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Original paper

Effect of grafting on some Romanian tomatoes cultivated in greenhouse

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Abstract

The research has been conducted in greenhouses where grafted and ungrafted tomatoes have been produced. A Romanian tomato variety and a Romanian tomato hybrid, 'Buzău 1600' and 'Siriana' F1, were used as scions and two of the *Lycopersicon* genus, 'Emperor' F1, 'Groundforce' F1 were used as rootstocks. They were obtained four grafted combinations. For all grafted combinations, the grafting percentage was ranging from 95% to 98%. Both rootstocks utilized have influenced the vigor of the grafted plants. Comparative to the ungrafted plants, the rootstock also influenced the productivity of plants. The highest fructification potential has been observed at 'Siriana' grafted on both rootstocks. Compared to ungrafted tomatoes, which has yielded 2.15 kg per plant, the highest yield obtained from 'Siriana' grafted on 'Emperor' has been of 3.25 kg per plant, followed by 'Groundforce' rootstock with 3.2 kg per plant. 'Buzău 1600' have been produced 3.21 kg per plant when grafted on the 'Emperor' rootstock and 3.15 kg per plant when grafted on the 'Groundforce' rootstock. The largest production augmentation (54.76%) was noted at 'Siriana' tomato grafted on the 'Emperor' rootstock. The 'Buzău 1600' tomato grafted on the 'Emperor' rootstock have registered a 49.3% increment in production. These rootstocks have slightly influenced the content of the soluble dry substance to both grafted tomatoes. The grafting has had an insignificant influence of the total amount of carbohydrates at all grafting combinations.

Keywords

Carbohydrates, grafting, *Lycopersicon* genus, soluble dry substance, yield.

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Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular used vegetable crops in the world. The carbohydrate (2.9-7%), vitamins (A, B, B2, B6, C), salts of important mineral elements (K, P, Fe, Ca, I, Mg) and organic acids (0.5-1.5%) content from tomato fruits is very important (I.O. JERCA & al [1]).

Vegetables grafting is a recent practice which has been introduced in Europe at the end of the 20th century. The grafting of the tomato cultivars onto rootstocks that are resistant to the soil-borne pathogens and nematodes is a method which has improved and spread quickly in the last years. Grafting on *Solanaceae* is an approach to reduce the incidence of disease and pest attack, similar to crop rotation (F. A. BLESTOS & al [2]); this is aimed to produce plants with higher resistance or tolerance to soil diseases (*Fusarium* and *Verticillium*) and pests (nematodes) and to abiotic factors. The grafting is an alternative agronomic practice to increase the vigor and productivity of vegetables specially in greenhouse production systems (N. TARCHOUT & al [3]).

Discrepant results concerning fruit quality provided by grafted plants were reported (A. R. DAVIS & al [4]); research in this regard is evolving. The research in the grafting field began in Horting Institute, Bucharest, Romania at 2002 and continues and up today.

Materials and Methods

Plant materials

The research was conducted between 2015 and 2017 at the Horting Institute Bucharest, Romania and involved two stages:

1. producing grafted tomato seedlings by using specific technology of vegetable grafting;
2. cultivation and comparing the grafted and ungrafted seedlings in a block greenhouse in order to evaluate the growth and the fruit production.

The plant material used were two Romanian tomatoes, the 'Siriana' F1 hybrid and the 'Buzău 1600' variety, obtained from Research and Development Station for Vegetable Growing Buzău, Romania, which were the scions and two rootstocks of the *Lycopersicon* genus, 'Emperador' F1 and 'Groundforce' F1.

This research has been implemented in a randomized complete block design with two grafting combinations and the ungrafted control for each cultivar used. 90 plants were used in 3 replications of 30 plants each for every combination and control, in the following experimental scheme (variants):

- V1 – 'Siriana' × 'Emperador';
- V2 – 'Siriana' × 'Groundforce';
- V3 – 'Siriana', control (ungrafted);
- V4 – 'Buzău 1600' × 'Emperador';
- V5 – 'Buzău 1600' × 'Groundforce';
- V6 – 'Buzău 1600', control (ungrafted).

