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FRUIT PRODUCTION BY NON-GRAFTED AND GRAFTED PASSIFLORA EDULIS BRS GIGANTE AMARELO IN TERRA NOVA DO NORTE, MATO GROSSO, BRAZIL

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ABSTRACT

The production of passion fruit in Mato Grosso is low in comparison with that of other Brazilian states and is insufficient to supply local demand. A key factor contributing to this poor performance is the use of mixed varieties that are susceptible to diseases such as *Fusarium* wilt. In this regard, cultivation of grafted plants would be advantageous in establishing healthy, homogenous and productive orchards. The aim of this study was to compare fruit production of non-grafted plants of the commercial cultivar *Passiflora edulis* BRS Gigante Amarelo grown under the climatic and soil conditions of Terra Nova do Norte, Mato Grosso, with the scion grafted onto rootstocks of native species/hybrids known to be resistant to *Fusarium* spp. Performances were determined by evaluating the number of fruits per plant, fruit production, average fruit mass and productivity. The rootstocks employed were *P. edulis* BRS Gigante Amarelo, *P. nitida*, *P. alata*, *P. alata* x *P. maliformis*, *P. edulis* BRS Gigante Amarelo x [(*P. quadrifaria* x *P. setacea*) F1 x *P. incarnata*], *P. setacea* x (*P. speciosa* x *P. coccinea*), and *P. katsshbachu* x (*P. vitifolia* x *P. setacea*). The best performances, with values in the ranges 183.6-232.8 fruits plant^{1}, 33.5-39.2 kg plant^{-1}, 165.8-190.9 g fruit^{-1} and 37-43 t ha^{-1}, were observed with non-grafted plants and with the scion grafted onto the first four mentioned rootstocks. The other scion/hybrid rootstock combinations presented significantly lower values and their performances were considered moderate to poor. The results reported herein will contribute to the improvement of passion fruit orchards in Mato Grosso.

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INTRODUCTION

Mato Grosso state is a producer of passion fruit (*Passiflora* spp.) although it contributed only 0.77% to the national Brazilian production in 2019 with an output of just 4625 t (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA, 2019). The low productivity (16.4 t.ha^{1}) and the inferior quality of the fruit grown in the state can be attributed to inadequate cultivation practices, the lack of technology adapted to regions in which the soil is contaminated by fungal spores, and the limited use of rootstocks. In addition, the majority of passion fruit producers in Mato Grosso grow non-commercial varieties that are susceptible to pests and diseases and generally produce low yields, uneven plantations, and small and irregular shaped fruits (CHAVES et al., 2004). Among the fungal diseases that affect passion fruit orchards is *Fusarium* wilt or base rot disease caused by *Fusarium oxysporum* f. sp. *passiflorae*. This soil-borne pathogen colonizes the roots of healthy plants and spreads to other parts through the vascular bundles by means of the transpiration stream. Mycelia growth in the vascular tissues interrupts the flow of sap leading to wilt and gradual death of the plants. The disease is particularly destructive such that, in some locations, entire infested crops have had to be abandoned (JUNQUEIRA et al., 2006; SALAZAR et al, 2017). In this regard, the use of grafting techniques, in which scions with desirable traits can be grafted onto resistant/tolerant rootstocks, would be advantageous for the establishment of healthy, homogenous and productive orchards (AMBRÓSIO et al., 2018). For example, *Passiflora edulis* Sims grafted onto *P. gibertii* N.E. Br. generated well-developed vines with enhanced productivity and higher survival rates (91%) in *Fusarium*-contaminated soil in comparison with plants grafted onto *P. edulis* or *P. alata* Curtis rootstocks (CAVICHIOLI et al., 2011a). Furthermore, combinations of commercial *P. edulis* cultivar FB 200 scion with *P. edulis*, *P. alata*, *P. gibertii*, *P. coccinea* Aubl. or *P. cincinnata* Mast.

