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Full Length Research Paper

Determining of the yield, quality and nutrient content of tomatoes grafted on different rootstocks in soilless culture

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Using of grafted plants provides a stability and tolerance against biotic and abiotic stress factors in tomato cultivation and increases yield and quality that depend on vigour of rootstocks. This study was conducted to determine the effects of different rootstocks on yield, quality and nutrient contents of grafted tomatoes in soilless culture. In the experiment, cv. Yankı F_1 and cv. Esin Fı were used as plant material. Groundforce, Spirit F_1, ES30501, ES30502, ES30503, body, Beaufort, Titron, 8411, R801 and K-8 were used as a rootstock. Nongrafted and selfgrafted plants were used as control treatments. Marketable yield was obtained increasing rate by 13.85 to 32.73% according to nongrafted and selfgrafted plants. Vitamin C, water soluble dry matter and titratable acidity were not affected significantly by rootstocks. Similarly, use of grafted plants did not affect the nutrient content of tomato fruits significantly.

Key words: Tomato, rootstocks, yield, nutrient content, quality, soilless culture, grafting.

INTRODUCTION

Tomato is one of the most important vegetable crops in respect of growing areas, production and consumption amounts and intensive studies. In recent years, most of the studies carried out on tomato focused on increasing yield and quality, and elimination of the effect of stress factors. For this purpose, alternative methods and new techniques are constantly investigated in tomato cultivation. To increase the yield and quality, less threatening on human and environmental health, and to minimize the effects of stress factors of tomato cultivation is preferable to the soilless agricultural techniques (Letard, 1982; Grillas et al., 2001; Olympios, 2002; Gruda, 2009). Soilless agricultural techniques provide important advantages in tomato cultivation. However, high cost, technical information requirements and disease infections are the most important risks (Gruda, 2009). To obtain higher quality product is even more important in soilless agriculture tomato cultivation due to high cost of production. Therefore, many methods are currently used in soilless agriculture.

Grafting takes an important place among these methods. This technique is still very new in the soilless tomato cultivation, but grafted plants are used for many years in open field and especially conventional greenhouse cultivation. Grafted plants that depend on characteristics of rootstocks in vegetable cultivation provide increasing the yield and quality (Chung et al., 1997; Kacjan-Marsic and Osvald, 2004; Khah et al., 2006; Flores et al., 2010; Rouphael et al., 2010). They also provide stability and tolerance against to salt stress

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Table 1. Nutrient solution concentration according to plant growth period (ppm).

Nutrients	Application Periods*				
	1	2	3	4	5
N	180	200	220	260	280
P	60	65	70	75	90
K	240	260	280	300	360
Ca	150	150	150	150	150
Mg	40	40	40	50	50
S	50	50	50	60	60
Fe	2.8	2.8	2.8	2.8	2.8
B	0.7	0.7	0.7	0.7	0.7
Mn	0.8	0.8	0.8	0.8	0.8
Zn	0.3	0.3	0.3	0.3	0.3
Cu	0.2	0.2	0.2	0.2	0.2
Mo	0.05	0.05	0.05	0.05	0.05

*1. From planting to first flowering;
2. From first flowering to second flower cluster;
3. From second flower cluster to third flower cluster;
4. From third flower cluster to fourth flower cluster;
5. From fourth flower cluster to last harvest.

(Estan et al., 2004; Santa-Cruz et al., 2001, 2002; Martinez-Rodriguez et al., 2008; Colla et al., 2010), low and high temperatures (Bulder et al., 1990; Rivero et al., 2003; Schwarz et al., 2010), and soil borne diseases (Lee and Oda, 2003; Sakata et al., 2008; Louws et al., 2010). The roots of tomato rootstocks have influenced against to many biotic and abiotic stress factors (Leonardi and Romano, 2004; Savvas et al., 2010) as well as capable of high absorption (Ruiz et al., 1997).

