Survival and compatibility of tomato grafted on solanaceous plants and by different grafting methods

Sobrevivência e compatibilidade de tomateiro enxertado em solanáceas e por diferentes métodos de enxertia

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Abstract

The objective of this work was to evaluate plant survival and grafting compatibility in tomatoes grafted on different solanaceous plants and by different grafting methods. Nine rootstocks were evaluated: 1- minitomato accession 0224-53; 2- minitomato accession RVTC 57; 3- minitomato accession RVTC 20; 4- minitomato accession 6889-50; 5- wild tomato species Solanum habrochaites var. Hirsutum (PI-127826); 6- wild tomato species Solanum pennelli ‘LA716’; 7- cubiu (Solanum sessiliflorum); 8- physalis (Physalis peruviana); and 9- tomato cultivar Santa Cruz Kada® (control), and two grafting methods [1- full cleft grafting (FCG); and 2- approach grafting (AG)]. Throughout the crop cycle, we evaluated: plant survival rate (PSR); and grafting incompatibility (GI). By means of the results obtained, it was possible to infer that the use of wild tomato species Solanum pennelli ‘LA716’ and physalis as rootstocks should not be recommended. Wild tomato species Solanum habrochaites var. hirsutum, cubiu and minitomato accessions 0224-53, RVTC 57, RVTC 20 and 6889-50 show potential for use as rootstocks. For using cubiu as rootstock, the full cleft grafting method is recommended, while for the other rootstocks, both the approach grafting method and the full cleft grafting method are feasible.

Additional keywords: grafting; Solanum lycopersicum, Solanum habrochaites.

Resumo

O objetivo deste trabalho foi avaliar a sobrevivência de plantas e compatibilidade de enxertia em tomateiro enxertado sobre diferentes solanáceas e por métodos de enxertia. Avaliou-se nove porta-enxertos: 1- acesso de minitomate 0224-53; 2- acesso de minitomate RVTC 57; 3- acesso de minitomate RVTC 20; 4- acesso de minitomate 6889-50; 5- espécie silvestre de tomateiro Solanum habrochaites var. hirsutum (PI-127826); 6- espécie silvestre de tomateiro Solanum pennelli ‘LA716’; 7- cubiu (Solanum sessiliflorum); 8- fisales (Physalis peruviana); e 9- tomateiro cultivar Santa Cruz Kada® (testemunha), e dois métodos de enxertia [1- fenda cheia (FC); e 2- encostia (EC)] . Ao longo do ciclo da cultura foi avaliada: taxa de sobrevivência de plantas (SP); e incompatibilidade de enxertia (IE). Por meio dos resultados obtidos, foi possível inferir que não se deve recomendar a utilização da espécie silvestre de tomateiro Solanum pennelli ‘LA716 e fisales como porta-enxertos. A espécie silvestre de tomateiro Solanum habrochaites var. hirsutum, cubiu e os acessos de minitomate 0224-53, RVTC 57, RVTC 20 e 6889-50 apresentam potencial para uso como porta-enxertos. E que para a utilização de cubiu como porta-enxerto, recomenda-se o método de enxertia por fenda cheia, enquanto para os demais porta-enxertos, tanto o método de encostia como o de fenda cheia são viáveis.

Palavras-chave adicionais: enxertia; Solanum lycopersicum, Solanum habrochaites.
Introduction

The use of appropriate rootstocks may confer resistance to grafted seedlings, allowing control of soil-related phytosanitary problems (Rivard et al., 2012; Gilardi et al., 2013). Moreover, it may also confer tolerance to salinity (Colla et al., 2010; Flores et al., 2010) and high and low temperatures (Martínez-Rodríguez et al., 2008; Venema et al., 2008; Abdelmageed & Gruda, 2009), and increase the water absorption efficiency and nutrient utilization (Santa-Cruz et al., 2002; He et al., 2009), physiological performance (Abdelmageed & Gruda, 2009), production and fruit quality (Flores et al., 2010).