rootstocks gave rise to vigorous plants (NOGUEIRA FILHO, 2010), while successful graftlings were also obtained by combining regional varieties of *P. edulis* (from the Universidade Federal do Acre) as scions and wild species such as *P. edulis*, *P. alata* or *P. serratodigitata* L. as rootstock (RONCATTO et al, 2011a). In addition, Lenza et al. (2009) achieved successful grafting between the commercial cultivar *P. edulis* FB 200 and wild *P. edulis* or *P. quadrangularis* L. as rootstock. Other examples of successful and productive grafts have involved combinations of commercial *P. edulis* f. *flavicarpa* (scion) with *P. nitida* Kunth, (*P. setacea* DC. x *P. edulis* f. *flavicarpa* O. Def.) F1 hybrid (CHAVES et al., 2004), *P. alata* (SILVA et al, 2005) and *P. nitida* (JUNQUEIRA et al., 2006) as rootstock. Although passion fruit production is expanding in Mato Grosso, there are still many challenges to overcome before the state can become self-sufficient in, or even an exporter of, this commodity. In this respect, one of the major shortcomings is the scarcity of high quality disease-resistant cultivars or hybrids that are appropriate for the region (KRAUSE et al., 2012). Thus, the present study aimed to compare the fruit production of non-grafted plants of the commercial cultivar *P. edulis* BRS Gigante Amarelo grown under the climatic and soil conditions of Terra Nova do Norte, Mato Grosso, with plants produced by grafting *P. edulis* BRS Gigante Amarelo onto the homologous rootstock or stocks of native species/hybrids known to be resistant to *Fusarium* spp.

MATERIALS AND METHODS

The experimental area was situated in the grounds of a private farm (10º31’01”S, 55º13’51”W; altitude 250 m) associated with the Cooperativa Agrícola Mista Terra Nova Ltda (Coopernova) in Terra Nova do Norte, a town located some 650 km from the capital city (Cuiabá) of Mato Grosso. According to the Köppen classification, the climate is classified as Aw (tropical sub-humid). The mean annual temperature in the area is 25.2°C, the mean relative humidity is 80.4%, and the annual rainfall is 1,348.3 mm with the rainy season extending from November to March. The experiment followed a randomized block design with a 3 x 3 m configuration and comprised eight treatments with four repetitions each and four plants per repetition. The commercial cultivar *P. edulis* BRS Gigante Amarelo (maracujá-azedo) was used as scion because the fruits are uniform in shape, size, color and weight (approximately 240 g each) and have thick skins that protect them from damage during handling and transport. This cultivar was developed by Embrapa Cerrados (Planaltina, Federal District, Brazil) for industrial purposes as well as for consumption *in natura*, and affords a pulp yield of around 36%, total soluble solids of 14.0 ºBrix and productivities of around 40 t ha^{-1} in the first year and 20 t ha^{-1} in the second year (BRAGA et al., 2008). The treatments comprised non-grafted plants of *P. edulis* BRS Gigante Amarelo (T1) along with plants grafted onto the following rootstocks: *P. edulis* BRS Gigante Amarelo (T2), *P. nitida* (maracujá-do-sono) (T3), *P. alata* (maracujá-doce) (T4), *P. alata* x *P. maliformis* L. (T5), *P. edulis* BRS Gigante Amarelo x [(*P. quadrifaria* R. Vanderpl. x *P. setacea*) F1 x *P. incarnata* L.] (T6), *P. setacea* x (*P. speciosa* Gardner x *P. coccinea*) (T7) and *P. katsshbachu* x (*P. vitifolia* Kunth x *P. setacea*) (T8). The wild species employed in T3 and T4 were accessions collected in Terra Nova do Norte, whereas the hybrids used in T5 toT8 were developed by Embrapa Cerrados but their field performance is still undergoing investigation. The seedlings from a wild accession of *P. coccinea* maintained at the Universidade Estadual Paulista, Jaboticabal, São Paulo, never reached the grafting stage and this species was excluded from the experiments. Passion fruit seedlings used for grafting were obtained from the nursery at Coopernova. Seeds of all species/cultivars/hybrids involved in the experiments (120 seeds each) were sown on 4 March 2012 in polyethylene tubes containing Plantmax® commercial vegetable substrate. The trays containing the tubes were arranged on benches inside a screen-shaded (50%) greenhouse and watered daily by means of a micro sprinkler system. Full cleft grafting was carried out with hypocotyls as described by Nogueira Filho et al. (2005) when scions and rootstocks were about 6 to 8 cm in height with three leaves on average, i.e. approximately 30 days after sowing for the fast growing and more vigorous types and around 90 days for the slow growing types. The non-grafted and grafted plants were transplanted to the experimental field on 17 June 2012 where plant pits had already been prepared and individually fertilized with 40 g FTE BR-12 and 1180 g of simple superphosphate. Training wires were fixed at 3 m intervals and at a height of 2 m from the ground, and the vines were trained to grow upwards with the help of string lines. Watering was provided twice a week until the beginning of the rainy season (around October). During the vegetative stage, cover fertilization was provided individually to each plant by application of 22 g of urea at 30 days after planting (DAP), 33 g of urea at 60 DAP and 112 g of urea together with 83 g of potassium chloride at 90 DAP. During the fruit production stage, each plant received cover fertilization with 150 g of simple superphosphate and 40 g of FTE BR-12 (September 2012) in addition to 700 g of NPK fertilizer supplied in five equal parts (September 2012 to January 2013). A solution of copper oxychloride in water (3 $g.L^{-1}$) was applied by spray every 15 days commencing at 90 DAO to prevent fungal and bacterial diseases, and dimethoate (2 $mL.L^{-1}$) was applied for the control of general insect pests whenever necessary. The results of the treatments were evaluated during one production cycle (May 2013 to June 2014) by harvesting the ripe fruits weekly and measuring the number of fruits per plant, fruit production (kg $plant^{-1}$), average fruit mass (g $fruit^{-1}$; determined by dividing fruit production by the number of fruits per plant), and productivity (t ha^{-1}). Data were submitted to analysis of variance, and the mean values compared using the Scott-Knott test with the significance level alpha set at 5%. Sisvar software (FERREIRA, 2011) was used in all analyses.

