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VEGETATIVE GROWTH OF *PASSIFLORA EDULIS*' BRS GIGANTE AMARELO 'IS INFLUENCED SIGNIFICANTLY BY GRAFTING

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ABSTRACT

Although Brazil is the largest producer of passion fruit, the mean fruit yield is only 13 t ha^{-1} and may be attributed to susceptibility to pests and diseases. An attractive solution to the problem would be to improve traits by grafting onto a rootstock presenting enhanced vegetative vigor. To this end, the commercial cultivar *Passiflora edulis* 'BRS Gigante Amarelo' was grafted onto rootstocks that included three native species of *Passiflora* and four passion fruit hybrids that are still under development. Grafts were performed with 30-day old seedlings of scion and rootstocks using the cleft graft technique, and stem diametersabove the graft and plant heights were determinedat 30, 60 and 90 days after planting (DAP). The diameters and heights of grafted plants formed on rootstocks *Passiflora edulis* Sims. and hybrid *P. edulis* 'BRS Gigante Amarelo' X [(*P. quadrifaria* V and erpl. X*P. setacea* DC.) F1 X *P. incarnata* L.)] were improved significantly compared with those of the control 30 and 60 DAP, although only the height increment was statistically significant at 90 DAP.The successful grafting performances of all scion-rootstock combinations can be attributed to the age of the seedlings employed and to the use of the cleft method of grafting.

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INTRODUCTION

Brazil is one of the largest producers of passion fruit worldwide with a total cultivated area of 41,090 ha and a harvest of554,598 t of fruit in 2017 (Instituto Brasileiro de Geografia e Estatística, 2017). Although passion fruit is cultivated in the State ofMato Grosso (MT), the overall production contributed only 0.1% of the total national yield according to data from 2017 (Instituto Brasileiro de Geografia e Estatística, 2017) and fruits have to be imported from other regions in order to supply local demand. Such poor productivity has been attributed to the existence of orchards established with inferior genetic material and the use of non-adapted agronomical techniques leading to low and uneven productivity per plant, poor quality of fruits and increased susceptibility to pests and diseases (Ambrósio, 2015; Ambrósio *et al*., 2018). If the full potential of passion fruit cultivation in MTis to be exploited, then new and more appropriate technologies must be generated along with alternative methods for fruit production. An appropriate response to this situation would beto replace old orchards with either seed-grown cultivars or grafted plants formed on rootstocks of tolerant or resistant species (Junqueira *et al*., 2006, Cerqueira-Silva *et al*., 2009, 2012a, b,2014). The main disadvantage of conventional seed propagation is that character separation is inherent in the method such that a variable, and possibly low, percentage of the desirable agronomic characteristics of the parents may be passed through to the seedling. In contrast, grafting is regarded as a cloning technique that allows faithful transmission of traits such as productivity, fruit quality, and resistance to pests and diseases, thereby enabling the formation of homogeneous orchards with high and early productivity (Morgado, 2011; Hurtado-Salazar *et al*., 2015; Morgado *et al*., 2015). In the case of passion fruit, some studies have demonstrated that grafting reduces the vegetative growth (stem diameter and plant height) of plants when rootstocks of native species of *Passiflora* spp.are employed, suggesting that grafting can give rise to smaller plants (Cavichioli *et al*., 2011a,b)with the possibility of employing higher plant densities, there by increasing productivity. Although a number of researchers have shown that the rootstock influences the survival and growth of grafted passion fruit (Chaves *et al*., 2004; Silva *et al*., 2005; Junqueira *et al*., 2006), some reports have suggested that grafting commercial cultivars of *Passiflora*can give rise to taller and/or less productive plants (Cavichioli *et al*., 2011c, Nogueira-Filho *et al*., 2010, 2011).