In general, rootstocks have a more vigorous root system than ungrafted plants (Martinez-Ballesta et al., 2010). By using rootstocks that present a vigorous root system, it is possible to increase water and nutrient uptake, promoting greater fruit production by the plant (Ruiz et al., 1997). However, in Brazil, the use of grafting in vegetables is limited by the lack of adequate rootstocks that present a good compatibility with the species to be grafted. Notwithstanding, not all species have morphophysiological characteristics that allow grafting (Peil, 2003; Farias et al., 2013).

Given the need to obtain rootstocks that have good morphological, physiological and chemical affinity with the tomato graft and that offer resistance to adverse soil and climatic conditions, and considering that the cultivated tomato plant shows little genetic diversity for all types of stress (Garcia-Martínez et al., 2005; Tam et al., 2005), the evaluation of the potential of different solanaceous plants to be used as rootstocks becomes an alternative (Farias et al., 2013; Petran & Hoover, 2014). Among these plants, wild tomato species and minitomato accessions with good vegetative development can be cited.

Although it is commonly reported that grafted tomato plants have higher yield than ungrafted plants (Martínez-Rodríguez et al., 2002), production may vary, depending on the rootstock-graft combination (Leonardi & Giuffrida, 2006). In case of rootstocks that present restricted communication at the point of union with the graft, due to vascular discontinuity, there is incompatibility and death of plants. This fact usually occurs in the early stages of development of the grafted plants, that is, during the formation of vascular connections, or even in the final stages of development of the plants, when there is a high demand of water and nutrients for flowering and fruiting (Giacobbo et al., 2007; Martínez-Ballesta et al., 2010).

Several researchers have identified the morphophysiological compatibility of rootstocks with grafts through physiological assessments (Rodrigues et al., 2001) and observing the stem diameter at the grafting point (Giacobbo et al., 2007; Farias et al., 2013; Simões et al., 2014). Notwithstanding, in non-woody species, little is known about the effects of rootstocks on the physiological behavior of the graft (Martinez-Ballesta et al., 2010).

The vascular connection between rootstock and graft may interfere with water uptake and salt translocation (Santa-Cruz et al., 2002; He et al., 2009; Flores et al., 2010), affecting several physiological characteristics (Rodrigues et al., 2001; Abdelmageed & Gruda, 2009; Martínez-Ballesta et al., 2010). After graft healing, there is insufficient connection of the vascular bundles between rootstock and graft, thus the absorption and flow of water, nutrients and other compounds are affected (Tori et al., 1992). In this way, there are losses in the physiological processes of the plant, reducing vegetative development and fruit production. In contrast, a good connection between rootstock and grafting favors the constant flow of water from rootstock to graft, promoting greater plant growth, nutrient uptake and photosynthetic yield (Martínez-Ballesta et al., 2010).

Considering these information, the present work had as objective to evaluate the plant survival and grafting compatibility of tomato on solanaceous plants, in addition to different grafting methods.

Material and methods

The experiment was carried out in a greenhouse at the Olericulture Sector of the Agronomy Department of the State University of the Midwest - UNICENTRO, located in the municipality of Guaraupava - PR, at 25° 41 'S latitude, 51° 38' W longitude and altitude of 1100 meters. The climate, according to Köppen classification, is type Cfb (subtropical humid mesothermal), temperate, without a defined dry season, with hot summer and moderate winter (Wrege et al., 2011).

To produce grafted tomato seedlings, the cultivar Santa Cruz Kada® was used as a graft, using a randomized block design in a 9 x 2 factorial scheme with four replications, and a plot consisting of four grafted plants. Nine rootstocks were evaluated: 1 - minitomato accession 0224-53; 2 - minitomato accession RVTC 57; 3 - minitomato accession RVTC 20; 4 - minitomato accession 6889-50; 5 - wild tomato species Solanum habrochaites var. hirsutum (Pl-127826); 6 - wild tomato species S. pennellii ‘LA716’; 7 - cubiu (Solanum sessiliflorum); 8 - physalis (Physalis peruviana); and 9 - tomato cultivar Santa Cruz Kada® (control), and two grafting methods: 1- full cleft grafting (FCG) and 2- approach grafting (AG).