Considering on the above-mentioned features, using of grafted plants is important in terms of yield and quality improvement of tomato cultivation in soilless agriculture. Reports about the using of grafted plants in soilless tomato cultivation are limited and also, these studies are considerably new (Oztekin et al., 2007; Lykas et al., 2008; Kubota, 2008; Parra et al., 2009). Therefore, the major aim of this study–is to determine the effects of different rootstocks on yield, quality and nutrient intake of grafted tomatoes in soilless culture.

MATERIALS AND METHODS

The study was carried out in the unheated glasshouse and soilless pot culture conditions in Tokat between April and October in 2009. Tokat Province is located in the central Black Sea region, which is a transitional zone between the East Black Sea Region and Central Anatolia Region with 39° 52' to 40° 55' north latitude and 35°27' to 37° 39 ' east longitude.

Plant materials

In the experiment, Yankı F_1 (Istanbul Tarım Seed Co.) and Esin F_1 (Toros Tarım Seed Co.) tomato cultivars were used as scion. Groundforce (Sakata), Spirit F_1 (Nunhems), ES30501, ES30502, ES30503 (Ergon Seed), body (Bruinsma Seed), Beaufort (De Ruiter), Titron (Western Seed), 8411, R801 and K-8 (Nirit Seed) were used as rootstocks. Nongrafted and selfgrafted plants of cv Yankı Fı and Esin Fı served as controls. Plants were grafted according to slunt-cut grafting technique.

Cultural applications

Grafted plants were kept for 10 days in the grafting unit and then they were kept for 7 days in growth chamber. After that, they were planted in the greenhouse on 20 April, 2009. Double row system was applied in the planting. The seedlings were planted in a perlite filled lay flat pots with a distance 0.8 x 1.2 x 0.25 m between narrow row, wide row and in row intervals respectively. The plants were grown single-stem system. Seedlings were in the same stage during planting. Fertilization was applied to nutrient solution form, and fertilizers are shown according to specified periods in Table 1. Irrigation intervals were determined by draining about 20% of solution that is given in irrigation applications. Samples that belong to drainage nutrient solution were taken every other day, and they were analyzed for pH and EC levels, so pH and salt levels of growing media were monitored in the experiment. Fruits were harvested when they reached marketable maturity (red fruits).

The experiment was designed according to split-plot experimental design with three replications. Observations were done on six plants in each plot.

Observations and analyzes

The first harvest was done on July 16, 2009 in the experiment and it was ended on October 18, 2009. Thirteen harvest were done during harvest period. Fruits were classified according to standards (UN/ECE STANDARD FFV-36) which accepted as internationally in each harvest (Anonymous, 2000). According to these standards, fruits were classified marketable product, which called as first class and second class and others, which are out of these standards,

Table 2. Marketable yield, average fruit weight, unmarketable yield and dry weight.

Rootstocks	Marketable yield (mg.kg^{-1})	Fruit weight (g)	Unmarketable yield (mg.kg^{-1})	Dry weight (%)
Groundforce	15.54 abcd	133.53 bc	1.07	6.94
Spirit	14.51 d	142.43 a	1.05	7.00
ES30501	16.77 a	141.44 a	1.21	7.16
Body	16.43 ab	141.85 a	1.21	7.04
Beaufort	14.88 bcd	130.43 cd	1.33	7.23
Titron	16.71 a	136.80 ab	1.56	7.15
8411	15.32 abcd	140.46 a	0.98	7.60
R801	14.52 d	136.14 abc	1.12	7.33
K8	14.80 bcd	138.07 ab	1.35	7.41
ES30502	15.23 abcd	138.81 ab	1.10	6.94
ES30503	16.23 abc	137.83 ab	1.11	7.00
Selfgrafted	12.34 e	126.67 d	1.52	6.75
Nongrafted	14.73 cd	126.73 d	0.91	7.69
		Cultivars		
Esin Fı	14.76	131.92	1.33	7.33
Yankı Fı	15.70	140.57	1.05	7.01
		Statistical significance		
Cultivar	**	***	*	NS
Rootstock	***	***	NS	NS
Cultivarx rootstock	**	*	NS	NS

