential in application of grafting on tomato plants. Results of this study will probably contribute to a better understanding of rootstock/scion interactions.

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