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THE PRODUCTION OF GRAFTED TOMATOES (*SOLANUM LYCOPERSICUM* L.) IN A MONOCULTURAL SYSTEM

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The possibility of applying different methods in grafting vegetable plants, give the possibility to improve the fruit quality. Genotypes of *Solanum lycopersicum* L. have been grafted on tomato rootstocks distinctively, and the impact of the rootstock on several important fruit quality parameters has been studied. The results obtained from the physicochemical analysis demonstrated that the maximum content of titratable acidity was observed in the control hybrids. The variants V-2 (Abellus + Emperador), V-5 (Lilos + Emperador), V-6 (Lilos + Maxifort) and hybrid V-7 (Beril) had a higher sugar and acid content. Results of evaluated were showed in many parameters in favour of variants. The following morphometric characteristics have been also assessed. The average number of clusters per plant of the non-grafted plant of the V-7 (Beril F1) hybrid was 12.6 compared with 14.3 (V-8) and 14.4 (V-9) pieces of variants. Overall, these results have shown the effectiveness of grafting in terms of plant productivity and the improvement of tomato fruit quality, which are of particular importance, because grafting is a quick and effective alternative to achieve these goals.

Keywords: graft, grafting, hybrid, scion, rootstock

Introduction

The production of vegetables on protected land using a monoculture system has a negative effect on the cultivation environment, the product quality and the productivity of vegetable species. Several authors signal the increase in the degree of aggression of diseases caused by pathogens that can be found in the soil (*Fusarium* spp., *Verticilium* spp., *Pythium* spp., *Phyttophthora* spp. etc.) of protected land, as the result of planting the same species on the same piece of land (Grimault and Prior, 1994; Oda, 1999; Miskovic et al., 2009). Repeated crop cultivation in greenhouse soil often leads to the spread of nematodes, which are difficult

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to fight using the thermal or chemical method (Roşca, 2009; Albacete et al., 2015). The grafting of vegetable plants is used to confer resistance against pathogens in the air and soil, to increase tolerance to abiotic stress factors, to improve water and nutrient absorption, and to increase the vigour of the graft (Lee, 1994; King et al., 2010). The grafting technology has been practiced with great success worldwide. Asia and Western Europe have been practicing this technology for a long time. Japan and Korea are the countries with the largest areas planted with grafted plants. The first scientific researches in the field of vegetable grafting were carried out at Kyusyu University and Korea University in Japan in 1920. They aimed at the establishing the technology of grafted seedlings production and the cultivation of grafted melons; the first rootstock used in research to graft watermelons was *Cucurbita moschata* Duch. Later on, during the second half of the 20th century, other vegetable species such as melons (1931), eggplants (1950), cucumbers (1960), tomatoes (1970) and bell peppers (1985) were commercially grafted (Bogoescu, 2015). Water melons accounts for 93–98% of the total area on which grafted plants grow, cucumber accounts for 72–95%, melons accounts for 35–90%, tomatoes accounts for 42–65% and the sweet peppers accounts for 15–35% of the total area. Greece, Turkey, the United States and Morocco are among the countries with a high share in the cultivation of grafted vegetables. In these countries some crops are cultivated on 100% of their total area; for example, the cultivation of melons in Greece (Taraka-Mavrona and Koutsika-Sotiriou, 2000). Recent studies have shown that the use of appropriate rootstocks helps to improve salinity and water stress in tomatoes (Schwarz et al., 2010; Keatinge et al., 2014). Turhan et al. (2011) reported that the grafting of tomato plants on rootstocks tolerant to abiotic stress had positively enhanced yields, especially of those grown in greenhouses. Also Oztekin et al. (2007) concluded that grafting could increase the tolerance of tomatoes to salinity, and promote the efficiency of water utilisation.

The research was conducted in order to study the growth, development and productivity of tomatoes in protected areas, according to the grafting method and the combination scion-rootstock.

