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INFLUENCE OF GROWTH CONDITIONS AND GRAFTING ON THE YIELD, CHEMICAL COMPOSITION AND SENSORY QUALITY OF TOMATO FRUIT IN GREENHOUSE CULTIVATION

Janina Gajc-Wolska, Katarzyna Kowalczyk, Monika Marcinkowska, Jadwiga Radzanowska, Dawid Bujalski

**Chair of Vegetable and Medicinal Plants
Warsaw University of Life Sciences – SGGW**

Abstract

The most popular and efficient growing medium in the soilless crop cultivation consists of rockwool slabs. Nowadays, researchers strive to develop other, more environmentally friendly growing media in horticultural practice. The aim of this work was to assess the effect of growth media and grafting on the yield and fruit quality of tomato in greenhouse cultivation. The tomato cultivar Admiro F_1 was used in the study. Half of the plants were grafted on the rootstock Maxifort. Tomatoes were cultivated on organic medium coconut fiber slabs and on rockwool slabs, the latter commonly used as the standard growing medium for tomato. Total yield and distribution of fruit weight classes in the total yield were investigated. The chemical quality attributes of tomato fruit, vitamin C, total soluble solids, titratable acidity, total sugars, dry matter, nitrates, phosphorus, potassium and calcium were determined. The total yield of tomato fruits was higher from plants cultivated on rockwool slabs than on coconut fiber slabs, which showed that at present rockwool is a better substrate for tomato cultivated all year round. The fruit weight distribution depended on the substrate used. Plants cultivated on rockwool slabs were characterized by higher fruit weight while those cultivated on coconut fiber slabs showed a tendency to grow smaller. There were no significant differences in the distribution of weights between fruits obtained from grafted and non-grafted plants. The chemical composition and sensory quality were mainly affected by the fruit harvest date and, to a lesser degree, by the substratum used and grafting.

Key words: transplant preparation, coconut fiber, rockwool slab, quality fruit.

dr hab. Janina Gajc-Wolska, Chair of Vegetable and Medicinal Plants, Warsaw University of Life Sciences, Nowoursynowska 166, 02-787 Warszawa, Poland, e-mail: janina_gajc_wolska@sggw.pl

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 cultivation consists of rockwool slabs. Nowadays, researchers strive to develop other, more environmentally friendly growing media in horticultural practice New, organic substrates have been introduced in hydroponic culture in order to substitute peat, which is a non-renewable resource, and use less rockwool or perlite due to their problematic recycling (Domeno et al. 2009, Jarosz et al. 2011).

During the past, the primary objective of horticulture was to increase the yield and productivity. However, high quality is even more important than total yield for attaining competitiveness in modern horticulture, arising from the beneficial role of vegetables in human diet. New investigations have created a chance to improve fruit quality based on an accurate genotype selection, optimization of environmental conditions and agricultural practices such as water management, fertilization strategies, growth system, harvesting stage and grafting (Michałoić, Buczkowska 2009, Jadczak et al. 2010, Rouphael et al. 2010, Buczkowska, Michałoić 2012, Majkowska-Gadomska, Wróblewska-Wierzbicka 2013). In the past, grafting was used in vegetable crops to limit the effects of soil pathogens (Lee 1994). According to 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.

