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EFFECT OF GRAFTING ON TOMATO DEVELOPMENT AND PRODUCTIVITY IN THE ECOLOGICAL CULTURE UNDER GREENHOUSE CONDITIONS

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Abstract

Tomato grafting can be considered an important strategy, especially in organic production. This work aimed to evaluate the performance of plant biometric indicators, fruit production quality, and quality indicators of five local tomato varieties Ștefăneşti 30, Ștefăneşti 67, Siriana F1, Costate 23, Ștefăneşti 24 grafted on the rootstock of Solanum sisymbriifolium sp., cultivated in an ecological system in a protected space. The rootstock used in this study increased both the weight of the roots and their number and improved the quality indicators in all the varieties analyzed. The rootstock induced a production increase of 1.4 kg/plant in the Ștefăneşti 22 variety, 1.25 kg/plant in the Costate 23 variety and 2.07 in the Ștefăneşti 30 variety. The use as rootstock of sp. Solanum sisymbriifolium proved to be a good choice to achieve good performance in organic culture. Future, it is recommended to continue additional studies for several years regarding the evaluation of the influence of the rootstock and on the tolerance of the varieties to the attack of the main pests.

Key words*: Solanum sisymbriifolium sp., Lycopersicum L., scion, rootstock, organic culture.*

INTRODUCTION

Grafting has become an environmentally friendly agronomic practice and is widespread even in vegetables. It is known that in ecological agriculture the production of tomatoes is limited compared to that shown in conventional culture. Studies in the field claim that the use of appropriate rootstocks tolerant to biotic and abiotic stress (Rivero et al., 2003) can improve the quality of vegetable plants Caradonia et al., 2020, their tolerance to very high temperatures, to salinity with positive impact on growth, physiological parameters and yield in an ecological cropping system. Currently, tomato grafting can be considered an important strategy especially in organic production, improving fruit yield and processing quality of tomato plants when they are grown in an ecological system under greenhouse conditions (Keatinge et al., 2014). Numerous studies support that the rootstock induces a strong root system that improves tomato production (Ruiz et al., 1997; Vitre, 2002) compared to ungrafted plants. Such studies were observed in watermelon (Ruiz Yetisir and Sari, 2003), cucumber (Pavlou et al., 2002), eggplant (Passam et al., 2005), and tomato quality (Roberts et al., 2005). Numerous studies claim that the well-chosen rootstock can help tomato crops overcome biotic and abiotic stresses (Santa-Cruz, 2001; Ntatsi et al., 2001; Huang et al., 2010; Savvas et al., 2017).

For these reasons, the right choice of rootstock is very important in the success of ecological crops of tomatoes grown in protected space. The right choice of rootstock is expected to address the specific problems and be beneficial for the cultivation of local varieties, with practical utility in ecological agriculture. This study investigates the efficacy of tomato grafting using as rootstock *Solanum sisymbriifolium*, a vigorous wild species considered resistant to biotic and abiotic factors

to improve plant biometric parameters, physiological parameters, quality and yield of five native cultivars grown in a culture system ecologically.

MATERIALS AND METHODS

Collect experimental data

The entire experiment was located at INCDBH Ștefanești, in a protected space of 300 m^2 and followed the influence of the rootstock on plant growth and development indicators, fruit quality and fruit production. 5 local tomato varieties *Ștefănești 30, Șfefănești 67, Stefănești 24, Costate 21* and *Siriana F1* were studied, the first 4 recently approved in our institute. All 5 cultivars were grafted onto *Solanum sisymbriifolium* rootstocks and compared with those grown on their own roots. The whole experience was organized based on organic fertilization. At planting, 0.5 l/plant of Biohumus was applied, and during the vegetation period, foliar fertilizers based on algae were applied, repeated every 14 days. At the end of the experiment, the biometric indicators of the plant were evaluated, such as the weight and number of roots, the diameter of the plants, the quality indicators regarding the fruit content in SSC (% Brix), MA (%), CA (%) and the quality of the harvest were analyzed comparatively.

Production of seedlings

Seedlings (on roots and rootstocks) were obtained in 32 alveolar plates using peat, a professional culture substrate, as substrate. For each variant (variety/portaltoi) 150 seeds were sown. The greenhouse where the observations were made is equipped with an irrigation system, with 16 mm diameter tubes, the emitters being arranged 40 cm apart from each other, recording a flow rate of 1.2-1.5 l/hour.