Material and methodology

Biological material

Three hybrids of tomatoes (*Solanum lycopersicum* L.) were selected as the aim of the study and were used as scions, namely Abellus F1 (V-1), Lillos F1(V-4) and Beril F1 (V-7), which were cultivated in greenhouses. Two hybrids were used as rootstocks (Emperador F1 and Maxifort F1), which were characterized by a similar resistance / tolerance to abiotic stress (Rumbos et al., 2011). From them were grafted 6 variants Abellus + Emperador (V-2), Abellus + Maxifort (V-3), Lillos + Emperador (V-5), Lillos + Maxifort (V-6), Beril + Emperador (V-8) and Beril + Maxifort (V-9). Both the scion and the rootstock hybrids were indeterminate and they had round and red-coloured fruit. The phytometric indices of tomato plants were studied according to the combination scion-rootstock in a solar greenhouse (Figure 1). The quality of grafted tomato fruit according to the combination scion-rootstock, and the content of assimilating pigments (mg/g of fresh products) of the grafted tomato plants at the stage of organogenesis were also studied. Thirty days after sowing, when the seedlings reached the stage of two or three leaves on the plant and the diameter of root neck was 2.5 mm, the plants were grafted by copulation and splitting.

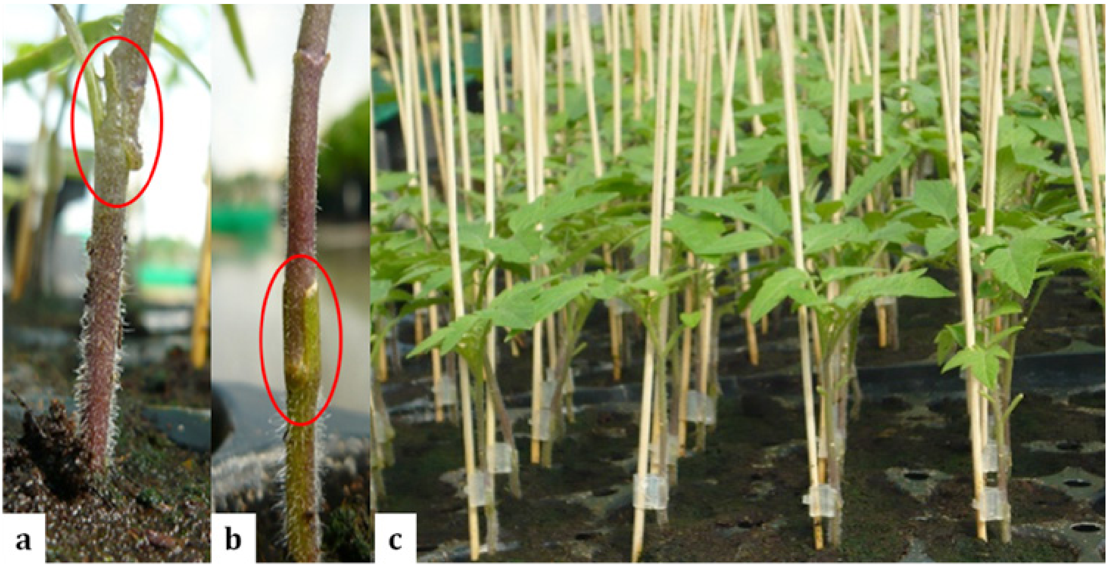

Figure 1 Grafting through the method: a – grafting by copulation, 16 days after grafting; b – grating through displacement; c – 16 days after grafting

The experiments were carried out at the company the SRL "Ecoplantera", which deals with the production of flowers and vegetables seedlings, during the years 2013–2018.

Morphometric analysis

The following properties were measured by morphometric analysis: a) height of stem (cm), b) height of the first cluster (cm), c) thickness of stem (mm), d) number of leaves (pcs), e) length of internodes (cm), f) number of leaves between two clusters (pcs), g) average number of flowers cluster (pcs), h) number of clusters per plants (pcs). The 9 variants of *Solanum lycopersicum* L. were measured using a ruler (a, b, e) and digital calliper (c).

Physicochemical analysis

Chemical analyses were provided for all 9 variants of fresh tomato fruit. We determined following characters: a) dry matter content (%), b) amount of sugar (%), c) titratable acidity (pH), d) malic acid (%) per 100 g of fresh fruit, e) firmness of fruit (kgf/cm^2) comparing texture and structure between mature peeled fruits and fruits with peel.

Statistical analysis

It was evaluated the variability of the test files in each character using descriptive statistics. For the characteristics of the files, it was used the basic descriptors of variability: average, the coefficient of variation (%), deviation from the mean. Data were analysed and differences between means compared through the Tukey-Kramer test ($\alpha = 0.05$).