MATERIAL AND METHODS

In 2010 and 2011, an experiment the tomato cultivar Admiro F_1 on was carried out at a Warsaw University of Life Sciences greenhouse with controlled microclimate. Half of the plants were grafted on the rootstock Maxifort. Tomato seeds were germinated in rockwool plugs. Grafting of one batch of plants was performed when seedlings developed 1 – 2 leaves, using the standard procedure in horticultural practice. After the graft was established, grafted and non-grafted seedlings were transferred to rockwool pots. When the first truss was visible, 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. Slab 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 extended 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 doses of macro- and micronutrients, according to the levels recommended for tomato. The amount of the nutrient supply ranged from 0.07 to 0.2 dm^3 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 $mg \cdot dm^{-3}$) 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 coloured maturity stage on 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 batch was examined for the content of vitamin C (ascorbic acid) using the Tillmans' method, based on 2.6-dichlorophenol-indophenol reduction; the total soluble solids (TSS) content was determined with a digital refractometer, the titratable acidity (TA) was measured with the potentiometric method according to the Polish Norm PN-90 A-75 101/04 and total sugars were analysed according to the Luff-Schoorl method. Dry matter was determined by drying fruit samples until stable weight in an oven at 105°C. The content of nitrates (NO_3) was determined spectrophotometrically, with the Fiastar device (Tecator, Sweden), using the wavelength of 440 nm; the content of P was assayed with the colorimetric test, while the concentrations of of K and Ca were determined with the flame method.

Sensory analysis was carried out using the profile method (QDA). This was achieved by a team of 20 trained panelists in two duplicates. 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 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 three-way analysis of variance (Anova). Detailed comparison of means was done using the Tukey's test at the significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

The results reveal that years of cultivation and the applied growing media significantly affected the yield and fruit weight distribution in tomato cultivation. A higher yield was characteristic for plants cultivated in 2011 as compared to 2010. Also, plants grown on rockwool slabs yielded higher than on coconut fiber slabs. On the other hand, no significant differences were observed in the yield of tomato from grafted and non-grafted plants (Table 1). In 2011, a higher yield was obtained in Class A (weight 48-93 g) and Class B (weight 93-144 g), but in 2010 more fruits belonged to 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 substrate also significantly affected the fruit weight. Tomato plants growing on rockwool slabs produced a bigger yield of fruits in Classes BB and BBB, which

Table 1

The yielding of tomato in relation to cultivation and growing factors

Factor		Total yield (dt ha^{-1})	Structure of fruit in total yield (dt ha^{-1})			
			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 separated at 5% level; same letters assigned to homogenous groups (the Tukey's test), within combination of fruit class and separately: year, growing medium, seedlings production.

were characterized by bigger weight, while plants cultivated on coconut fiber slabs produced a bigger yield of fruits in Classes A and B, with the 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 to plants cultivated on rockwool slabs. Grafted and non-grafted plants were characterized by a similar fruit weight distribution, except fruits with the smallest weight (Class A), where yield was significantly higher from non-grafted than from grafted plants ones, which shows that grafted plants produced fewer small fruits than non-grafted plants (Table 1). Similar results were obtained by Passim et al. (2005) and Pogonyl et al. (2005), who showed that grafted tomato and eggplant plants yielded bigger fruits than their non-grafted counterparts.

The results of the current investigations concerning fruit chemical composition showed the harvest date had a stronger effect on the fruit quality than to the substrate 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 rockwool slabs. The content of the remaining chemical compounds in tomato fruit was at a similar level irrespective of the substrate (Table 2). Chemical composition of fruits obtained from grafted and

Table 2

The content of chemical composition in tomato fruits (FW) – mean for 2010-2011

Factor	Specification	Dry matter (g 100 g^{-1})	Total sugars (g 100 g^{-1})	TSS (^{0}B)	Vitamin C (mg kg^{-1})	TA (g 100g^{-1})	TSS/TA	N-NO_3 (g kg^{-1})	P (g kg^{-1})	K (g kg^{-1})	Ca (g kg^{-1})
Substrates	rockwool	4.751 *a**	1.990 *a*	4.45 *a*	256.9 *b*	0.33 *a*	6.26 *a*	0.049 *a*	0.159 *a*	1.675 *a*	0.032 *a*
	coconut fiber	4.590 *a*	1.991 *a*	4.26 *a*	306.1 *a*	0.32 *a*	6.27 *a*	0.046 *a*	0.146 *b*	1.675 *a*	0.035 *a*
Seedlings productin	non grafting	4.582 *a*	2.103 *a*	4.32 *a*	286.5 *a*	0.33 *a*	6.59 *a*	0.047 *a*	0.147 *a*	1.640 *a*	0.033 *a*
	grafting	4.751 *a*	1.880 *b*	4.40 *a*	276.4 *a*	0.33 *a*	5.93 *a*	0.048 *a*	0.158 *a*	1.713 *a*	0.034 *a*
Time of harvest	June	4.690 *a*	2.141 *a*	4.23 *b*	253.7 *b*	0.31 *a*	6.93 *a*	0.037 *b*	0.161 *a*	1.733 *a*	0.043 *a*
	September	4.641 *a*	1.852 *b*	4.48 *a*	309.2 *a*	0.35 *a*	5.60 *b*	0.059 *a*	0.144 *b*	1.620 *b*	0.024 *b*