Control and maintenance of grafted tomato seedlings

As a method of grafting, grafting in simple copulation was used, which involves the sectioning of both symbionts at an angle of 45 degrees. For fixing I used silicone clips with a diameter of 2.1 mm. Therefore, both partners must be approximately 2-2.2 mm in diameter to be able to use 2.1 mm clips (Figure 1). Once the seedlings used as rootstocks and grafts were suitable for grafting, the actual grafting proceeded. Seedlings of wild tomato species reached the optimal size for grafting after 40 days from sowing. The seedlings of the five varieties chosen for grafting reach the optimal size for grafting after about 30 days. Successful tomato grafting was conditioned by a climatic chamber, which would maintain the temperature and humidity at a high level so that the graft would not dehydrate and initiate the process of callusation-welding-vascularization at the grafting point. For the success of a good percentage of grafting in the growth chamber, the temperature was maintained at 24°C and 95% RH during the first 7 days after grafting.

Statistical processing of results

The statistical processing regarding the effect of the experimental factors (varieties and rootstocks) and the effect of the rootstock on the main indicators of quality and productivity indicators was completed by applying the Duncan test, for a level of assurance of 5%. The statistical processing was carried out using the data was done using IBM SPSS 14 software and MS Office Excel 2010. The difference is in the way of calculation and in the fact that the Duncan test is more severe in terms of significance limits.

Figure 1. The programmers for the temperature and RH of the air in the climate room pallet with eight cells planted with grafted seedlings in the growth chamber (original)

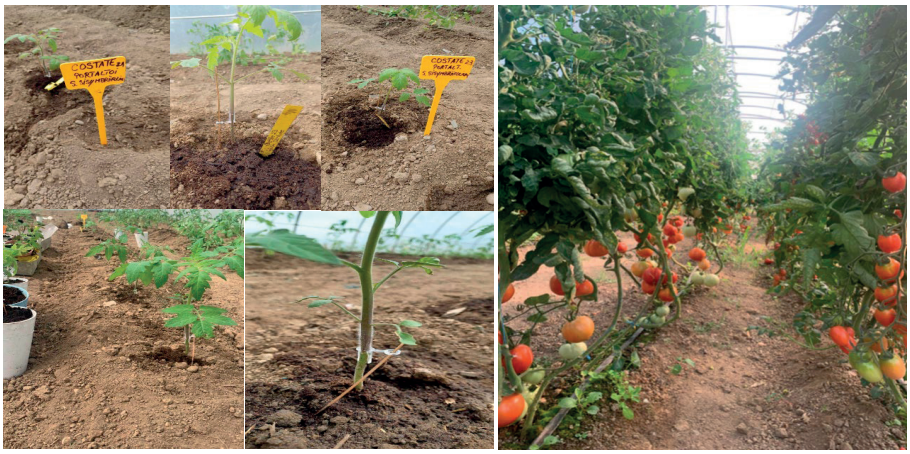

Figure 2. Experimental field image (original)

RESULTS AND DISCUSSIONS

Evaluation of morphology parameters of tomato plants grown in an ecological system

Grafted plants reflect their advantageous properties in organic culture. In this study, total yields and plant stem diameter, plant fresh, and dry weight increased by using rootstock. These results are consistent with studies that show that the effect of grafting changed depending on the other portal genotype (Santa Cruz et al., 2002; Khah, 2005; Öztekin, 2009). In the case of grafting the studied varieties on the *S. sysimbrifolium* rootstock, the root mass recorded significant increases in all the grafted varieties, compared to the control (plants grown on their roots). The highest root mass was recorded in grafted plants, regardless of the variety, the values significantly exceeding the root mass indices in the case of varieties grown on their roots. The rootstock induced the Ștefăneşti 30 variety a weight of the roots by 61.32 g higher than in plants grown on their own roots (Table 1). The same significant differences are also observed in the case of the number of roots formed, the rootstock significantly influenced this indicator in all the grafted varieties, *Solanum sisymbriifolium*, being known to be a very vigorous plant.