RESULTS AND DISCUSSION

The highest numbers of fruits per plant were obtained with the non-grafted scion *P. edulis* BRS Gigante Amarelo (T1), and with the scion grafted onto the rootstocks T2 (homograft), T3 and T4 (*P. nitida* and *P. alata*, respectively) and T5 (*P. alata* x *P. maliformis*), although there were no significant differences between these treatments (Table 1). In comparison with rootstocksT3 and T4, the numbers of fruits per plant were up to 33% lower when the scion was grafted onto hybrid rootstocks T7 and T8, and approximately 64% lower when the hybrid rootstock T6 was employed. Regarding fruit production, the best treatments were T1 toT5 with yields in the range 33.5 to 39.2 kg $plant^{-1}$, while the yields with T6 to T8 were significantly lower (14.2-25.9 kg $plant^{-1}$). Average fruit mass was significantly higher in treatments T1, T2, T5 and T6 (178.5-190.9 g $fruit^{-1}$) in comparison with T3, T4, T7 and T8 (165.8-171.2 g $fruit^{-1}$), but all experimental plants generated firm healthy fruits. Based on these findings, estimates of productivity fell within the range 29 to 43 $t.ha^{-1}$ for all treatments with the exception of T6, the productivity of which was substantially lower (16 t ha^{-1}) because of the reduced number of fruits per plant even though the average fruit mass was comparable with all other treatments.

These findings demonstrate that non-grafted plants and all of the grafted cultivar combinations exhibited, with the single exception of T6, high or moderately high numbers of fruits per plant under the climatic conditions of Terra Nova do Norte. The wild species *P. nitida* and *P. alata* are recognized as *Fusarium*-resistant (RONCATTO et al., 2011a,b; LEÃO, 2011; SEMPREBOM et al., 2012; FALEIRO et al., 2014, 2015a,b) and have the added advantage of being indigenous to the experimental area. The hybrids employed as rootstocks in this study are also known to be resistant to *Fusarium* wilt and are able to survive in infested soil and produce plentiful fruits but, as shown by our results, there are notable differences between them. It is also important to mention that, although wild *P. coccinea* is considered resistant to *Fusarium* spp., seedlings produced in the nursery at Terra Nova do Norte from seeds originating from southeastern Brazil did not develop well enough for grafting, suggesting that the use of seeds or cuttings from well-adapted plants is essential for increasing the chances of successful cultivation (SANTOS et al., 2012; FALEIRO et al., 2013; SILVA et al., 2018).

Table 1. Performance of grafted and non-grafted *Passiflora edulis* BRS Gigante Amarelo grown in Terra Nova do Norte, Mato Grosso, assessed during one production cycle (May 2013 to June 2014)

Treatment - Rootstock	Number of fruits (fruits plant^{-1})	Fruit production (kg plant^{-1})	Average fruit mass (g fruit^{-1})	Productivity (t ha^{-1})
T1 - Non-grafted *P. edulis* BRS Gigante Amarelo	186.9 ^{a}	34.2 ^{a}	188.6 ^{a}	38
T2 - *P. edulis* BRS Gigante Amarelo (homograft)	184.0 ^{a}	33.5 ^{a}	190.9 ^{a}	37
T3 - *P. nitida*	229.0 ^{a}	37.3 ^{a}	165.8 ^{b}	41
T4 - *P. alata*	232.8 ^{a}	39.2 ^{a}	170.3 ^{b}	43
T5 - *P. alata* x *P. maliformis*	183.6 ^{a}	33.9 ^{a}	184.7 ^{a}	38
T6 - *P. edulis* BRS Gigante Amarelo x [(*P. quadrifaria* x *P. setacea*) F1 x *P. incarnata*)]	83.6 ^{c}	14.2 ^{b}	178.5 ^{a}	16
T7 - *P. setacea* x (*P. speciosa* x *P. coccinea*)	156.8 ^{b}	27.0 ^{b}	171.2 ^{b}	30
T8 - *P. katsshbachu* x (*P. vitifolia* x *P. setacea*)	152.6 ^{b}	25.9 ^{b}	166.8 ^{b}	29
Overall mean	176.2	30. 7	177.1	
Coefficient of variance (%)	38.7	41.4	10.5	

Within a column, mean values followed by dissimilar letters are significantly different according to the Scott-Knott test ($p \leq 0.05$).