NS: Not significant; *, **, and *** refers to significant differences at level of P≤ 0.05, P≤ 0.01 and P≤ 0.001 respectively.

were considered as unmarketable product. Fruit samples, which represent the whole plants, were taken from 3rd and 4th clusters and quality analyzes were done on them. Water soluble dry matter was done with refractometric method, and vitamin C and titratable acidity were done by titrimetric method. Samples in nutrient analysis were burned with wet burning method, and mineral values were determined with ICP-AES (inductively coupled plasma atomic emission spectroscopy).

Statistical analysis

The effects of rootstocks were analysed using ANOVA, with means seperated by the Duncan test (P≤0.05) in the study.

RESULTS

Yield

Marketable yield was significantly affected by rootstocks (P≤0.001) and cultivars (P≤0.01), and it was obtained between 12.34 kg.m$^{2-1}$ (selfgrafted plants) and 16.77 kg.m$^{2-1}$ (ES30501). All of the rootstocks, except for spirit and R801 give higher yield than nongrafted plants. Yankı F_1 had higher yield than cv. Esin F_1. Average fruit weight was determined between 142.43 g (spirit) and 126.67 g (selfgrafted plants), and it was significantly affected by rootstocks (P≤0.001). The lowest average fruit weight was obtained from control treatments. Average fruit weight was also significantly affected by cultivars (P≤0.001) and Yankı F_1 had higher fruit weight. Unmarketable yield was obtained between 0.91 kg.m$^{2-1}$ (nongrafted plants) and 1.56 kg.m$^{2-1}$ (Titron). Unmarketable yield was significantly affected by cultivars (P≤0.05) and Esin F_1 had higher unmarketable yield. Dry weight values were obtained between 7.69% (nongrafted plants) and 6.75% (selfgrafted plants). There was no significant difference among the rootstocks and cultivars.

Esin F_1 had higher dry weight value (7.33%). Marketable yield, unmarketable yield, average fruit weight, dry weight values and their statistical analyzes were given in Table 2.

Quality

Vitamin C values were obtained between 13.97 mg.100g^{-1}

Table 3. Some quality characteristics of tomato fruits according to rootstocks.

Rootstock	Vitamin C (mg.100 g^{-1})	pH	Water soluble dry matter (%)	Titratable acidity (%)
Groundforce	14.41	4.23 bcd	5.55	0.70
Spirit	14.56	4.23 bcd	5.32	0.62
ES30501	14.22	4.10 d	5.40	0.74
Body	14.58	4.41 a	4.97	0.68
Beaufort	14.19	4.26 abcd	5.30	0.66
Titron	14.29	4.16 cd	5.10	0.68
8411	15.22	4.22 bcd	5.65	0.66
R801	15.55	4.22 bcd	5.32	0.64
K8	13.97	4.40 ab	5.03	0.73
ES30502	15.61	4.22 bcd	5.60	0.72
ES30503	15.63	4.19 cd	5.83	0.67
Selfgrafted	14.42	4.31 abc	5.22	0.69
Nongrafted	14.83	4.28 abc	5.45	0.65
		Cultivars		
Esin Fı	14.52	4.24	5.24	0.70
Yankı Fı	14.94	4.26	5.48	0.66
		Statistical significance		
Cultivar	NS	NS	*	*
Rootstock	NS	*	NS	NS
Cultivar x rootstock	NS	NS	NS	NS

NS: Not significant; *, refers to significant differences at level of P≤ 0.05.