In view of the somewhat contradictory results reported in the literature, the present study aimed to evaluate the vegetative growth of the commercial cultivar *P. edulis*' BRS Gigante Amarelo'grafted onto rootstocks from threenative passion fruit species and four hybrids still under development. The experiments were carried out inanareaof a producer/supplier of Cooperativa AgrícolaMista Terra Nova Ltda (Coopernova) located in the municipality of Terra Nova do Norte, Mato Grosso, Brazil (10º31'01"S, 55º13 '51"W; 250 m altitude), which is situated some 650 km from the State capital Cuiabá. The climate of the region is Aw (sub-humid tropical) according to the Köppen classification system with a mean temperature of 25.2ºC (maximum 30.92ºC; minimum 20.84ºC) and a mean annual rainfall of 1348.3 mm. The rainy season extends from November to March with mean relative humidity of 80.4%. The experiment was of randomized block design comprising eight treatments with four replicates of four plants per plot. The treatments consisted of non-grafted plants of commercial cultivar *P. edulis*' BRS Gigante Amarelo' as control and seven types of grafted plants produced with the commercial cultivar as scion and native *Passiflora* species or passion fruit hybrids still under development as rootstock, the origins and characteristics of which are shown in Table 1.

The scion cultivar was developed by Embrapa Cerrados, Planaltina, DF, Brazil, throughcross-breeding several genotypes with the aim of obtaining fruits for industrial processing and for consumption *in natura*. According to Braga *et al*. (2019), the cultivar presents a number of valuable traits that include: (i) fruits of uniform size (mean weight 240 g), shape and color, presenting a thick rind that provides enhanced resistance during handling and transportation, (ii) apulp yield of approximately 36% with sugar content 14 ºBx, and (iii) a potential productivity of40 t ha^{-1} in the first year and 20 t ha^{-1} in the second year. Seeds (n =120) of the scion cultivar and each of thespecies/hybridsthat were to serve as rootstocks were sownin March 2012 and grown on in polyethylene tubes containing commercial Plantmaxsubstrate (Plantmax Seeds, Lemon tree from North, Ceará, Brazil). Grafting was performed when the rootstocks and scion had reached the attachment stage when the seedlings were 6 to 8 cm in height and with three definitive leaves, and this occurred around 30 days after sowing for the early and vigorous species/hybrids and 90 days for the slower plants. The cleft graft method employed was as described by Nogueira-Filho (2010) and involved a full slit in the hypocotyl of the rootstocks. Grafted seedlings were maintained in the experimental nursery of Coopernova, the structure of which was covered by black netting to provide 50% shade. The tube trays were maintained at approximately 0.5 m above the ground on brick-built benches and the grafted seedlings were watered daily by means of a micro sprinkler irrigation system. Any roots that exceeded the confines of the container were pruned.

The experimental fieldwas cleared and lines staked out for the appropriate locations of plant pits (40 x 40 x 40 cm) and supporting posts to give spacing of 3x3 m between plants and lines. The training-espalier wires were secured on the posts at a height of 2 m above the ground. Planting, training of branches and fertilization were performed as recommended by Lima (2005). However, liming was not required because base saturation was higher than 60% and the magnesium content was higher than 9 mmolc dm^{-3}. Localized fertilization with 40 g of FTE BR-12 and 1.18 kg of superphosphate was performed in each pit to provide a nutrient foundation**.** The field experiment commenced in June 2012 (dry season) at 30 days post-grafting when grafted seedlings were transferred to the prepared pits, which were then covered with mulch. Watering was performed twice a week until the rainy season. Top dressing-fertilization was performed at regular intervals to provide additional nitrogen and to stimulate growth by application of22 g urea per plant at 30 days after planting (DAP), 33g urea at 60 DAP, and 112g urea together with 83g KClat 90 DAP. Vines were trained to grow upwards with the aid of thin bamboo poles and string, and allowed to grow as a single stem until they exceeded the wire of the espalier by around 10 cm, following which they were pruned to promote the emission of secondary branches. When these branches reached neighboring plants, they were pruned to encourage the emission of tertiary branches, following which tendrils were removed in order to allow the branches to grow as a curtain. The parameters of vegetative growth, namely stem diameter and plant height, were evaluated during the juvenile stage of the grafted plants at 30, 60 and 90 DAP. A digital caliper was used to measure the diameter above the grafting point, while plant height was determined using a graduated ruler. The mean values of these parameters for alleight treatments were compared using the Scott-Knott test with the significance level alpha set at 0.05. The most successful scion-rootstock combination was T5 (intraspecific graft) in which the commercial cultivar *P. edulis* 'BRS Gigante Amerelo' was grafted onto native *P. edulis* as rootstock (Table 2). The superior growth of the grafted plants, as verified by stem diameter and plant height measurements, indicated good graft compatibility resulting in the rapid restoration of the vascular connections after grafting. Graft combinations employed in treatmentsT1 and T2, both of which involved *Passiflora* hybrid rootstocks, also showed high graft compatibility although the growth parameters were somewhat lower than those of T5.These results are in accord with the generalization of Goldschmidt (2014) that intraspecific grafts (T5) are virtually always compatible while interspecific grafts (T1 and T2) are frequently compatible.

