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The influence of growth conditions on the yield, chemical composition and sensory quality of tomato fruit in greenhouse cultivation

INTRODUCTION

Tomato is one of the most important horticultural crops in the world. (Flores et al., 2010). The cultivated area worldwide has increased by about 23% during the last 10 years and greenhouse cultivation has become economically important (He et al., 2007; FAO 2009). The most popular and efficient growing medium in the soilless crop are rockwool slabs. Nowadays researchers aim at introducing to horticultural practice other growing media, more environment friendly. New organic substrates have been introduced in hydroponic culture in order to substitute peat, because is a non-renewable resource, and use less rockwool or perlite due to their problematic recycling (Domeno et al..., 2009).

During the past year the primary objective of horticulture was to increase the yield and productivity. However, high quality is even more important than the total yield for attaining competitiveness in modern horticulture due to the beneficial role of vegetables in human diet. New investigations have provided the possibility of improving fruit quality based on the accurate genotype selection, optimization of environmental conditions and agricultural practices such as water management, fertilization strategies, growth system, harvesting stage and grafting (Rouphael et al., 2010). In the past, grafting was used in vegetable crops to limit the effects of soil pathogens (Lee, 1994). According to the recent studies, grafting is a useful technique to enhance nutrient uptake, increase yields, avoid diseases and improve stress tolerance because of the vigorous root system of the rootstocks (Santa-Cruz et al., 2002, Chen et al. 2003, , Bletsos, 2006, Ahmedi et al., 2007, Erismann et al., 2008; Martinez-Rodriguez et al., 2008, Johkan et al..., 2009).

The aim of this work was to estimate the effect of growth media, and grafting on the yield and fruit quality of tomato in greenhouse cultivation.

RESULTS

The experiment was carried out at a Warsaw University of Life Sciences greenhouse with controlled microclimate in 2010 and 2011. The tomato cultivar Admiro F1 was used in the study. Half of the plants were grafted on the rootstock 'Maxifort'. Tomato seeds were germinated in rokwool plugs. Grafting of one part of plants was performed when seedlings developed 1 – 2 leaves, using the procedure of horticultural practice. After the graft was established, grafted and non grafted seedlings were transferred to rokwool pots. When the first truss was visible and non grafted plants were transplanted on two different types of growing medium slabs. Tomatoes were cultivated on organic medium coconut fiber slabs (manufactured by Ceres Intern.), and rockwool slabs (Grodan BV), commonly used as the standard growing medium for tomato. Slabs dimensions in all the cases were 100 x 15 x 7.5 cm (length x width x height). Plants were trained on a single stem up a string according to the high wire system for a long extend growing cycle with a mean density of 2.7 plants m-2 in the whole greenhouse. Tomatoes were fertigated by a computer controlled drip-irrigation system and fertilized with similar rates of macro- and micro-nutrients, according to the levels recommended for tomato. The amount of the nutrient supply ranged from 70 to 200 cm3 per plant and was adjusted to the plant growth phase, light conditions as well as growing medium. Nutrient concentration in the solution, EC (electro-conductivity) and pH were continuously controlled and kept at uniform levels for all experimental objects. The concentration of nutrients (in mg.dm-3) was as follows: N-NO_3 – 210, P – 60, K – 340, Mg – 50, Ca – 200, Fe – 2, Mn – 0.6, B – 0.3, Cu – 0.15, Zn – 0.3, Mo – 0.05. The experiment was established in a random design, in three replicates, with 8 plants in each.

At harvest, fruits were collected to determine their yield and quality. Total yield and fruit structure in the total yield were investigated. Fruits for quality evaluation were harvested at the full colored maturity stage at two different harvest dates: the end of June and the end of September. At each harvest time, 40 fruits were collected from each combination. One part of them was examined for the chemical quality attributes of tomato fruit, such as the content of vitamin C (ascorbic acid) using Tillmans' method, based on 2.6-dichlorophenol-indophenol reduction and expressed in mg per 100 g of fresh weight, the total soluble solids (TSS) content was determined with the digital refractometer and expressed in per cent, the titratable acidity (TA) was measured with the potentiometric method according to the Polish Norm PN-90 A-75 101/04 and expressed as percent of citric acid, and total sugars were analysed according to the Luff-Schoorl method. Dry matter was determined by drying fruit samples at 1050C, in an oven, until reaching a stable weight, and expressed in percent. Nitrates (NO_3) content was determined spectrophotometrically, with the Fiastar device (Tecator, Sweden), using the wavelength of 440 nm, and expressed as mg per 100 g of fresh weight, the content of P with the colorimetric test, the content of K and Ca with the flame method.