'Siriana' F1 and 'Buzău 1600' are creations from the germplasm bank of Research and Development Station for Vegetable Growing Buzău, Romania and are being tested as grafted and ungrafted plants cultivated in field and greenhouses at Horting Institute Bucharest, Romania.

'Siriana' F1 is a vigorous, spherical shaped and slightly flattened fruit, red in color, with an up to 150 g in weight, height of 5 cm, diameter of 6.5 cm and 4-5 seminal lodges.

The plant is early (110-115 days), indeterminate and well adapted to field conditions and protected areas.

'Buzău 1600' is a vigorous, spherical shaped fruit, red in color, with an up to 180 g in weight, height of 6.5 cm, diameter of 7.5 cm and 5-6 seminal lodges. The plant is semi-late, indeterminate and well adapted to field conditions and protected areas.

'Emperador' F1 (seed source – Rijk Zwaan company, Netherlands) and 'Groundforce' F1 (seed source – Sakata Seed company, Japan) are two tomato rootstocks very vigorous which impacts the grafted plant with a harmonious growth. These rootstocks are very resistant to the attack of the nematodes and to *Fusarium* sp., *Verticillium* sp. and *Tomato Mosaic Virus*, recommended for protected areas and field production.

Producing grafted seedlings

The grafted and ungrafted seedlings have been produced in a plastic professional greenhouse. The technology for obtaining of tomato seedlings was according the specific technology of solanaceous vegetable grafting.

The seedlings (scions and rootstocks) has been made in 70 alveolar plates with a capacity of 50 ml per alveolus, using as substrate a peat with a grain size 0-10 mm, NPK (1 kg/m³), microelements B, Mg, Cu, Mn, Zn, Fe, S (0.050 kg/m³), calcar (4.7 kg/m³), pH 6 and wetting agent 100 ml/m³.

Scions and rootstocks have been seeded at the same time.

Grafting has been made when scion and rootstock plants have had stem diameters of about 3 mm. The grafting method utilized has been splice grafting by performing a 45° cut on the rootstock stem and a silicone sleeve (tube with split) has been applied over the cut.

The scion stem was cut at a 45° and placed in the tube in a perfect contact with the rootstock.

After grafting, the grafted plants have been placed in callusing tunnels for a period of 7-8 days at a temperature of 23°C, relative humidity of 98-99%, in the absence of light for the first 3 days. Seedlings have been managed by following specific technology for producing vegetable seedlings until they were planted in the greenhouse.

The number of seedlings studied was of 140 for each grafting combination.

Experimental design of grafted and ungrafted tomato culture

The culture was established at the end of May in greenhouse, without heating systems, with a metallic structure, covered in glass. The planting was made in a

density of 20.000 grafted plants per hectare and 27.000 ungrafted plants per hectare.

Tomato culture specific works in protected spaces have been applied during the vegetation time.

Fruit harvesting started in the first decade of July for 'Siriana' and in mid-July for 'Buzău 1600', continuing until the beginning of September.

Biometrical determinations

The survival percentage after grafting was obtained by comparing the number of healthy grafted seedlings to the total grafted plants for each grafting combination.

Biometric determinations have been performed in the vegetation period regarding seedling growth (total weight and root length) and fructification (number of total yield on the plant and per hectare).

Fruit chemical analysis

The analysis has been performed at Horting Institute Bucharest using five fruits per variant, harvested at consumer maturity. The soluble dry substance has been

determined using the WM-7 digital refractometer with a precision of ±0.1% by ATAGO.

The total carbohydrates amount has been determined by the Bertrand method.

