ISSN 1644-0692
www.acta.media.pl

Acta Sci. Pol. Hortorum Cultus, 15(6) 2016, 149-159

EFFECT OF EGGPLANT ROOTSTOCK ON YIELD AND QUALITY PARAMETERS OF GRAFTED TOMATO

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Abstract. The effect of eggplant rootstock on yield and quality characteristics of tomato fruit have been studied in a three subsequent cropping years at the Faculty of Agriculture in Novi Sad, Serbia. Tomato cultivar 'Jeremy' was used as scion and as an ungrafted control, and as rootstock eggplant cultivar 'Madona' and *Lycopersicon esculentum* ssp. *subspontaneum* var. *cerasiformae*. In the case of *Lycopersicon esculentum* ssp. *subspontaneum* var. *cerasiformae* as a rootstock high percentage (82%) of successful grafting was observed, while survival rate of treatment 'Jeremy' as a scion and eggplant 'Madona' as a rootstock was only 68%. A negative effect of grafting on the eggplant rootstock was observed regarding fruit yield per plant, number of fruits per plant and total yield. These parameters were significantly higher in the ungrafted treatments and in the treatment *Lycopersicon esculentum* ssp. *subspontaneum* var. *cerasiformae* as a rootstock. Organic acid and lycopene content was significantly higher when the eggplant 'Madona' was used as a rootstock. Total sugar and vitamin C content was highest in the treatment *Lycopersicon esculentum* ssp. *subspontaneum* var. *cerasiformae* as a rootstock.

Key words: *Solanum lycopersicum* L., scion, fruit yield, organic acids, vitamin C, lycopene

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important cultivated species in the World [Cebolla-Cornejo et al. 2007]. It contains antioxidants, vitamins, organic acids, sugars, minerals, etc., which makes it an important part of human diet. Because of high level of antioxidants in fruits, tomato is important in the prevention of many cancer types and cardiovascular diseases [Takeoka et al. 2001] as well as osteoporosis and diabetes.

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Tomato cultivation is a main source of agricultural income and has vast economic impact in many rural regions. Because of it, continuous cropping is inevitable in the tomato production, especially in protected cultivation [Miskovic et al. 2008]. Continuous cropping has a negative effect on the nutrient status of the medium because of the uneven uptake of different nutrients. Most of the damage from continuous cropping in greenhouses is caused by soil-borne diseases (corky root, fusarium wilt, verticilium wilt and bacterial wilt) and nematodes [Lee and Oda 2003]. Soil-borne diseases used to be controlled by fumigants, mainly with methyl bromide. However, in 1992, methyl bromide was added to the list of the substances that deplete ozone layer in Copenhagen Amendment to the Montreal Protocol.

Being an excellent alternative to methyl bromide application use of grafted tomato seedlings has become fast spreading practice in highly specialized greenhouses [Pogonyi et al. 2005]. In addition to the soil-borne pathogen control, tomato grafting has a number of advantages. Khah et al. [2006] showed that tomato grafting on suitable rootstocks has positive effects on cultivation performance, especially in greenhouse conditions. When produced in infected soils, grafted tomato gave higher yield than ungrafted control [Bersi 2002, Kacjan-Marsic and Osvald 2004, Miskovic et al. 2005]. Synthesis of endogenous hormones increased [Proebsting et al. 1992], water and minerals use was improved [Lee and Oda 2003] and tolerance to drought, salinity and flooding was enhanced in grafted tomato [Estan et al. 2005]. Miskovic et al. [2005] reported better root development in grafted tomato plants. In recent years, number of researches has been done regarding quality of the grafted tomato fruits. Romano and Paratore [2001] as well as Khah et al. [2006] state that grafting did not have an effect on quality of tomato fruits, while Lee [1994] showed that quality traits of tomato were influenced by rootstock.