Sensory analysis was carried out using the profile method (QDA). It was done by the team of 20 trained panelists in two replication. Ten quality factors, chosen in the initial research, including the odour, texture and taste were assessed. The following attributes were evaluated: tomato odour, strange odour, skin hardness, flesh hardness, flesh juiciness, tomato flavour, taste (sweet, sour, strange) and overall quality. Each panelist marked his subjective evaluation of the investigated sample on a scale – a segment of a straight line with border marks. The marked notes were converted to numerical values in the stipulated units from 0 to 10.

Statistical analysis was performed using the three-way analysis of variance. Detailed comparison of means was done using the Tukey's test at the significance level of α=0.05.

MATERIAL AND METHODS

The obtained results reveal that years of cultivation and the applied growing media significantly affected the yield and its structure in tomato cultivation. A higher yield was characteristic for plants cultivated in 2011 as compared to 2010. Also a higher yield was obtained from cultivation on rockwool slabs than on coconut fiber slabs which shows that rockwool slabs form the substratum of better environmental conditions for the root system. On the other hand, no significant differences were observed in the yield of tomato from grafted and non grafted plants (Table 1). In 2011 higher yield was obtained in Class A (weight 48-93 g) and Class B (weight 93-144 g) and in 2010 in Class BB (weight 144-245 g). The yield of the biggest fruit of the Class BBB (246-484 g) was on the same level in both years of cultivation. The investigated substratum also significantly affected the structure of tomatos. Tomato plants growing on rockwool slabs produced a bigger yield of fruits in Class BB and BBB which were characterized by a bigger weight while plants cultivated on coconut fiber slabs produced a bigger yield of fruits in Class A and B, with a smaller weight of a single fruit. These results may suggest that plants growing on coconut fiber slabs have tendency of producing smaller fruits in contrast with plants cultivated on rockwool slabs. Grafted and non grafted plants were characterized by a similar fruit structure, except fruits with the smallest weight (Class A) whose yield was significantly bigger from non grafted plants as compared to grafted ones which shows that grafted plants produced less small fruits as compared to non grafted plants (Table 1). Similar results were obtained by Passim et al. (2005) and Pogonyi et al. (2005) which shows that grafted tomato and eggplant plants were characterized by bigger fruits as compared to non grafted plants.

The obtained results of the investigations concerning fruit chemical composition show that the bigger effect on the fruit quality was observed by the harvest date than by the substratum used for cultivation and grafting. Fruits from plants cultivated on coconut fiber were characterized by a significantly higher content of vitamin C, while a higher phosphorus content was observed in fruits from the cultivation on the rockwool slabs. The content of the remaining chemical compounds in tomato fruit was at a similar level irrespective of the used substratum (Table 2). Chemical composition of fruits obtained from grafted and non grafted plants was on a similar level except the total sugars content the higher content of which was observed in fruits from non grafted plants (Table 2). Fruits picked in June were characterized by a higher content of total sugars, phosphorus, potassium and calcium and a higher total sugars to titratable acidity (TS/TA) while fruits picked in September showed a higher content of total soluble solids, nitrates and vitamin C. The seasonal variations in vitamin C content were observed in greenhouse-grown tomatoes, and were directly correlated with temperature variations (Liptay at al. 1986). In fact, several works have reported that fruit increase their ascorbic acid levels in response to light (Davey et al. 2000, Dumas et. al. 2003). On the other hand, Raffo et al. (2006) reported no correlation between antioxidant content and mean solar radiation or average temperature. Furthermore, Hernández et al. (2008) maintained that the sampling period is a more influential factor than the cultivar or cultivation methods in the differentiation of tomato samples according to the chemical characteristics. The remaining chemical compounds were at a similar level irrespoctive of the harvest date (Table 2).

The results of the profile assessment of tomato fruits are shown in Figure 1 in a form of a “quality map”, in the space created by the first two main components PC 1 and PC 2, which shows 66.41% of variability in the sensory quality of the analysed cultivar. The location of the analyzed samples of fruits from different combinations on the chart proves their variability in regard to the analysed taste, smell and texture attributes. High notes of tomato flavour and taste were given to fruits from the cultivation on coconut fiber slabs and picked in September and fruits from grafted plants picked in June. Fruits obtained from plants cultivated on rockwool slabs picked at both harvest dates were given high notes for sour taste. High marks for skin firmness and sweet taste were obtained by fruits from grafted plants, which were picked in September. Fruits from non grafted plants picked in June had high noted for flesh firmness and foreing taste, traits which are responsible for a lower quality of tomato fruits. The highest notes for the total quality assessment and flesh juiciness were obtained by fruits obtained from plants cultivated on coconut fiber slabs which were picked in June and fruits from non grafted plants picked in September. This chart shows that the positive and negative attributes mostly depended on the harvest time, and to a lesser degree on the growing media and grafting (Matsuzone et al., 1996, Di Gioia et al., 2010).