Regarding the diameter of the root collar, respectively of the grafting point, the highlighted values are very different and significant, regardless of the variety. The diameter of the plants was influenced by the rootstock, and it varied between 40.73 mm in the Ștefănești 22 variety grafted on *S. sysimbrifolium* rootstock and 29.68 mm, as was evident in the Costate 23 variety, in the case of control plants. All 5 varieties grown on the rootstock recorded significantly higher values than those grafted on their own roots (control) (Table 1). The research results showed that the rootstock *S. sysimbrifolium* rootstock influenced the morphology of the studied genotypes for plant height, diameter, root weight and their number. Rootstock also induced the greatest increases in plant height. The tallest plants were evident in the variety Ștefănești 30 (175.45 cm) in plants grafted on sp. *Solanum sisymbriifolium* which exceeds the height of plants grown on their own roots by 37.00 cm, the differences being significant. For all the varieties analyzed, the plant height was greatly improved in the case of grafting, the differences being significant (Table 1).

Table 1. Effects of grafting on biometric parameters of tomato plants grown in an ecological system

Factor's	Root weight (g)	Root number	Diameter (Rootstock/Scion) (mm)	Plant height (cm)
Ştefăneşti 30 cv.				
Grafted plant	130.10±2.01[a]	87±1.12 [a]	44.78±0.88 [a]	175.45±2.15a
Non-grafted plant (scion)	68.78±1.75[b]	58±0.33 [b]	34.58±0.46 [ab]	138.45±1.38[b]
Ştefăneşti 67 cv.				
Grafted plant	98.85±6.87[a]	88±1.19 [a]	48.41±0.62 [a]	177.59±3.15[a]
Non-grafted plant (scion)	56.93±1.39[b]	49±0.66 [b]	31.28±1.20 [b]	149.78±1.45[b]
Ştefăneşti 24 cv.				
Grafted plant	88.89±[a]	73±2.07[a]	38.89±0.78[a]	152.27±1.25[a]
Non-grafted plant (scion)	64.45±[b]	33±2.51 [b]	31.78±1.25[ab]	138.22±1.99[b]
Costate 21 cv.				
Grafted plant	114.12±1.05[a]	69±1.74[a]	38.13±1.14[a]	159.77±2.01[a]
Non-grafted plant (scion)	90.67±0.98[b]	18±2.25[b]	29.68±2.60[ab]	138.44±2.21[b]
Siriana F1 cv				
Grafted plant	91.45±5.14[a]	48.45±0.45[a]	46.89±2.25[a]	149.45±1.78[a]
Non-grafted plant (scion)	64.56±3.45[b]	34.89±0.15[b]	34.56±1.65[b]	134.89±3.45[b]

Evaluation of the quality parameters of the yields of grafted tomato plants grown in an ecological system

The influence of rootstocks resistant to the abiotic and biotic stress factors of grafting on production and fruit quality indicators have become topics of great interest in recent years (Patanè et al., 2015; Rahmanq et al., 2021). It can be concluded that *S. sysimbrifolium* sp. as a rootstock positively influenced the yield per plant confirming the good performance of the grafted plant, regardless of variety (Table 2). This result confirms the ability to use the *S. sysimbrifolium* rootstock to achieve the productive performance of genotypes from organic crops. The results showed significant differences between the varieties studied and the analyzed parameters, thus allowing growers to select varieties based on consumer requirements and establish the optimal culture technology. The rootstock induced an increase in fruit weight compared to the values shown in the control, the differences being statistically significant. The greatest increases in the weight of fruit were evident in the Ştefănești 67 variety, where the rootstock induced a fruit weight of 114 g higher than in the case of control fruits (Table 2).