According to the recent studies, grafting was a useful technique to enhance nutrient uptake, increase yields, avoid diseases and improve stress tolerance because of the vigorous root system of rootstocks [Lee 1994, Bletsos 2006, Leonardi and Giuffrida 2006, Miskovic et al. 2008, Kowalczyk and Gajc-Wolska 2011]. Many cultivars of tomato have a potential to produce fruits with high sugar content. Japanese farmers, in the beginning of 90s, started to use a scarlet eggplant (*Solanum integrifolium* Poir.) as a rootstock for tomato plants to produce fruits with high sugar content [Oda et al. 1996].

The aim of this study was to examine the effect of eggplant rootstock, as an interspecies example of grafting for better taste of fruits. Also we want to investigate possibilities for usage of wild tomatoes as scion for grafting. That can be used in organic production as tool against soil borne diseases. Yield was not only aim, so because of that we did not use any hybrid rootstocks.

MATERIALS AND METHODS

The experiment was conducted in a three subsequent cropping years, from 2007 until 2009, in a plastic tunnel without heating. In this study tomato hybrid 'Jeremy' (SEMINIS), eggplant hybrid 'Madona' (SEMINIS) and *Lycopersicon esculentum* ssp. *subspontaneum* var. *cerasiformae* were used. Treatment design is given in the Table 1.

Table 1. Treatment design of the experiment

Treatments	Description
Jeremy	ungrafted control
Cerasiformae	'Jeremy' as a scion and a *Lycopersicon esculentum* ssp. *subspontaneum* var. *cerasiformae* as a rootstock, grafted control
Madona	'Jeremy' as a scion and 'Madona' as a rootstock

Seeds were sown between 10th and 15th of February in all three years of the experiment. Seeds of the rootstocks were sown two days prior to the sowing of scion seeds. Seedlings were produced in the plastic tunnel with heating. Until the emerging of the tomato plants temperature was maintained at the 25–26°C, and after decreased at 21°C. Seedlings were grafted 25 to 30 days after emerging of the rootstocks and scions, when the stem diameter was 2 mm. Grafting was done by hand using cleft grafting method. During the grafting process it is very important to increase temperature at the 24°C. After the grafting, plants are placed in germination chamber, where the temperature of 20°C and relative humidity of 100% is maintained for 3 days. In next 5 days relative humidity is slowly decreased and temperature was set at 22°C, until the transplanting time.

Grafted plants were transplanted in plastic tunnel without heating between 20th and 25th of April. The experiment was set as randomized block system with three replications, each replication consists of 30 plants. Plants were transplanted at the distance 80 cm between the rows and 40 cm in the row. This spacing gave the density of 3 plants m^{-2}.

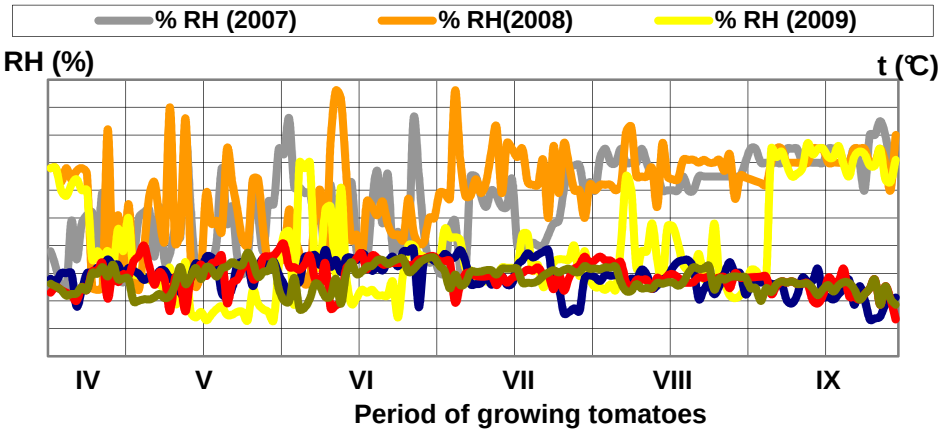


Fig. 1. The values of temperature (°C) and relative humidity-RH (%) in the greenhouse at 12.00 in the period from 2007–2009

During the whole period of growing tomatoes in three years period we measured two meteorological parameters (temperature and relative humidity) in four period per day (in 06.00, 12.00, 18.00 and 24.00 hours). In this work we present in next graph only results from morning measurements (fig. 1).