Statistical analysis

The results obtained have been statistically processed by the variant analysis method, for 3 levels of significance: 0.05, 0.01 and 0.001. The Duncan test has been used to determine the 0.05 significance level. The regression equation and measurement coefficient has been calculated for both hybrids to highlight the correlation between production and dry substance and between production and carbohydrates.

Results and Discussions

The grafting success has been observed to be between 95% and 98%, which showed a good compatibility between scion and rootstock (Table 1).

Table 1. The percentage of plants resulted from grafting combinations (%)

Rootstock	Scion	
	'Siriana'	'Buzău 1600'
'Emperador'	98a	97a
'Groundforce'	95b	95b

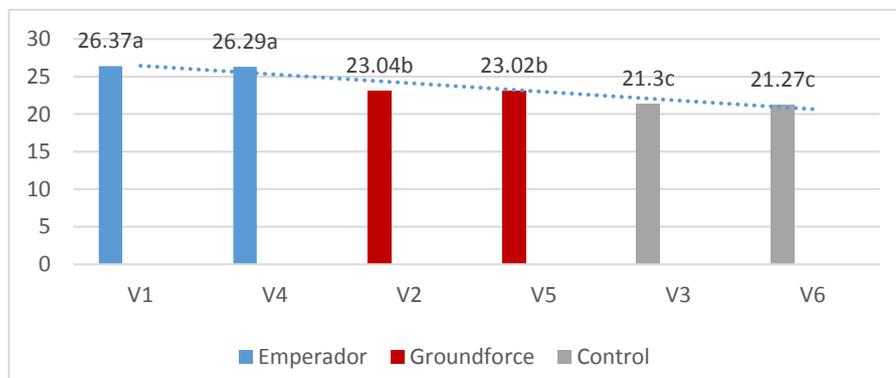
Different letters between variants denote significant differences (Duncan test, p < 0.05).

Survival rate has also been influenced by the stem diameter which the best was 2.5 mm both for scion and rootstock, thus ensuring a perfect cover of the grafting area and a successful vascularization. The compatibility between diameters is outlined by other researchers (M. BOGOESCU & al [5], R. MCAVOY [6]). For a successful grafting, the scion should have the same strain diameter as the rootstock.

The highest survival rate was recorded at the 'Siriana' grafted on 'Emperador' (98%), similar result were recorded at the 'Buzău 1600' grafted on 'Emperador' (97%) and the lowest at 'Siriana' and 'Buzău 1600' grafted on 'Groundforce' (95%).

The total weight of the tomato seedlings has been influenced by the rootstocks.

At the 'Siriana' and 'Buzău 1600' hybrids, the influence of 'Emperador' and 'Groundforce' rootstocks has been visible, the seedlings being 26.37 and 23.02 g total weight in comparison to 21.27 and 21.3 g at control. At 'Siriana' and 'Buzău 1600', the 'Emperador' rootstock has most impacted the total weight of seedlings (26.37 and 26.29 g), then followed the 'Groundforce' rootstock (23.04 and 23.02 g) (Figure 1).

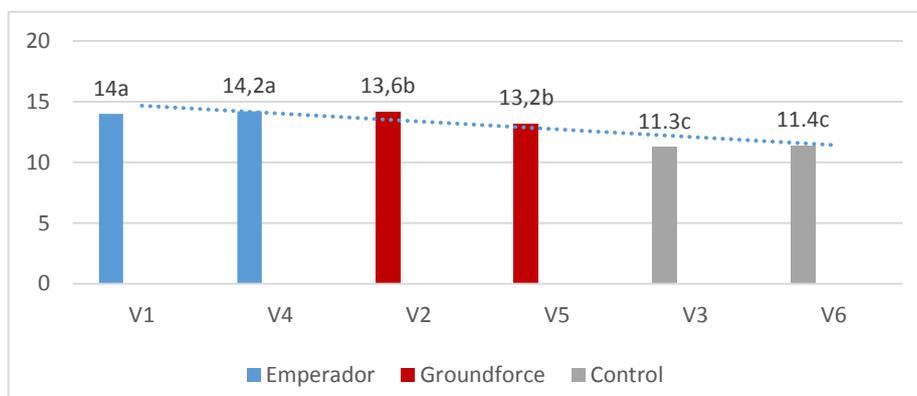


Different letters between variants denote significant differences (Duncan test, p < 0.05).