* Means separated at 5 % level; same letters assigned to homogenous groups (the Tukey's test), one factor analysis: year, growing medium, seedlings production.

non grafted plants was on a similar level except the total sugars content; a higher sugars content 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. Seasonal variations in vitamin C content directly correlated with temperature variations were observed in greenhouse-grown tomatoes (Liptay at al. 1986). Also, several reports demonstrated 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 the 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 a cultivar or cultivation methods in the differentiation chemical characteristics of tomato samples. In our study, the remaining chemical compounds were at a similar level irrespective of the harvest date (Table 2).

The results of the profile assessment of tomato fruits are shown in Figure 1 as 'a quality map', in the space created by the first two main components PC 1

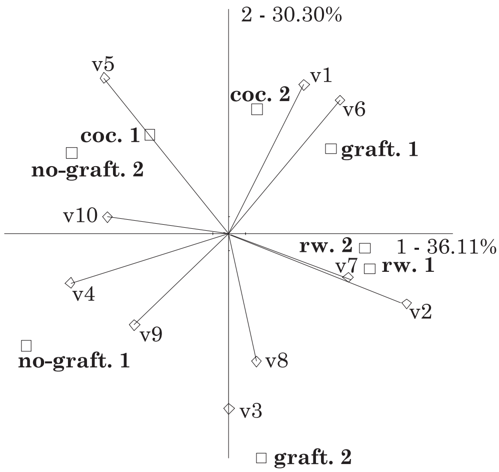

Fig. 1. PCA projection of similarities differences and of sensory quality of fruit tomato (2010-2011). The factors of cultivation (points marks numbers): rw. 1 – rockwool first term of harvest, rw. 2 – rockwool second term of harvest, coc. 1 – coconut fiber first term of harvest, coc. 2 – coconut fiber second term of harvest, no-graft. 1 – non-grafted plants first term of harvest, no-graft. 2 – non-grafted plants second term of harvest, graft. 1 – grafted plants first term of harvest graft. 2 – grafted plants second term of harvest. Attributes evaluated (vectors marks numbers): v1-tomato smell, v2-strange smell, v3-tough skin, v4-flesh texture, v5-juiciness of flesh, v6- tomato taste, v7-sour taste, v8 –sweet taste, v9 – strange taste, v10 – overall quality

and PC 2, which show 66.41% of the variability in the analysed cultivar's sensory quality. The position of 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 which were picked in September from grafted plants. Fruits from non-grafted plants picked in June had high notes for flesh firmness and foreign taste, traits which are responsible for a lower quality of tomato fruits. The highest notes for the total quality assessment and flesh juiciness were scored by fruits from plants cultivated on coconut fiber slabs which were picked in June and fruits from non-grafted plants harvested 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).

CONCLUSION

The total yield of tomato fruits was higher from plants cultivated on rockwool slabs than on coconut fiber slabs, which showed that at present rockwool is a a better substrate for tomato cultivated all year round.

The fruit weight distribution was affected by the substrate. Plants cultivated on rockwool slabs were characterized by a higher fruit weight while those cultivated on coconut fiber slabs showed a tendency for growing smaler fruit. There were no significant differences in the fruit weight distributions between grafted and non-grafted plants.

The chemical composition and sensory quality were mainly affected by the fruit harvest date and, to a lesser degree, by the substratum that was used and by grafting.

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