Tomato was grown in the soil, and soil characteristics are given in the Table 2.

Table 2. Physicochemical properties of soil

Year	Depth	pH in KCl	pH in H_2O	$CaCO_3$ (%)	Humus (%)	Total N (%)	Al P_2O_5 (mg 100 g^{-1})	Al K_2O (mg 100 g^{-1})
2007	30 cm	7.99	8.55	7.98	1.92	0.165	22.3	20.1
2008	30 cm	7.49	8.19	8.5	1.62	0.107	37.3	33.2
2009	30 cm	7.50	7.94	8.5	1.74	0.145	45.3	28.5

Total amount of each fertilizers were applied according to recommendation of Yara company for Serbian market. All quantities are in grams, and same as all producers use. So, aim was to use equal quantities as in normal plastic tunnel production is used. Fertilization and irrigation we combined every second day, and in extreme temperature conditions we irrigated plants every day.

Composition of nutrient solution is given in the Table 3. For the irrigation of tomato plants drip irrigation system was used.

Table 3. Composition of nutrient solution (given amounts of fertilizers are in grams)

Plant growth stage	Ferticare starter 15:30:15	Ferticare I 14:11:25	Ferticare II 24:8:16	Ferticare III 10:5:26	$K(NO)_3$	K_2SO_4	$Ca(NO_3)_2$	EC (mS)
After the transplanting	80	470	350	160	390	–	940	2.2
First flower	290	390	290	130	420	100	780	2.5
2–4 inflorescence	330	450	340	150	680	330	910	2.5
5–6 inflorescence	350	520	390	170	750	380	1040	2.2
Harvest	200	500	380	170	490	270	1000	1.8

Chemical compounds of each fertilizers:
Yara Ferticare starter – 15% N, 30% P_2O_5, 15% K_2O, 2.5% MgO, 1.5% S, 0.01% B, 0.005% Cu, 0.05% Fe, 0.05% Mn, 0.001% Mo, 0.005% Zn; Yara Ferticare I – 14% N, 11% P_2O_5, 25% K_2O, 2.2% MgO, 1.8% S, 0.02% B, 0.1% Cu, 0.1% Fe, 0.1% Mn, 0.002% Mo, 0.1% Zn; Yara Ferticare II – 24% N, 8% P_2O_5, 16% K_2O, 3.9% MgO, 1.3% S, 0.03% B, 0.1% Fe; Yara Ferticare III – 10% N, 5% P_2O_5, 26% K_2O, 2.5% MgO, 1.7% S, 0.01% Fe

Following measurements were recorded: survival rate of grafted seedlings, fruit yield (kg $plant^{-1}$), number of fruits per plant, total yield (kg m^{-2}), pH, total sugar (%), vitamin C (mg 100 g^{-1}), organic acids, lycopene (mg 100 g^{-1}) and dry matter content (%)

in tomato fruit. All the measurements were done on the ripe fruits, which were harvested by hand. Data were analyzed using SPSS 13.0 for Windows.

RESULTS

The effect of grafting on the yield parameters of grafted tomato. The effects of grafting on to two different rootstocks on fruit yield, fruit number and total yield, in three years of experiment, are given in Table 4.