Results and discussion

During the growth stage of the plants, a series of biochemical and morphometric measurements and phenological observations were performed at different stages of the plants' development. These indicators were better ninety days after the plants planting. The grafting of tomato plants had a significant effect on the vegetative growth (Table 1).

The results were similar to the results obtained by Khah et al. (2006), Gutul and Iliev (2017). They specified that grafted tomato plants were more vigorous and healthier than the control plants.

Table 1 Phytometric indices of tomato plants according to the combination scion-rootstock in a solar greenhouse

Parameters	Variant								
	V-1	V-2	V-3	V-4	V-5	V-6	V-7	V-8	V-9
Height stem (cm)	245	251	247	250	260	312	263	262	265
Height first cluster (cm)	22.3	27.4	23.4	38.2	33.7	34.4	26.4	19.5	19.3
Thickness stem (mm)	12.0	14.3	13.9	12.7	14.6	13.5	12.9	13.9	13.5
Number leaves (pcs)	32.6	33.6	33.0	33.0	33.0	30.5	29.1	32.5	35
Length internodes (cm)	7.4	7.3	6.4	6.3	6.0	7.5	6.7	7.8	7.7
Number leaves between two clusters (pcs)	3.1	2.5	2.8	2.7	3.1	2.9	3.4	2.8	2.4
Average number flowers cluster (pcs)	6.2	6.4	5.8	4.3	5.8	5.3	5.1	6.3	6.4
Number clusters (pcs)	10.4	14.9	12.4	10.7	13.6	15.1	12.6	14.3	14.4

During the growth period of the grafted plants, the morphometric parameters such as the average number of flowers per cluster, the number of clusters per plant, the thickness of stem, etc. increased significantly because of the influence of the rootstock, in comparison with the control group of plants (Figure 2). On all the rootstocks, the clusters of the grafted plants had a larger number of flowers compared to the plants which had not been grafted. For example, the average number of clusters per plant of the non-grafted plant of the V-7 (Beril F1) hybrid was 12.6 compared with 14.3 (V-8) and 14.4 (V-9) pieces, respectively, in the plants grafted on the Emperador F1 and Maxifort F1 rootstocks. These differences are due to the fact that they had been positively influenced by the vigorous growth of the rootstock. Due to a more developed root system of the selected rootstocks, a better absorption of nutrients and water happened (Mohammed et al., 2009), and as a result of it, an increase in fruit productivity and quality could be observed. Thus, plant grafting in an intensive system is a good alternative to common technologies. It helps to obtain cost-effective production.

Figure 2 Measurement of the phytometric indications of tomato plants: a – length of internodes, b – diameter of the stem, c – number of leaves between two clusters

The increased number of tomatoes on the grafted plants could be attributed to the excessive growth of plants (Table 2).

Table 2 Quality of grafted tomatoes depending on the scion-rootstock combination

Variant	Dry matter content (%)	Amount of sugar (%)	Titratable acidity, pH	Malic acid (%)
Abellus	5.20±0.050	4.1±0.000	4.38±0.005	0.44±0.005
Abellus + Emperador	5.12±0.110	5.0±0.000	4.26±0.005	0.44±0.005
Abellus + Maxifort	4.50±0.000	4.6±0.110	4.36±0.010	0.43±0.005
Lilos	4.98±0.150	4.8±0.110	4.26±0.005	0.51±0.002
Lilos + Emperador	4.90±0.150	4.8±0.230	4.25±0.003	0.56±0.005
Lilos + Maxifort	4.90±0.150	4.9±0.110	4.26±0.013	0.41±0.005
Beril	5.20±0.000	5.0±0.000	4.29±0.010	0.46±0.001
Beril + Emperador	4.40±0.000	4.2±0.110	4.23±0.017	0.44±0.010
Beril + Maxifort	4.60±0.000	4.7±0.110	4.28±0.010	0.54±0.002

Table shows the value of the titratable acidity and dry matter content in the tomato fruit grafted on two different rootstocks. The results obtained from the physicochemical analysis demonstrated that the rootstocks had affected neither the pH value of the titratable acid nor the soluble dry matter content in tomato fruits, which falls within the value range of 4.38–4.23%; its maximum content was observed in the control hybrids. Similar results were reported by Arvanitoyannis (2005), who stated that grafting had not affected to the pH value of tomato fruit. Turhan et al. (2011), Echevarria et al. (2012) and Gajc-Wolska et al. (2010) observed that grafted tomato plants had improved the yield and components of the fruit. The pleasant taste is the result of a balanced ratio between acidity and sugar content, and the tomatoes which have a sweet-sour taste are the most appreciated.