To obtain mother plants, the rootstocks and grafts were sown in 200-cell expanded polystyrene trays containing commercial substrate (Mecplant®) and grown in a floating hydroponic system. Graftings were performed on (10/31/2013 and 11/1/2013), when the grafts presented 3 to 4 young and expanded leaves, using, for both grafting methods, carbon steel slides, biodegradable tape for fixation and wood stem to support the plant in order to reduce seedling stress coming from the grafting process.

After graft healing, at 21 days after grafting, it was carried out the transplanting of seedlings to pots...
with a capacity of 10 dm³ containing sieved soil and bovine manure in the ratio of 3:1. The pots had their surface covered with a 3-cm layer of decomposed wood shavings in order to reduce weed infestation and maintain moisture. The compound with soil and sieved manure was corrected in advance by liming, according to the need indicated by soil analysis, following the recommendation for tomato crop. The plants were grown through the maintenance of a main stem and conducted via vertical cutting. For irrigation, a localized system was used by means of micro-drippers, and fertigation was carried out in the morning, according to the recommendations of Trani & Carrijo (2004), following the requirements throughout the crop cycle, based on soil analysis results. During the cycle, phytosanitary control was carried out according to the recommendations for tomato crop described by Alvarenga (2013), by preventive spraying with fungicides and insecticides.

Along the experimental period, minimum (Tmin) and maximum (Tmax) air temperature data were collected daily by means of minimum and maximum thermometers installed inside the greenhouse. The mean air temperature (Tmed) was calculated by the arithmetic mean between Tmin and Tmax. By observing the temperature data in the months that comprised the experimental period of the crop studied (November 2013 to February 2014) under greenhouse conditions, it was observed that there was an oscillation from 11.0 ºC (November) to 14.7 ºC (January) for Tmin, from 34.0 ºC (November) to 37.0 ºC (December) for Tmax and from 22.1 ºC (November) to 24.6 ºC (January) for Tmed.

Plant survival rate (PSR) was analyzed throughout the crop cycle, being determined by the percentage of surviving grafted plants at 30 and 60 days after transplanting.

Grafting incompatibility (GI) was verified 60 days after transplanting, by measuring rootstock stem diameter (RSD), grafting point diameter (GPD) and graft diameter (GD) transversely and longitudinally to the planting line, with a digital caliper (mm), at ± 1 cm above and below the grafting point, and estimated using the equation (1):

\[
GI = \frac{1}{2} \left( \frac{RSD - GD}{2} + \frac{GPD - GD}{2} + \frac{GPD - RSD}{2} \right)
\]

The data obtained were tested for normality and homogeneity and later submitted to analysis of variance by F test and, when significant, submitted to comparison by the Scott-Knott grouping test at 5% probability. The data expressed as a percentage were transformed into arcsin (x/100)^0.5. The statistical program ASSISTAT version 7.7, 2014 (Silva & Azevedo, 2016), was used.

### Results and discussion

For the variables PSR, at 30 and 60 days after transplanting, and GI at 60 days after transplanting, it was verified that except for PSR at 30 days after transplanting, where there was a significant difference only for the factor rootstock, there was a significant interaction among the sources of variation (rootstock vs. grafting method), thus demonstrating a high dependence between the factors (Table 1).

### Table 1 - Plant survival rate (PSR), 30 and 60 days after transplanting and grafting incompatibility (GI), 60 days after transplanting, tomato grafted on different Solanaceae and different methods of grafting [cleft (FCG); and approach (AG)].