Table 4. Commercial fruit yield (kg plant^{-1}), number of fruits per plant and total yield (kg m^{-2}) of grafted and non-grafted plants in three years of experiment

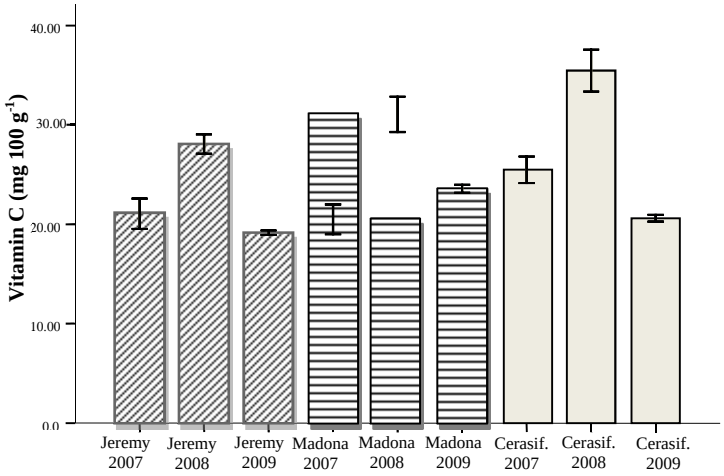
Main factors		Fruit yield per plant	Number of fruits per plant	Commercial yield
Grafting treatment (average for years)	'Jeremy'	4.29 b	33.07 b	12.87 b
	'Madona'	1.98 a	18.16 a	5.93 a
	'Cerasiformae'	4.55 c	33.78 c	13.64 c
Year (average for grafting)	2007	3.49 b	24.32 a	10.47 b
	2008	4.67 c	31.46 c	14.02 c
	2009	2.65 a	29.24 b	7.95 a
Statistical significance	grafting treatment	***	***	***
	year	***	***	***
	interaction: grafting treatment × year	*	***	*

NS – indicate not significant, * – significant at $p \leq 0.05$, ** – significant at $p \leq 0.01$; *** significant at $p \leq 0.001$

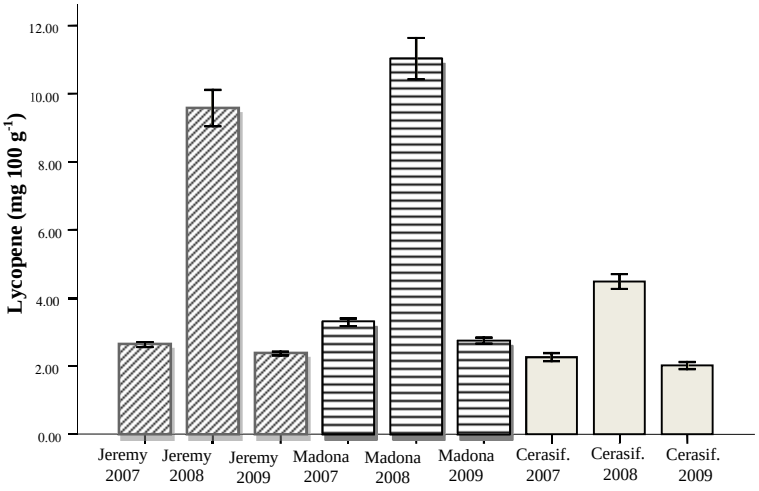
A positive effect of grafting was obtained in the treatment 'Cerasiformae'. In this grafted combination the yield per plant, total yield and also the number of fruits per plant was significantly higher than in non-grafted control 'Jeremy'. However, negative effect of the grafting was observed when eggplant hybrid 'Madona' was used as the rootstock. All the observed yield parameters were significantly lower in comparison with both non-grafted control 'Jeremy' and grafted control 'Cerasiformae'. Fruit yield per plant ranged from 1.98 kg in the treatment 'Madona' up to 4.55 kg in the treatment 'Cerasiformae'. Number of fruits per plant was lowest in the treatment 'Madona' with 18.16 fruits, 33.07 fruits in the treatment 'Jeremy' and 33.78 fruits in the treatment 'Cerasiformae'.