The fruit size influenced the fruit weight, the differences being significant regardless of the variety analyzed (Table 2). To obtain good harvest quality, good management of the main technological links is important (Gruda et al., 2018; Sumedrea et al., 2021). During the experiment, it can be observed that the rootstock induced a production increase of 2.2 kg per plant in the Ştefănești 30 variety, 1.0 kg per plant in the Ştefănești 67 variety and 1.43 kg in the Ştefănești 24 variety. The Ştefănești 30 variety recorded productions of 6.6 kg/plant in the case of plants grafted on the *S. sysimbrifolium* rootstock, compared to 4.4 kg/plant, as shown in the control variant. The same significant differences were evident in all the grafted varieties, compared to the control (Table 2). Numerous studies claim that the use of a well-chosen rootstock can improve the quality of the harvest and fruits (Rouphael et al., 2018). The use of *S. sysimbrifolium* sp. as a rootstock increased the weight and number of root roots and the production of tomatoes. These can be due to the development of the roots, but also to a good supply of water and minerals (Mauro et al., 2020). The rootstock taken in the study obviously had a positive effect on the varieties studied, in all cases it increased both the root mass and the number of roots, and induced a higher production, regardless of the variety.

Table 2. The effects of grafting on the quality parameters of the yield of tomato plants grown in an ecological system

Factors	Mean fruit weight (g)	Total fruit number (no plant^{-1})	Production of plant (kg)
Ștefănești 30 cv.			
Grafted plant	380.12±4.30^{a}	17±0.18^{a}	6.6±0.45^{a}
Non-grafted plant (scion)	310.14±3.78^{a}	16±0.21^{a}	4,4±0.12^{b}
Ștefănești 67 cv.			
Grafted plant	371.12±2.50	18±0.33^{a}	6.00±0.42^{a}
Non-grafted plant (scion)	257.12±2.14	20±0.42^{a}	5.0±0.10^{b}
Ștefănești 24 cv.			
Grafted plant	367.13±3.47^{a}	15±0.15^{a}	5.68±0.12^{a}
Non-grafted plant (scion)	257.00±2.89^{b}	16±0.14^{a}	4.25±0.31^{b}
Costate 21 cv.			
Grafted plant	371.48± 3.44^{a}	15±0.22^{b}	5.63±0.45^{a}
Non-grafted plant (scion)	275.33± 3.78^{b}	19±0.68^{a}	5.26±0.54^{a}
Siriana F1 cv.			
Grafted plant	194±2.78^{a}	29±0.89^{a}	5.6±0.24^{a}
Non-grafted plant (scion)	178±2.96b	27±0.78^{a}	4.9±0.33^{b}

The effects of plant grafting on the quality parameters of varieties grown in an ecological system

From Figures 3, 4 and 5 it can be seen that the rootstock did not significantly influence the quality indicators, these being rather a characteristic of the variety and less influenced by the rootstock. Results similar to our study on reported in a recent study on the effects of rootstock on quality indicators and certain organic acids were reported by Doltu (2017). Tartaric acid was reduced in grafting, regardless of the variety, while the content of dry matter and malic acid was high, although the differences are not significant.

According to studies reported by Fernandez-Garci et al. (2004), grafting could be a useful tool for increasing tomato fruit quality by increasing the sugars and acid composition of tomatoes.

Some studies claim that the right choice of the rootstock used in tomato culture can lead to significant increases in the content of sugar and titratable acids in the fruit (Flores et al., 2010; Schwarz et al., 2013).

In this study, even if in the case of the grafted plants the SSC (% Brix) values were higher than in the case of the control variant, they were insignificant.

A higher content of SSC was evident in the case of the Costate 21 variety in the grafted variant (4.91% Brix). These increases could be more due to organic fertilization and less could be attributed to the rootstock.

These increases could be due, on the one hand, to organic fertilization, but it is obvious that they can also be attributed to the rootstock. János Ágoston (2017), states that tomatoes intended for consumption in a fresh state should register values of content in dry matter between 3.5-4.5% Brix, and tomato varieties intended for industrialization must exceed the value of 5% Brix.

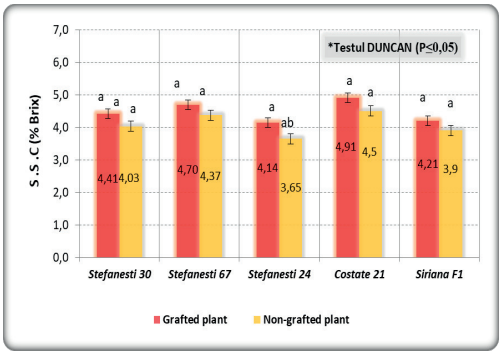

Figure 3. Rootstock influence on SSC (% Brix)

Of the total soluble solid content, which represent 75% of the total dry substance, 15% are organic malic and tartaric acids and approximately 10% are represented by sugars, the major constituents providing the nutritional value (Sima et al., 2010; Sumedrea et al., 2021). In general, fruit organic acid content was similar in grafted and ungrafted tomatoes.