<table>
<thead>
<tr>
<th>Treatments</th>
<th>PSR - 30 days (%)</th>
<th>PSR - 60 days (%)</th>
<th>GI (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FCG</td>
<td>AG</td>
<td>Average</td>
</tr>
<tr>
<td>0224-53</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00 a</td>
</tr>
<tr>
<td>RVTC 57</td>
<td>87.50</td>
<td>87.50</td>
<td>87.50 b*</td>
</tr>
<tr>
<td>RVTC 20</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00 a</td>
</tr>
<tr>
<td>6889-50</td>
<td>87.50</td>
<td>87.50</td>
<td>87.50 b</td>
</tr>
<tr>
<td>S. habrochaites</td>
<td>100.00</td>
<td>87.50</td>
<td>97.50 a</td>
</tr>
<tr>
<td>S. pennellii</td>
<td>75.00</td>
<td>75.00</td>
<td>75.00 b</td>
</tr>
<tr>
<td>Cubiu</td>
<td>87.50</td>
<td>62.50</td>
<td>75.00 b</td>
</tr>
<tr>
<td>Fisalis</td>
<td>37.50</td>
<td>37.50</td>
<td>37.50 c</td>
</tr>
<tr>
<td>Control</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00 a</td>
</tr>
</tbody>
</table>

Average 86.11 A 81.94 A 87.50 78.12 7.98 3.57

CV (%) 22.04 21.22 8.92

* Means followed by distinct upper-case letters in the distinct lines and lowercase in the columns belong to the same group differ significantly by the Scott-Knott test at probability level <5%.

For both grafting methods, FCG and AG, it was verified that physalis rootstock had the lowest survival of grafted plants, at 30 days after transplanting, with total plant death being observed at 60 days
after transplanting. It was also found that, at 30 days after transplanting, grafting methods did not influence the survival rate of grafted plants. However, at 60 days after transplanting, cubiu rootstock showed influence of the grafting method, with higher plant survival rate for FCG in comparison to the AG method (Table 1).

By eliminating the physalis rootstock and evaluating only the other rootstocks, at 60 days after transplanting, it was verified that S. pennellii rootstock, with both grafting methods, and cubiu, with AG, had the lowest seedling survival rate, while the other combinations (rootstocks x grafting methods) showed PSR > 87.50% (Table 1).

For the variable GI, evaluated at 60 days after transplanting through the measures of rootstock stem diameter at the point of connection between the structures, it was verified, by means of the rootstock/grafting method interaction, that rootstocks 0224-53, RVTC 57, RVTC 20, 6889-50 and S. pennellii showed higher compatibility when using the AG method, compared to the FCG method. Therefore, for S. habrochaites, cubiu and control rootstocks, the grafting methods did not exert influence, with the lowest GI values being observed in all treatments for control (autografting) and S. habrochaites rootstocks (GI=2.41 mm). In contrast, cubiu rootstock had the highest GI in comparison to the other rootstocks.

Based on the difference between the grafting point diameters, 1 cm below and above the grafting point, the FCG method showed high GI. Notwithstanding, differences between grafting point stem diameter, rootstock diameter and graft diameter may be due to the formation of callus. It can also be considered an indication that there was satisfactory tissue regeneration (Sirtoli et al., 2011), which is the link between rootstock and graft, promoted by the proliferation of new vascular tissue from the secondary xylem and phloem, being responsible for a safe grafting connection, which may favor the vegetative development and photosynthetic yield of the grafted plant (Martinez-Ballesta et al., 2010). Thus, according to Peil (2003), the difference between grafting compatibility and incompatibility may not be well defined.

The FCG method has the advantage of providing a better connection of the graft vascular bundles with the rootstock, preventing grafting rupture (Simões et al., 2014). Nonetheless, the AG method is considered the most viable for when grafted plants are subjected to adverse temperature conditions (Lee et al., 2010).