On the basis of soluble dry matter content, and by reading the values, the content of carbohydrates and acidity (expressed in malic acid equivalent) in the tomatoes fruit was also determined. Concerning the sugar-acidity balance, it can be seen that variants V-2 (Abellus + Emperador), V-5 (Lilos + Emperador), V-6 (Lilos + Maxifort) and hybrid V-7 (Beril) had a higher sugar and acid content (Table 2). The grafted plants had a more favourable balance between the content of sugar and acids. It is very important to know the firmness of the fruit which results from the interdependence between texture and structure, because it allows determining the time of harvest, the mode of harvesting, packing and transporting, as well as the quality and the storage life of tomatoes.

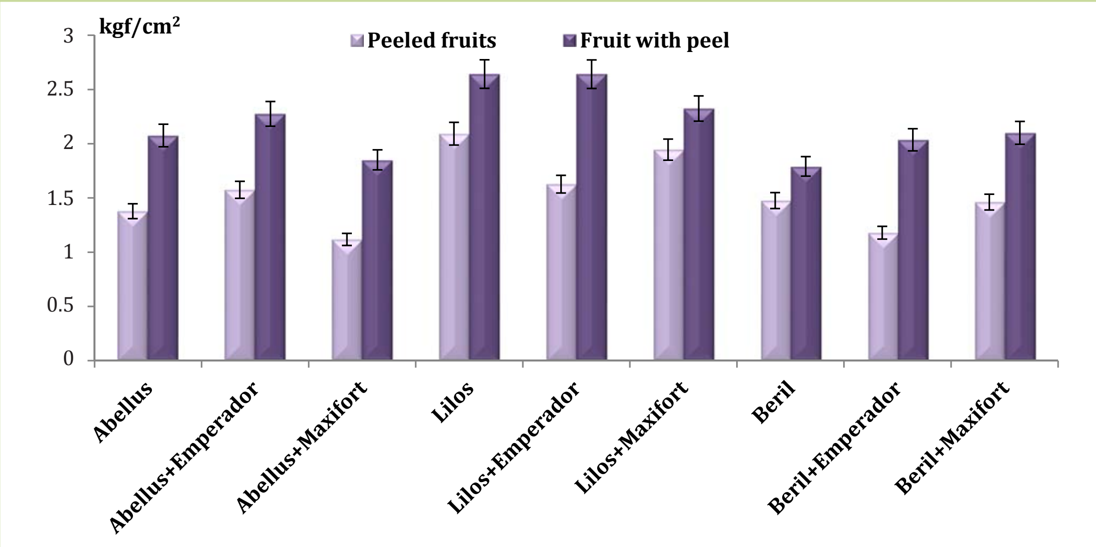

Figure 3 Structural and textural firmness of scion-rootstock tomato fruit

Concerning the "structural and textural firmness" index, all variants were resistant to transportation and storage, but variants V-3 (Abellus + Emperador), V-5 (Lilos + Emperador) and hybrid V-4 (Lilos) proved to be more resistant (Figure 3). Based on the results obtained in the experiments, it is obvious that the grafting of tomatoes on the Maxifort F1 and EmperadorF1 rootstocks has had a very important impact on the growth and development management of the plants. This technique, in most cases, hurries the flowering process which results in quantitative and qualitative production gains. The analysis of the biochemical and morphometric characteristics of the aerial parts of the plants indicates that all the grafted variants have the best indices compared to the control plants.

Conclusions

Our study and analyses of the morphometric and physicochemical characteristics of the aerial part of the plant, it was noticed that the grafted plants had the best results. In terms of sugar content and the balance between sugars and acidity in the fruit of the control plants, hybrid V-7 (Beril F1) was the best; among the grafted plants the variant V-2 (Abellus + Emperador), V-5 (Lilos + Emperador) and V-9 (Beril + Maxifort) were more remarkable. The obtained results represent a balanced sugar-acid ratio for all the variants; it has the key role in establishing the taste. The research has been aimed at demonstrating that the use of rootstocks in tomatoes growing influences positively the biotic stress resistance, increases the productivity and enhances the ability to adapt to the environment.

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