Regarding malic acid (%), it was higher in the grafted plants, except for the Ștefănești 30 and

Ștefănești 67 varieties, which presented higher values in the control variant (plants grown on their own roots), although the differences are not significant.

Those studies highlight that certain rootstocks used for grafting tomatoes can affect the characteristics of fruit quality Savvas et al. (2011). Tomato cultivar and fruit harvest maturity were the main factors affecting the nutritional value of tomatoes (Erba et al., 2013).

Studies developed by Huitrón-Ramírez (2009) concluded that portaltoi induced a greater firmness in tomatoes without changing the quality of the fruits (Huitrón-Ramírez et al., 2009).

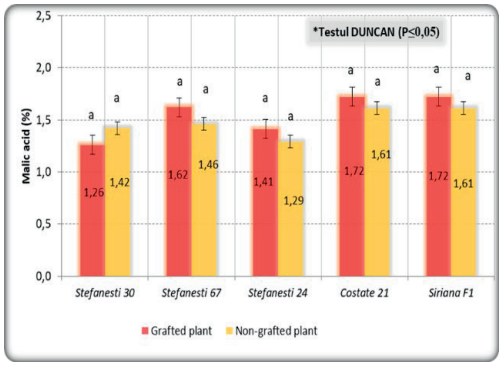

Figure 4. Rootstock influence on MA (%)

Table 5 shows the influence of grafting on the citric acid content of the fruit. As in the case of the other organic substances, citric acid had similar and insignificant values between grafted and non-grafted plants, regardless of the variety.

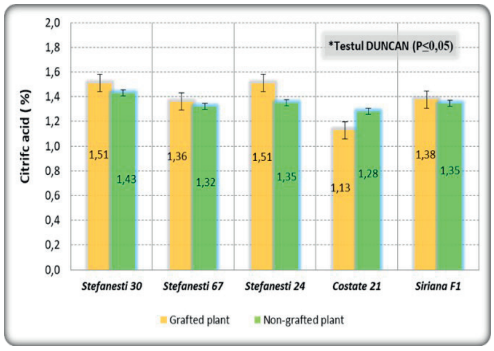

Figure 5. Rootstock influence on CC (%)

Higher CA (%) values were evident in the case of the Ștefănești 30 and Ștefănești 67 varieties grown on rootstocks (Figure 5). Results similar to our study were also reported by Sayvas, in a study in which he used several valuable tomato genotypes as rootstocks (Sayvas et al., 2017).

CONCLUSIONS

The rootstock induced greater vigor in the cultivars analyzed, more vigorous roots, and a greater number of roots and positively influenced the yield quality in the cultivars grown in the greenhouse in organic culture.

S. sysimbrifolium can be recommended for organic production due to its higher performance. We can conclude that grafting could be used in organic culture, in our study the rootstock induced a production increase of up to 2.2 kg per plant.

The rootstock induced an increase in both average fruit mass and fruit production. During the experiment, the rootstock induced a production increase of 2.2 kg per plant in the Ștefănești 30 variety, 1.0 kg per plant in the Ștefănești 67 variety, and 1.43 kg in the Ștefănești 24 variety. The Ștefănești 30 variety recorded productions of 6.6 kg/plant in the case of plants grafted on the S rootstock, compared to 4.4 kg/plant, as shown in the control variant.

We can state that the rootstock used in our study for the 5 autochthonous varieties of tomatoes positively influenced both the quality of the fruits, by increasing the values of SSC and malic acid. The results showed that the grafting of tomatoes on a suitable rootstock, such as *S. sysimbrifolium*, has positive effects on the morphological characteristics of the varieties, the quality of the yields and their quality, in ecological culture, compared to the ungrafted ones.

Nevertheless, it is recommended to continue the study for several years, to evaluate the influence of the rootstock on the tolerance of the varieties to the attack of the main pests, as well as on the quality and productivity indicators, cultivated in other environments.

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