It was observed low PSR for physalis rootstock, in which there was total plant death, and for S. pennellii rootstock, where only 50% of the plants survived, with both grafting methods, at 60 days after transplanting. The result agrees with that reported by Peil (2003), who mentions that not all plant species show morphophysiological characteristics that favor grafting. Unsatisfactory results for grafting compatibility may occur when tomato grafting is carried out on rootstocks of solanaceous plants belonging to different species. Similar results were found by Farias et al. (2013), who verified the compatibility and yield of tomato plants grafted on different Solanum species (S. gilo; S. lycopersicum; S. stramonifolium e S. viarum) and observed that S. viarum is not recommended for use as a rootstock. Furthermore, Flashman et al. (2008), when grafting Arabidopsis on tomato rootstocks, verified complete incompatibility and differentiation of vascular tissues.

According to the results obtained for PSR, at 30 and 60 days after transplanting, it can be considered that the evaluated rootstocks, except for physalis and S. pennellii, have potential for use as tomato rootstocks.

Some wild tomato species, even under minimal conditions of water availability, develop vegetatively and reproduce, since they are native to regions where water availability is scarce throughout their cycle (Rousseaux et al., 2005). According to Easlon & Richards (2009), S. pennellii, under water deficit conditions, provides superior performance regarding water use efficiency when compared to cultivated tomato (S. lycopersicum). However, given the low plant survival shown by S. pennellii in the present work, its use as a rootstock is limited. The survival of only 50% of the grafted plants, as presented by the treatment for both grafting methods, considerably reduced the production efficiency, since grafting increases the cost of cultivation.

In contrast to S. pennellii, the wild species S. habrochaites showed high survival of grafted plants after transplanting and low grafting incompatibility, thus demonstrating a good morphological, chemical and physiological affinity with cultivated tomato. As discussed by Venema et al. (2008), S. habrochaites is adapted to a wide range of geographical distribution, thus exhibiting characteristics that may favor the development of grafted tomato, even when conditions during the day or along the cycle are not favorable for the development of ungrafted tomato (Venema et al., 2008; Flores et al., 2010; Lee et al., 2010).

Wild tomato species and minitomato accessions, even with the disadvantage of being non-fruit species, or producing fruits that often have low economic potential, are mostly vigorous plants with tolerance/resistance to certain pathogens, edaphoclimatic conditions, temperature, drought, humidity and salinity. Minitomato accessions 0224-53, RVTC 57, RVTC 20 and 6889-50, in addition to being accessions of high vegetative development, had a PSR not differing from the control treatment in the present work, showing potential for grafting. Cubiu can also be considered an important alternative for use as a rootstock. When grafted by full cleft grafting, it provided a PSR not differing from minitomato accessions or wild tomato species S. habrochaites and autografting. Cubiu can be used to avoid graft contact with pathogen-contaminated soil, based on the fact that there are no reports of cubiu infection by soil pathogens.

Considering that the grafting methods showed no difference regarding the variable plant survival rate
for the evaluated rootstocks (except for cubiu), it can be concluded that both grafting methods are feasible for tomato crop. Notwithstanding, the preference for the most suitable method to be used, as seen with cubiu, may depend on the rootstock. To choose the grafting method to be used by farmers who cultivate grafted tomato, the practicality of the technique to be used and the final cost for seedling grafting must be considered (Lee, 1994). Therefore, it is recommended to take into account the available rootstock, the method practicality and the final cost of grafting.

Conclusions

Wild tomato species Solanum pennellii ‘LA716’ and physalis should not be used as rootstocks for Solanum lycopersicum.

Minitomato accessions 0224-53, RVTC 57, RVTC 20 and 6889-50, wild tomato species Solanum habrochaites var. hirsutum and cubiu showed potential for use as rootstocks. To use cubiu as rootstock, full cleft grafting method is recommended, while for the other rootstocks tested, both the approach grafting method and the full cleft grafting method are feasible.

References