Figure 1. Influence of rootstock on total weight (g)

At the 'Siriana' and 'Buzău 1600' hybrids, the influence of 'Emperor' and 'Groundforce' rootstocks has been evident, the seedlings being 14.2 and 13.6 cm root length in comparison to 11.3 and 11.4 cm at control.

In 'Siriana' and 'Buzău 1600', the 'Emperor' rootstock had the most influence on the root length of seedlings (14 and 14.2 cm), then followed 'Groundforce' rootstock (13.6 and 13.2 cm) (Figure 2).



Different letters between variants denote significant differences (Duncan test, $p < 0.05$).

Figure 2. Influence of rootstock on root length (cm)

It has been observed that at both grafted hybrids studied, the vigor of grafted plants was higher than control (ungrafted), which demonstrates that tomato grafting is a good method to obtain vigorous plants with high productive potential.

Fructification

The fruit yield of grafted tomatoes has been influenced by the rootstock used.

Regarding the production obtained on plant and on hectare, the rootstock used had an important influence (Table 2 and 3).

Table 2. Fruit yield of 'Siriana' grafted on different rootstocks

Variants	Average production (kg plant ⁻¹)	Difference of production per plant		Average production (t ha ⁻¹)	Difference of production per ha	
		kg	%		t	%
V1	3.25***	1.15	154.76	65.0***	8.3	114.64
V2	3.20***	1.10	152.38	64.0***	7.3	112.87
V3 (Ct)	2.10	0	100	56.7	0	100
LSD 5%	0.14			0.6		
LSD 1%	0.24			0.9		
LSD 0.1%	0.31			1.2		

* = significant at 5%; ** = significant at 1%; *** = significant at 0.1%

V1-'Siriana' × 'Emperor'; V2-'Siriana' × 'Groundforce'; V3-'Siriana', control (ungrafted).

Table 3. Fruit yield of 'Buzău 1600' grafted on different rootstocks

Variants	Average production (kg plant ⁻¹)	Difference of production per plant		Average production (t ha ⁻¹)	Difference of production per ha	
		kg	%		t	%
V4	3.21***	1.06	149.30	64.20***	6.15	110.25
V5	3.15***	1	146.51	63.00***	4.95	108.53
V6 (Ct)	2.15	0	100	58.05	0	100
LSD 5%	0.10			0.7		
LSD 1%	0.21			0.9		
LSD 0.1%	0.35			1.1		

* = significant at 5%; ** = significant at 1%; *** = significant at 0.1%

V4-'Buzău 1600' × 'Emperor'; V5-'Buzău 1600' × 'Groundforce'; V6-'Buzău 1600', control (ungrafted).

Considering fruit yield based on plant at the 'Siriana', the 'Emperador' and 'Groundforce' rootstocks have obtained the largest fruit production of over 3 kg of fruit per plant, compared to the same control on which fruit production per plant was 2.10 kg.

The absolute difference in fruit yield due to rootstock influence has been between 1.15 kg for 'Emperador' and 1.10 kg for 'Groundforce'.

Translated as a percentage, this difference has been between 54.76% for the *Emperador* rootstock and 52.38% for the *Groundforce* rootstock. Tomato production at hectare was higher at grafted plants than control, ranging from 65 tons to 64 tons, compared to 56.7 tons at control.

Regarding production obtained on plant at 'Buzău 1600', the 'Emperador' and 'Groundforce' rootstocks have registered the largest fruit production of over 3 kg of fruit per plant, compared to the same control on which fruit production per plant was 2.15 kg.