According to Braga et al. (2008), the productivity of non-grafted *P. edulis* BRS Gigante Amarelo is approximately 40 t.ha^{-1} in the first year, a value equivalent to that obtained in this study for treatment T1. A number of researchers have described good productivity with *P. edulis* cultivars grafted onto wild varieties. For instance, Chavichioli et al. (2011b) reported productivities for *P. edulis* grown in an area without a history of disease of 41.9 t .ha^{-1} for non-grafted plants, 43 t.ha^{-1} for homografts and 38.8 t.ha^{-1} for grafts on *P. alata*. These productivities were slightly higher than those obtained in the present study for analogous treatments T1 and T2 but lower in comparison with treatment T4. Moreover, Junqueira et al. (2006) reported values of fruit production (13.2-26.8 kg plant^{-1}) and productivity (21.1-42.8 t ha^{-1}) for *P. edulis* f. *flavicarpa* clone grafted onto *P. nitida* and grown in an *Fusarium*-infested area of the Federal District. Nogueira-Filho (2011a,b) investigated the production parameters of non-grafted *P. edulis* f. *flavicarpa* FB200 and of grafted plants involving *P. edulis* f. *flavicarpa*, *P. caerulea* L., *P. alata*, *P. gibertii*, *P. coccinea* or *P. cincinnata* as rootstock. Although fruit production was higher in non-grafted plants, the values were not significantly different from those of the grafted plants. An interesting report from Aguiar et al. (2015) described how fruit production among 13 *P. edulis* hybrids cultivated in the southern state of Paraná almost trebled from the first (21.3 - 28.3 kg plant^{-1}) to the second (57.4-76.3 kg plant^{-1}) cycle by virtue of the increased number of fruits, resulting in productivities within the range 34.5 to 43.6 t ha^{-1} over the two cycles. Zaccheo et al. (2012) had reported similar findings following an earlier study involving 36 *P. edulis* hybrids cultivated in the same region. The average fruit mass values obtained with treatments T1, T2, T5 and T6 were comparable with those reported by Chavichioli et al. (2011a) for *P. edulis* grafted onto *P. edulis*, *P. alata* and *P. gibertii* (185.4, 190.1 and 182.0 g fruit^{-1}, respectively) and cultivated in an area with a history of disease. However, when the same scion/rootstock combinations were grown in an area without a disease history, average fruit masses were higher at 218.4, 223.0 and 199.6 g.fruit^{-1}, respectively (Chavichioli et al., 2011c). The average fruit masses reported herein are also in agreement with those reported by Meletti et al. (2000) for eight IAC hybrids of *P. edulis* f. *flavicarpa* (155.3-237.7 g) cultivated in the southeastern state of São Paulo. According to Aguiar et al. (2015), the average fruit masses of 13 *P. edulis* hybrids grown in Paraná decreased slightly from the first to the second cycle with an overall range of 172.3-227.8 g fruit^{-1}, although Zaccheo et al. 2012 did not observe a reduction from the first to the second cycle and reported average fruit masses in the range 130.6 to 202.3 g fruit^{-1}. Based on the data above, it is possible to state that the general performances of the treatments described here (with the exception of T6) were analogous to those described in earlier studies, indicating that such treatments could be applied successfully in Terra Nova do Norte.

CONCLUSIONS

Considering all the fruit production indicators, the best performances were observed with non-grafted *P. edulis* BRS Gigante Amarelo along with its homograft and grafting combinations with *P. nitida*, *P. alata* or hybrid *P. alata* x *P. maliformis* (T1 to T5). The performances of the other *P. edulis* BRS Gigante Amarelo/hybrid rootstock combinations (T7 and T8) were considerate moderate, whereas that with *P. edulis* BRS Gigante Amarelo x [(*P. quadrifaria* x *P. setacea*) F1 x *P. incarnata*)] (T6) was classified as poor. The results reported herein will contribute to the improvement of passion fruit orchards in Mato Grosso.

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