Table 4 also shows that measured yield characteristics were significantly higher in 2008 in comparison with other two years of experiment. Main factors, grafting treatment and year, were significant at the level of $p \leq 0.001$, while interaction of these two factors was significant at the level $p \leq 0.001$ in 2008 and at the level $p \leq 0.05$ in 2007 and 2009.

a)


Vitamin C (mg 100 g-1)
40.00
30.00
20.00
10.00
0.0
Jeremy 2007
Jeremy 2008
Jeremy 2009
Madona 2007
Madona 2008
Madona 2009
Cerasif. 2007
Cerasif. 2008
Cerasif. 2009

b)


Lycopene (mg 100 g-1)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Jeremy 2007
Jeremy 2008
Jeremy 2009
Madona 2007
Madona 2008
Madona 2009
Cerasif. 2007
Cerasif. 2008
Cerasif. 2009

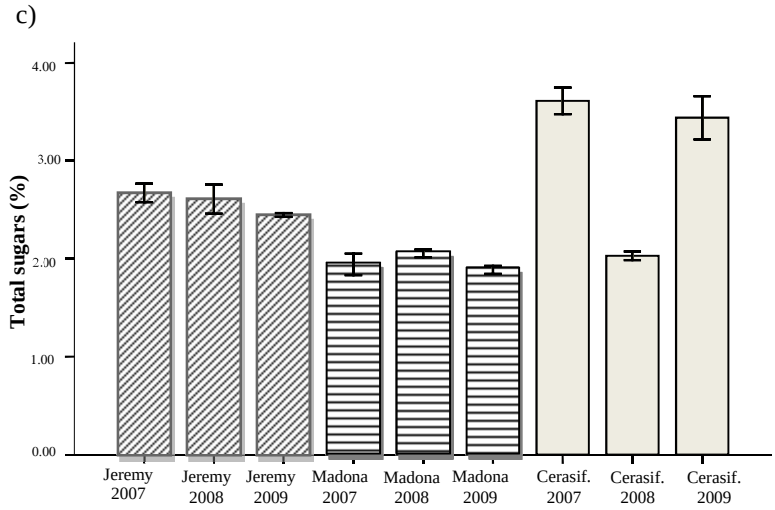


Fig. 2. Concentration of vitamin C (a), lycopene (b) and total sugars (c) in the tomato fruit

The effect of grafting on the quality traits of tomato fruit. Organic acid concentrations, pH and dry matter content of the tomato fruits are given in Table 5. Treatment 'Madona' had significantly higher concentration of organic acids than other two treatments. There were no significant difference among non-grafted control 'Jeremy' and grafted control 'Cerasiformae'. Also, in 2007 concentration of organic acids was significantly higher than in 2008 and 2009. It is observed that main factors, grafting treatment and year, as well as their interaction were significant at the level of $p \leq 0.001$.

Table 5. Organic acids concentration, pH and dry matter content of grafted and non-grafted plants in three years of experiment

Main factors		Malic acid (g dm^{-3})	Citric acid (g dm^{-3})	Oxalic acid (g dm^{-3})	Lactic acid (g dm^{-3})	Acetic acid (g dm^{-3})	Tartaric acid (g dm^{-3})	pH	Dry matter (%)
Grafting treatment (average for years)	'Jeremy'	0.394 a	0.368 a	0.258 a	0.523 a	0.347 a	0.410 a	4.48 b	4.39 b
	'Madona'	0.522 b	0.500 b	0.349 b	0.710 b	0,473 b	0.565 b	4.33 a	4.11 a
	'Cerasiformae'	0.414 a	0.394 a	0.276 a	0.560 a	0.374 a	0.449 a	4.51 b	4.31 ab
Year (average for grafting)	2007	0.494 b	0.479 b	0.329 b	0.676 b	0.446 b	0.560 b	4.21 a	3.91 a
	2008	0.434 a	0.406 a	0.286 a	0.581 a	0.390 a	0.420 a	4.59 b	5.08 b
	2009	0.402 a	0.377 a	0.268 a	0.536 a	0.359 a	0.444 a	4.53 b	3.82 a
Statistical significance	grafting treatment	***	***	***	***	***	***	*	*
	year	***	***	***	***	***	***	***	***
	interaction: grafting treatment × year	***	***	***	***	***	***	ns	ns