There is contradicting evidence about the effects of grafting on growth, development and productivity of plants. For instance, Corrêa *et al*, (2010) e Cavichioli *et al*. (2011a) compared the interactions between *Passiflora edulis* Sims. (maracujá-amarelo or maracujá-azedo) scion and rootstocks of native *P. alata* Curtis (maracujá-doce), *P.gibertii* N.E. Br. (maracujá-de-veado) and *P. edulis*, and reported that fruits produced by the grafted plants were of larger diameter and higher fresh mass when the low growing *P. alata* was employed. In contrast, Nogueira-Filho *et al*. (2010) demonstrated that plants produced by grafting *P. edulis* variety FB200 onto native *P. edulis*, *P. serratodigitata*L., *P. quadrangularis* L. or *P. alata* rootstocks presented reduced vegetative growth, while Aguiar *et al*. (2010, Preisgke (2014) e Preisgke *et al*. (2015) reported that grafted plants produced using similar combinations of scion and rootstocks grew well and exhibited excellent survival rates.In addition, Lenza *et al*. (2009) compared the establishment index and the precocity of tendril emission of *P. edulis* variety FB200 when grafted onto various native *Passiflora* spp. rootstocks and found that *P. edulis, P. quadrangularis,* and FB200 afforded superior plants that were ready to be transplanted to the field between 30 and 120 days after grafting. In comparison with the non-grafted control T8, the stem diameters and heights of grafted plants in T1, T2 and T5 were significantly larger ($p< 0.05$) at 30 and 60 DAP with the exception of stem diameter of T1 at 60 DAP. In contrast, treatment T3 involving the hybrid *P. setacea* x (*P. speciosa* x *P. coccinea*) as rootstock, was the least successful combination and the growth parameters of the grafted plants were significantly lower than those of the non-grafted control (T8). While statistical differences between treatments with respect to stem diameter could be observed up to 60DAP, such differences became more subtle and non-significant at 90 DAP. On the other hand, significant differences between treatments regarding plant height could be observed throughout the experimental period. Nevertheless, in all treatments, including the control, there was a direct relationship between stem diameter and plant height throughout the experimental period.

The grafted plants arising from graft combination T5grew more vigorously in comparison with those resulting from the other treatments, not only because of the scion-rootstock compatibility but also by virtue of the positive influence exertedby the native *P. edulis* rootstock, which typically presents vigorous growth. Moreover, the diameters of the scion and rootstock in T5 grafts were more uniform, and this facilitatedthefusion and lignification of the joining tissues as already recognized by Roncatto *et al*. (2011). Despite the difference in growth, most of the grafted plantssurvived in the field regardless of the graft combination, and such grafting success may be attributed to the age of scion and rootstocks and the grafting technique employed. Similar to the study by Roncatto *et al*. (2011), grafting was performed in the present research with young plants (30 dayold seedlings) and using the cleft method with full split of rootstock hypocotyls.