The absolute difference in plant production due to rootstock influence has been between 1.06 kg for 'Emperador' and 1 kg for 'Groundforce'.

Translated as a percentage, this difference has been between 49.3% for the 'Emperador' rootstock and 56.51% for the 'Groundforce' rootstock. Tomato production at hectare

was higher at grafted plants than control, ranging from 64.20 tons to 63 tons, compared to 58.05 tons at control.

The highest yield per hectare, has been obtained at grafted 'Siriana' and 'Buzău 1600' tomatoes on the 'Emperador' rootstock.

Analyzing the results obtained, statistically, it has been observed that the grafting has had a significant positive influence on production plant⁻¹ and production ha⁻¹; from a statistical point of view the results were very positive for tomatoes grafted on both rootstocks.

A positive effect of grafting was obtained when 'Emperador' was used as rootstock; the yield of the grafted plants was significantly higher in comparison with ungrafted plants (M. DOLTU & al [7]). The effect of the two rootstocks on the agronomic characteristics of the two tomato cultivars, allow a series of considerations on the feasibility of this technique in the cultivars tested (N.K. MARŠIĆ. & al [8]).

Fruits quality

The content of soluble dry substance in fruits was similar at grafted and ungrafted plants (Table 4). It has been observed that fruits produced from grafted tomatoes had slightly higher dry substance content than those from control tomatoes.

Table 4. Soluble dry substance content and total carbohydrates from tomato fruits

Variants	Soluble dry substance (%)	Total carbohydrates (%)
V1	2.15a	3.13a
V2	2.13a	3.10a
V3 (Ct)	2.08a	3a
V4	2.14a	3.12a
V5	2.14a	3.10a
V6 (Ct)	2.10a	3.05a

Different letters between variants denote significant differences (Duncan test, p < 0.05).

At both rootstocks the content of the soluble dry substance and the carbohydrate content have been slightly higher in fruits produced from grafted plants compared to the ungrafted plants.

Fruit quality, measured in terms of dry matter, concentration of soluble solids, total sugar and vitamin C content, was lower in the fruits of grafted plants than in ungrafted ones, titratable acid content was improved by grafting (A. TURHAN & al [9]).

Analyzing the dependence between fruit yield and soluble dry substance content, a negative dependence was observed at both hybrids, r² = 0.9423 'Siriana' and r² = 0.75 'Buzău 1600' (Figure 3).

Between tomato production per hectare and the total carbohydrate content the coefficient of determination was negative at both hybrids at 'Siriana', r² = 0.9119 and at 'Buzău 1600', r² = 0.9423 (Figure 4).

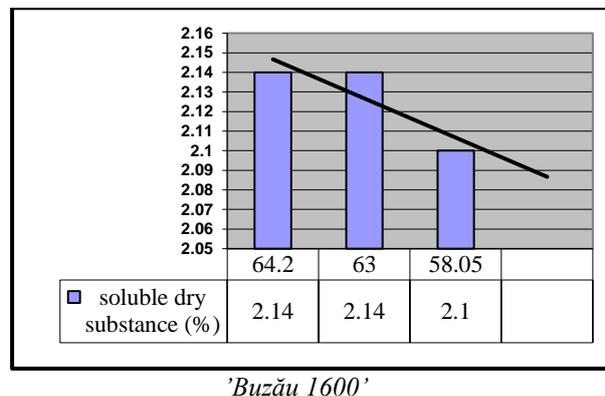
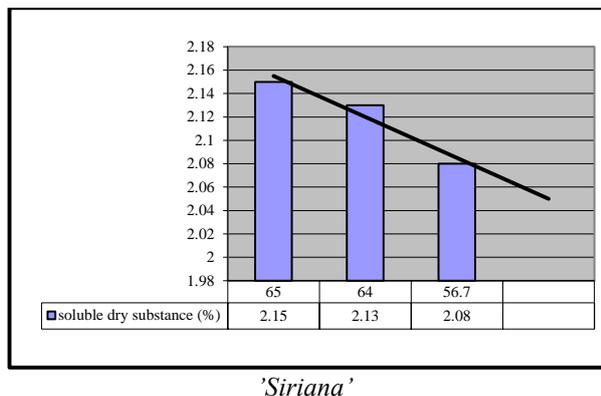