NS – indicate not significant, * – significant at $p \leq 0.05$, ** – significant at $p \leq 0.01$, *** – significant at $p \leq 0.001$

As presented in the Table 5 and Figure 2, a significant difference in quality traits of tomato fruit was observed among the treatments. The maximum value of pH 4.51 was in treatment 'Cerasiformae' while 4.48 and 4.33 in treatments 'Jeremy' and 'Madona', respectively (tab. 5). The maximum dry matter content was in the non-grafted control 'Jeremy', 4.39 %, which was significantly higher than in the treatment 'Cerasiformae', 4.31% and 'Madona' 4.11%. The vitamin C and total sugar content was significantly higher in the treatment 'Cerasiforame' than in non-grafted control 'Jeremy' and 'Madona'. Total sugar content was highest in the treatment 'Cerasiformae' 3.03%, followed by 2.58% in the treatment 'Jeremy' and 1.96 % in the treatment 'Madona'. Treatment 'Madona' had significantly higher lycopene content than other two treatments.

DISCUSSION

Grafting of tomato on tomato or eggplant rootstocks is becoming common practice in Asian countries. Researchers from the Asian Vegetable Research and Development Center [AVRDC 2000] recommend grafting scions onto selected rootstocks of eggplant or tomato to minimize problems caused by flooding and soil-borne diseases [Kacjan-Marsic and Osvald 2004]. Significant decrease of the yield and number of fruits was observed when eggplant rootstock was used. This is in agreement with results of Oda et al. [1996] who observed significant reduction of yield (from 13 up to 47%) in a tomato plants grafted on the scarlet eggplant rootstock. In this study grafted control (treatment 'Cerasiformae') had significantly higher yield and fruit number than non-grafted control 'Jeremy'. This result is in agreement with the observations of Pek et al. [2007] who observed significant increase in yield parameters in grafted plants in comparison with non-grafted control. Similarly, Jaksch and Kell [1997] reported increased yield in grafted plants for 15–35% and Oda et al. [1996] found that yield of grafted tomato was up to 68% higher than in ungrafted control.

Hybrid 'Jeremy' has high dry matter content and with grafting it decreased (tab. 5). Romano and Paratore [2001] reported increase in dry matter content when rootstock 'Beaufort' was used and significant decrease when eggplant cultivar 'Energy' was used as rootstock. Khah et al. [2006] also observed that dry weight of grafted tomato plants was greater than in non-grafted plants. Many authors that have studied influence of grafting on pH of tomato fruit showed that grafting did not have influence on this trait [Arvanitoyannis et al. 2005, Christokou et al. 2005]. In our research grafting on the rootstock 'Madona' significantly decreased pH of the tomato fruit, while when tomato rootstock *Lycopersicon esculentum* ssp. *subspontaneum* var. *cerasiformae* was used grafting did not influenced pH of the tomato fruit.

Chemical and physical components of fruit quality are of crucial importance to the consumer [Serrano-Megias and Lopez-Nicolas 2006, Chaib et al. 2007]. Content of primary metabolites such as organic acids and sugars as well as sugar/acid ratio, are known to be an important determinant of taste. High sugar content and acidity result in a good flavor of tomato fruit [Zanor et al. 2009]. However, consumers in the Southeast part of the Europe prefer tomato cultivars with low sugar content and have slightly sour taste [Miskovic et al. 2005]. XiuPing and Miyajima [1997] reported that sugar content

in grafted tomato increased. In our study grafting on the *Lycopersicon esculentum* ssp. *subspontaneum* var. *cerasiformae* rootstock increased while grafting on the eggplant rootstock lowered the sugar content in tomato fruits.