Table 1. The yielding of tomato in relation to term of cultivation and growing factors

Factor		Total yield kg m^{-2}	Structure of fruit in total yield kg m^{-2}			
			A	B	BB	BBB
Year of cultivation	2010	33.08 b*	2.21 b	13.59 b	15.79 a	1.56 a
	2011	37.79 a	4.12 a	17.42 a	12.42 b	1.60 a
Substrates	Rockwool	36.51 a	2.62 b	15.01 b	15.17 a	2.14 a
	Coconut fiber	34.37 b	3.71 a	15.91 a	13.07 b	1.03 b
Seedlings production	non grafting	35.22 a	3.39 a	15.59 a	13.73 a	1.52 a
	grafting	35.65 a	2.94 b	15.34 a	14.48 a	1.65 a

BBB – fruit weight: 246–484 g, BB – fruit weight: 144-245 g, B – fruit weight: 93–144 g, A –fruit weight: 48–93 g

*** Means separation at 5 % level; letters assign combination to homogenous groups (Tukey's test), within combination of fruit class and separately: year, growing medium, seedlings production**

Table 2. The content of chemical composition in tomato fruits (mean for 2010 – 2011)

Factor		Dry matter %	Total sugars %	TSS %	Vitamin C mg $100g^{-1}$	TA %	TS/TA	NO_3 mg 100 g^{-1}	P mg 100 g^{-1}	K mg 100 g^{-1}	Ca mg 100 g^{-1}
Substrates	rockwool	4.75 a*	1.99 a	4.45 a	25.69 b	0.33 a	6.26 a	4.97 a	15.95 a	167.55 a	3.24 a
	coconut fiber	4.59 a	1.99 a	4.26 a	30.61 a	0.32 a	6.27 a	4.69 a	14.63 b	167.55 a	3.54 a
Seedlings productin	non grafting	4.58 a	2.10 a	4.32 a	28.65 a	0.33 a	6.59 a	4.79 a	14.74 a	164.02 a	3.38 a
	grafting	4.75 a	1.88 b	4.40 a	27.64 a	0.33 a	5.93 a	4.87 a	15.84 a	171.38 a	3.40a
Time of harvest	June	4.69 a	2.14 a	4.23 b	25.37 b	0.31 a	6.93 a	3.70 b	16.18 a	173.37 a	4.31 a
	September	4.64 a	1.85 b	4.48 a	30.92 a	0.35 a	5.60 b	5.96 a	14.41 b	162.03 b	2.46 b

*** Means separation at 5 % level; letters assign combination to homogenous groups (Tukey's test), one factor analysis: year, growing medium, seedlings production**

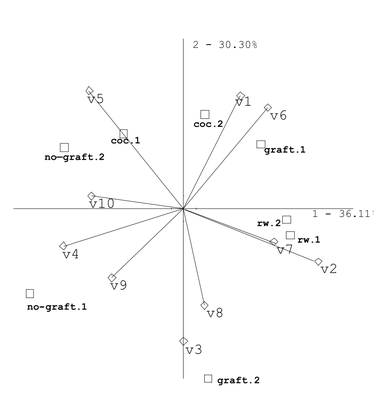

Figure 1. PCA projection of similarities differences and of sensory quality of fruit tomato (2010 – 2011)

The factors of cultivation (points marks numbers) rw. 1 – rockwool first term of harvest, rw. 2 – rockwool second term of harvest, coc. 1 – coconut fiber first term of harvest, coc. 2 – coconut fiber second term of harvest, no-graft. 1 – no-grafting plants first term of harvest, no-graft. 2 – no-grafting plants second term of harvest, graft. 1 – grafting plants first term of harvest graft. 2 – grafting plants second term of harvest.

Attributes evaluated (vectors marks numbers) v1 – tomato smell, v2 – strange smell, v3 – tough of skin, v4 – flesh texture, v5 – juiciness of flesh, v6 – tomato taste, v7 – sour taste, v8 – sweet taste, v9 – strange taste, v10 – overall quality

CONCLUSIONS

1. **A total yield of tomato fruits was bigger from plants cultivated on rockwool slabs than on coconut fiber slabs, which shows that at present a better substratum for tomato cultivated all year round is rockwool.**
2. **Yield structure of tomato fruit depended on the substratum used. Plants cultivated on rockwool slabs were characterized by a bigger fruit weight while those cultivated on coconut fiber slabs showed a tendency for becoming smaller. No significant differences in the structure of fruits obtained from grafted and non grafted plants.**
3. **Chemical composition and sensory quality were mainly affected by the fruit harvest date and to a lesser degree by the substratum used and grafting.**

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