(K8) and 15.63 mg.100 g^{-1} (ES30503), and it was not significantly affected by rootstocks. pH values was obtained between 4.10 (ES30501) and 4.41 (Body), and it was significantly affected by rootstocks (P≤0.05). Vitamin C and pH values were not significantly affected by cultivars. The lowest water soluble dry matter was obtained from body rootstock (4.97%), and the highest was obtained from ES30503 rootstock (5.83%), and it was not significantly affected by rootstocks, while it was significantly affected by cultivars (P≤0.05). Yankı F_1 had higher water soluble dry matter (5.48%). Titratable acidity was obtained between 0.62% (spirit) and 0.74% (ES30501), and it was not significantly affected by rootstocks, but it was significantly affected by cultivars (P≤0.05). Esin F_1 had higher titratable acidity (0.70%) than cv. Yankı F_1. Quality characteristic values and their statistical analyzes were given in Table 3.

Nutrient content

Rootstocks and cultivars did not significantly affect on macro nutrient levels (K, P, Mg, and Ca) in tomato fruits. K content in tomato fruits was obtained between 3.03% (K8) and 4.00% (ES30503). P content in tomato fruits was obtained between 0.43% (Beaufort) and 0.50% (K8 and ES30502). Mg content in tomato fruits was obtained between 0.15% (selfgrafted plants) and 0.19% (groundforce, spirit and ES30502). Ca content in tomato fruits was obtained between 0.10% (Titron, K8, ES30502 and ES30503) and 0.13% (selfgrafted plants). Micronutrient contents (Fe, Cu, Zn, Mn, B and Mo) were not significantly affected by rootstocks. Zn (P≤0.001) and Cu, B and Mo (P≤0.05) were significantly affected by cultivars. Fe content was obtained between 24.32 mg.kg^{-1} (Titron) and 35.35 mg.kg^{-1} (groundforce). Mn content was obtained between 8.33 mg.kg^{-1} (body) and 13.05 mg.kg^{-1} (groundforce). Cu content in tomato fruits was obtained between 8.22 mg.kg^{-1} (nongrafted) and 10.59 mg/kg (ES30501). Zn content in tomato fruits was obtained between 10.62 mg.kg^{-1} (Body) and 14.63 mg.kg^{-1} (groundforce). B content in tomato fruits was obtained between 8.87 mg.kg^{-1} (ES30501) and 10.95 mg.kg^{-1} (K 8). Mo content in tomato fruits was obtained between

Table 4. Nutrient contents of tomato fruits according to rootstocks.

	Macro nutrients (%)				Micro nutrients (mg.kg^{-1})					
	K	P	Mg	Ca	Fe	Cu	Zn	Mn	B	Mo
Groundforce	3.72	0.48	0.19	0.11	35.35	8.25	14.63	13.05	9.61	0.39
Spirit	3.76	0.49	0.19	0.11	33.35	9.60	14.01	11.88	10.31	0.63
ES30501	3.85	0.47	0.17	0.11	30.10	10.59	12.31	10.75	8.87	0.37
Body	3.44	0.48	0.17	0.13	26.38	9.70	10.62	8.33	9.67	0.50
Beaufort	3.73	0.43	0.16	0.12	26.21	8.44	11.69	8.60	9.22	0.45
Titron	3.48	0.47	0.18	0.10	24.32	8.74	13.22	9.62	10.51	0.46
8411	3.40	0.49	0.18	0.11	29.68	9.34	13.06	12.69	10.41	0.34
R801	3.47	0.48	0.18	0.11	28.48	8.39	12.17	12.79	9.94	0.36
K8	3.03	0.50	0.18	0.10	35.10	9.45	12.44	9.57	10.95	0.38
ES30502	3.66	0.50	0.19	0.10	32.01	9.07	12.95	10.42	10.19	0.62
ES30503	4.00	0.44	0.17	0.10	28.01	9.20	12.14	10.20	10.66	0.39
Selfgrafted	3.37	0.44	0.15	0.13	33.13	9.16	10.74	11.37	10.20	0.31
Nongrafted	3.52	0.46	0.16	0.12	25.97	8.22	14.52	11.83	10.66	0.32
Cultivars										
Esin Fı	3.73	0.47	0.18	0.11	31.39	9.69	11.69	11.28	11.86	0.39
Yankı Fı	3.42	0.47	0.17	0.11	28.32	8.80	13.62	10.43	9.40	0.33
Statistical significance										
Cultivar	NS	NS	NS	NS	NS	*	**	NS	*	*
Rootstock	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cultivar x rootstock	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS: Refers to not significant; * and ** refers to significant differences at level of $P \leq 0.05$ and $P \leq 0.01$ respectively.