Vitamin C is very important part of the human diet. Grafting on both, tomato and eggplant rootstock significantly increased vitamin C content in tomato fruits (fig. 2 a). Miskovic et al. [2008] also observed that grafting increased the vitamin C content when rootstock 'Madona' was used. Ramandeep et al. [2002] stated that grafting did not show significant difference in vitamin C content in comparison with non-grafted control. In contrast, Turhan et al. [2011] found a decrease for fruit vitamin C content in grafted tomato plants.

Treatment 'Madona' had significantly higher lycopene content (5.69 mg 100 g^{-1}) compared with treatment 'Cerasiformae' (2.92 mg 100 g^{-1}) and 'Jeremy'(4.86 mg 100 g^{-1}). This results agrees with those reported by HeeDon et al. [1997] who found that grafting significantly increased lycopene content in tomato fruits, which improved its nutritional value. In contrast, Mohammed et al. [2009] found a decrease for lycopene in grafted tomato plants.

Chemical composition of fruits had big differences between the observed years. That is in correlation to meteorological conditions that obtained during year 2008. But, all statistical trends were same, so it is important to observe trends, not only values.

CONCLUSION

Although in different countries hybrid rootstocks for grafting have been already used, this experiment demonstrated that other tomato plant species, i.e. subspecies can be also used for this purpose. Grafting of 'Madona' resulted in reduced yield, but organic acid and lycopene content in the fruit was significantly higher. The rootstock of *Lycopersicon esculentum* ssp. *subspontaneum* var. *cerasiformae* also caused increase in the yield and number of fruits, but indirectly it also enhanced vitamin C and total sugars content.

General conclusions of our investigation are that eggplant can also be used as scion for grafting. In that case yields are lower, but quality of fruits are higher. On the other case we also try to use wild tomato as scion, and we achieved both (quality and yield) better than non grafted plants. In this case that can be use in some special type of production (for example in organic production) as good tool against soil born diseases.

ACKNOWLEDGEMENT

Supported by the Ministry for Science and Technological Development of the Republic of Serbia, Project TR- 331009.

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EFFEKT PODKŁADKI BAKŁAŻANA NA PLON I PARAMETRY JAKOŚCI SZCZEPIONEGO POMIDORA

Streszczenie. Badano wpływ podkładki z bakłażana na plon i cechy jakości owoców pomidora w trzech kolejnych latach upraw. Odmiana pomidora 'Jeremy' była użyta do szczepienia i jako nieszczepiona kontrola, natomiast jako podkładki użyto odmiany bakłażana 'Madona' oraz *Lycopersicon esculentum* ssp. *subspontaneum* var. *cerasiformae*. W przypadku 'Madona' oraz *Lycopersicon esculentum* ssp. *subspontaneum* var. *cerasiformae* jako podkładki zaobserwowano wysoki procent (82%) udanych szczepień, natomiast wskaźnik przeżycia dla 'Jeremy' jako zrazu i bakłażana 'Madona' jako podkładki wynosił tylko 68%. Zaobserwowano negatywny wpływ szczepienia na podkładce bakłażana jeśli chodzi o plon owoców z rośliny, liczbę owoców na roślinie oraz plon całkowity. Parametry te były istotnie wyższe przy zabiegach bez szczepień oraz przy

zabiegu z użyciem *Lycopersicon esculentum* ssp. *subspontaneum* var. *cerasiformae* jako podkładki. Zawartość kwasów organicznych i likopenu była istotnie większa, gdy jako podkładki użyto bakłażana 'Madona'. Największą zawartość cukru i witaminy C stwierdzono w owocach podczas zabiegu przy użyciu *Lycopersicon esculentum* ssp. *subspontaneum* var. *cerasiformae* jako podkładki.

Słowa kluczowe: *Solanum lycopersicum* L., zraz, plon owoców, kwasy organiczne, witamina C, likopen

Accepted for print: 5.07.2016

For citation: Miskovic, A., Ilic, O., Bacanovic, J., Vujasinovic, V., Kukić, B. (2016). Effect of eggplant rootstock on yield and quality parameters of grafted tomato. Acta Sci. Pol. Hortorum Cultus, 15(6), 149–159.