Table 1. Experiments involving commercial cultivar *Passiflora edulis* 'BRS GiganteAmarelo'as scion grafted onto different rootstocks

Treatment	Rootstock	Type	Origin	*Fusarium* resistance
T1	*P. alata* Curtis x *P. maliformis* L.	hybrid (under study)	Embrapa Cerrados, DF, Brazil	Yes
T2	*P. edulis*'BRS Gigante Amarelo' x [(*P. quadrifaria*Vanderpl. x *P. setacea* DC.) F1 x *P. incarnata*L.)]	hybrid (under study)	Embrapa Cerrados, DF, Brazil	Yes
T3	*P. setacea* x (*P. speciosa* Gardner x *P. coccinea* Aubl.)	hybrid (under study)	Embrapa Cerrados, DF, Brazil	Yes
T4	*P. katsshbachu* x (*P. vitifolia* x *P. setacea*)	hybrid (under study)	Embrapa Cerrados, DF, Brazil	Yes
T5	*P. edulis*Sims.(maracujá-amarelo ou maracujá-azedo)	Native	Cuiaba, MT, Brazil	No
T6	*P. nitida* (maracujá-do-sono)	Native	Terra Nova do Norte, MT, Brazil	Yes
T7	*P. alata* (maracujá-doce)	Native	Terra Nova do Norte, MT, Brazil	Yes
T8 (control)	Non-grafted *P. edulis* 'BRS GiganteAmarelo'	commercial cultivar	Embrapa Cerrados, DF, Brazil	Yes

Table 2. Comparison of vegetative growth parameters of commercial cultivar *Passiflora edulis* 'BRS Gigante Amarelo' grafted onto different rootstocks

Treatment	Diameter above grafting point (cm)			Plant height (cm)		
	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP
T1	5.40 [a]	9.47 [c]	13.81 [a]	0.66 [b]	3.12 [a]	4.20 [a]
T2	5.18 [a]	11.88 [b]	14.19 [a]	0.67 [b]	3.29 [a]	4.31 [a]
T3	3.71 [b]	7.61 [c]	12.33 [a]	0.29 [c]	1.85 [b]	2.89 [c]
T4	4.96 [a]	11.72 [b]	15.43 [a]	0.64 [b]	2.88 [a]	4.09 [a]
T5	5.54 [a]	15.78 [a]	18.60 [a]	0.83 [a]	3.71 [a]	4.71 [a]
T6	4.74 [a]	9.43 [c]	12,38 [a]	0.38 [c]	1.96 [b]	3.43 [b]
T7	4.82 [a]	9.63 [c]	13,12 [a]	0.37 [c]	2.17 [b]	3.49 [b]
T8 (non-grafted control)	2.66 [c]	8.99 [c]	16.00 [a]	0.22 [c]	1.98 [b]	3.67 [b]
Mean	4.62	10.56	14.48	0.51	2.62	3.85
CV	11.73	18.55	18.12	22.36	16.10	9.93

DAP, days after planting; CV, coefficient of variation.

These two approaches increase the chances of success for the following reasons: (i) young seedlings tend to have uniform stem diameters with very little lignifications and this facilitates matching and fusion of the tissues in the grafting region, whereas stems in adult plants are often isoporized and this may undermine the success of the graft, and (ii) the cleft method of grafting allows the scion to be placed centrally with respect to the rootstock, thereby facilitating fusion of the tissues and healing of the injured parts for manyscion-rootstock combinations Roncatto *et al* (2011). Under the experimental conditions employed, native *P. edulis* was the best rootstockon which to graft the commercial cultivar*P. edulis* 'BRS Gigante Amarelo' since the grafted plants exhibited superior vegetative growth in comparison with other scion-rootstock combinations andthe non-grafted scion. The worse graft combinationinvolved*P. setacea* x (*P. speciosa* x *P. coccinea*) as rootstock in view of the substantial reduction in growth performance in comparison with the non-grafted control. Additionally, two hybrid plants that are still under development at Embrapa Cerrados, namely *P. edulis*' BRS GiganteAmarelo' x [(*P. quadrifaria* x *P. setacea*) F1 x *P. incarnata*)] and *P. alata* x *P. maliformis*, offer promise as potential rootstocks. The successful grafting performances of all scion-rootstock combinations tested in this study can be attributed to the age of the seedlings employed and to the use of the cleft method of grafting.

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