0.31 mg.kg^{-1} (selfgrafted plants) and 0.63 mg.kg^{-1} (spirit). According to rootstocks, macro and micro nutrient contents and their statistical analyzes were given in Table 4.

DISCUSSION

It is known that grafted plants increase the yield by depending on the rootstocks in tomato cultivation which is in regular and under stress conditions (Chetelat and Peterson, 2003; Khah et al., 2006; Leonardi and Giufrida, 2006; Kacjan-Marsic and Osvald, 2004). Qaryouti et al. (2007) indicated that grafted plants, which use soilless tomato cultivation, increases the yield. Those findings agree with our experiment results. Davis et al. (2008) reported that grafted plants increase the average fruit weight. Those also agree with the experiment results. When average fruit weight increased, marketable yield was increased. Unmarketable yield was not significantly affected by rootstocks. This situation can be resulted from low unmarketable yield. In addition, losses, which depend on fertilization disorders, mechanical damage, diseases and physiological disorders, were minimal under controlled conditions such as plant nutrition, irrigation, pruning etc. cultural applications in greenhouse. Martorana et al. (2007) stated that grafted plants have no effect on unmarketable yield. Grafted plants did not significantly affect dry weight. There is no knowledge of the literature on increasing effect of dry weight in grafted tomato plants. Also, Khah et al. (2006) indicated that grafted plants have no effect on dry weight. Those findings agree the with our experiment results.

Quality characteristics were not significantly affected by grafted plants. Some quality characteristics in this study are higher than previous studies. It is considered that they originated from differences in genotype and ecology. Pogonyi et al. (2005); Khah et al. (2006); Martorana et al. (2007) and Ulukapi and Onus (2007) showed that rootstocks have no influence or little bit on Vitamin C, water soluble dry matter and titratable acidity. Their findings agree with our results. Also, it is necessary to consider that these studies were not carried out in soilless agricultural conditions. This study's findings agree with the experiment results, which was carried out in soilless agricultural conditions. It is expected that rootstocks should absorb more nutrients than control plants because they develop strong roots, and they have higher capability on absorbing more nutrients, whereas findings differ according to studies. For example, Mohammed et al. (2009) found that grafted plants have more macro and micro nutrients in their leaves. Djidonou and Zhao (2010) stated that tomato builds up have more macro and micro nutrients in early harvests, but there is no difference between grafted and nongrafted plants in late harvests.

Khah et al. (2006) reported that using of grafted plants have no effect on Zn, Cu, Mn, Fe, Mg and K contents, but have higher Ca and P content. Here, the ecological conditions and training systems of studies, genotype, sample locations and samples taking time for analysis from plants, presence of the stress conditions, and the effect of analyzing methods should be taken into account. Our results were obtained from fruits, which harvest from plants in the middle of harvest period and grown at minimum stress conditions. Our findings agree with some previous experiment results.

Conclusion

Use of grafted plants in soilles tomato production increased the yield together varies depending on the rootstocks. In some rootstocks, grafting were resulted to increase in pH value, but not effected on Vitamin C, water soluble dry matter and titratable acidity. Potassium, phosphorus, calcium, magnesium and micro nutrients content of grafted plants were found higher than nongrafted and selfgrafted plants. But, those differences were not found significantly important. As a result, use of grafted plants in soilles tomato cultivation were raised marketable yield, fruit quality and pH content of fruits depending on rootstocks. Dry weight, Vitamin C, soluble solid water, titratable acidity, and macro and micro nutrients content of fruits were not effected from grafting.

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