Figure 3. The regression equation between production (t per hectare) and soluble dry substance

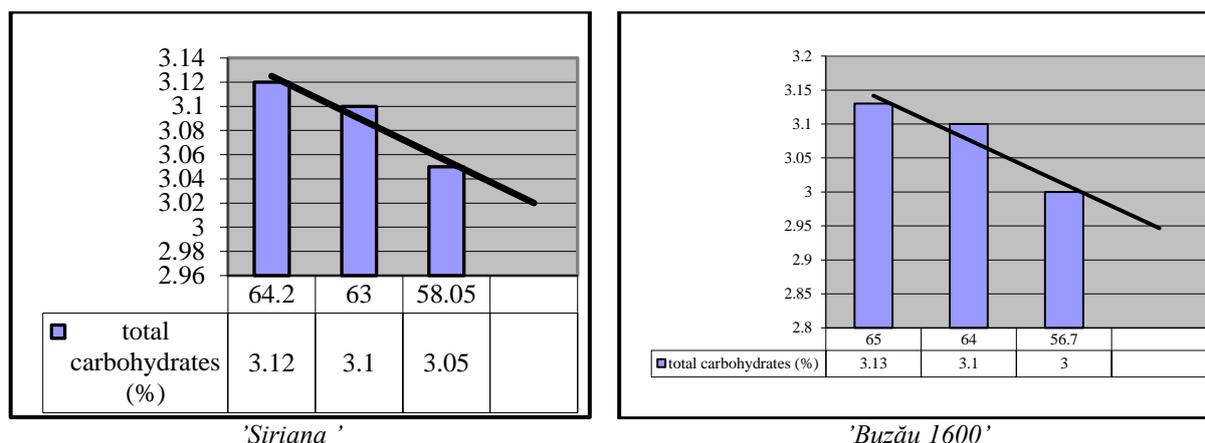


Figure 4. The regression equation between production (t per hectare) and total carbohydrates

Some researchers show that the grafting is a technique to enhance tomato plant growth productivity and quality (N. FERNÁNDEZ-GARCÍA & al [10], M. T. ESTAN & al [11], G. COLLA & al [12]) and fruit quality improvement (A. KRUMBEIN & al [13]; M. Alexandru & al [14]; V. SIMION & al [15]).

Conclusions

This research on the production and cultivation of Romanian grafted tomatoes ('Siriana' and 'Buzău 1600') has shown that this agronomic technique leads to producing plants with superior attributes compared to the ungrafted ones. Analyzing the influence of rootstock on the growth and fructification capacity of the grafted tomatoes revealed that both rootstocks used ('Emperador' and 'Groundforce') had a positive influence on tomato plant growth.

The grafting success was between 95% and 98%, which showed a good compatibility between scion and rootstock.

The total weight and the root length of the tomato seedlings were influenced by the grafting.

Regarding the yield based on plant and on hectare, the grafting had meaningful influence. The highest yield per hectare, has been obtained with 'Siriana' and 'Buzău 1600' tomatoes grafted on the 'Emperador' rootstock.

The fruit content of soluble dry substance was similar at grafted and ungrafted plants. It has been noted that fruits produced from grafted tomatoes had slightly more dry matter content than those from control tomatoes.

There was a negative dependency between the fruit yield and soluble dry substance content, as well as the fruit yield and total carbohydrate content at both hybrids ('Siriana' and 'Buzău 1600').

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