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Fruit quality and production of yellow and sweet passion fruit in Northern state of São Paulo

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Abstract-Yield and quality of yellow and sweet passion fruits produced in northern state of São Paulo, Brazil were evaluated, including FB200 Yellow Master, Isla Redondo Amarelo, BRS Rubi do Cerrado, BRS Sol do Cerrado and BRS Gigante Amerelo cultivars, GP09-02, GP09-03, H09-09, H09-14, HFOP-08 and HFOP-09 intraspecific hybrids, and two selections of sweet passion fruits, BGP-DG and BGP-DP. Experimental design was comprised of randomized blocks with 13 treatments, five replicates and three plants per plot. BGP-DG was the sweet passion fruit selected for fresh fruit market as a result of its higher yield (52.7 t ha^{-1}) and fruit size and mass (243 g). Among yellow passion fruits, GP09-02 stood out because it showed the highest number of fruits per plant after two years of cultivation, even though GP09-02, H09-09, BRS Sol do Cerrado, Isla Redondo Amarelo and FB200 had also presented higher juice content, on average 32.3%, and equivalent accumulated fruit yield. All fruits had high soluble solids contents, with higher concentration for sweet passion fruits (20.0 °Brix) than yellow passion fruits (average of 14.28 °Brix). These cultivars, hybrids and selections have potential for cultivation in northern state of São Paulo and in regions with similar edaphoclimatic conditions.

Index terms: *Passiflora edulis, P. alata,* horticultural performance, juice content, variety selection.

Qualidade de frutos e produção de maracujazeiros-amarelos e doces no Norte de São Paulo

Resumo-Avaliaram-se produção e qualidade de frutos de maracujazeiros-amarelos e doces na região norte do Estado de São Paulo, incluindo-se as cultivares FB200 Yellow Master, Isla Redondo Amarelo, BRS Rubi do Cerrado, BRS Sol do Cerrado e BRS Gigante Amarelo, os hibridos intraespecíficos de maracujazeiro-amarelo GP09-02, GP09-03, H09-09, H09-14, HFOP-08 e HFOP-09, e duas seleções de maracujazeiro-doce, BGP-DG e BGP-DP. O delineamento experimental foi em blocos casualizados, com 13 tratamentos, cinco repetições e três plantas na parcela. O maracujazeiro-doce BGP-DG foi selecionado para mercado de frutas frescas, em função da elevada produtividade (52,7 t ha^{-1}) e da maior massa e tamanho de fruto (243 g). Entre os maracujazeiros-amarelos, o híbrido GP09-02 destacou-se pelo maior número acumulado de frutos por planta, em dois anos de cultivo, embora GP09-02, H09-09, BRS Sol do Cerrado, Isla Redondo Amarelo e FB200 tenham apresentado maior rendimento de suco, em média 32,3%, e produtividade acumulada por área semelhante. Todos os frutos apresentaram elevada concentração de sólidos solúveis, maior nos maracujás-doces (20,0 °Brix) em relação aos amarelos (média de 14,28 °Brix). Essas cultivares, híbridos e seleções apresentam potencial de cultivo no norte do Estado de São Paulo e em regiões com condições edafoclimáticas similares.

Termos para indexação: *Passiflora edulis, P. alata,* desempenho horticultural, seleção de variedades, rendimento de suco.

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Introduction

Brazil is the largest producer and consumer of yellow passion fruit (*Passiflora edulis* Sims), producing 694,539 t in a planted area of 50,837 ha in 2016 (IBGE, 2018). This species represents 95% of the cultivated area in the country, used for both processing and fresh fruit consumption, followed by sweet passion fruit, *P. alata* Curtis (FALEIRO et al., 2011), for fresh consumption.

Passion fruit is of great socioeconomic importance because it is predominantly cultivated by family farming, ranging in size from 3 to 5 ha, being adapted to all regions of the country (MELETTI, 2011; RAMALHO et al., 2011). The annual production cycle varies from eight months in the southeast region, ten months in the northeastern region and twelve months in the northern region, generating continuous harvests and income (PIRES et al., 2011).

However, the productivity of passion fruit cultivation in Brazil is still low, averaging 14.10 t ha^{-1} $year^{-1}$ (IBGE, 2018), compared to the productive potential of the crop that can exceed 40 t ha^{-1} (FREITAS et al., 2011). This result is due to inadequate cultivation techniques, phytosanitary problems and low availability or use of improved cultivars adapted to the edaphoclimatic conditions of each region (AGUIAR et al., 2015). Different breeding programs of yellow passion fruit selected cultivars and hybrids with high fruit productivity with good quality and also presenting resistance to some diseases (CRUZ NETO et al., 2016; FALEIRO et al., 2011). On the other hand, sweet passion fruit cultivars are not available, in spite of their growing demand for the fresh fruit market.

In this context, fruit yield and quality of five cultivars and six hybrids of yellow passion fruit and two sweet passion fruit selections grown in northern state of São Paulo were evaluated.

Material and Methods

Experiment was carried out in the field from March 2015 to March 2017 in Bebedouro-SP (20 ° 53'16 '' S, 48 ° 28'11 '' W, 601 m a.s.l.). The climate of the locality is Cwa type, region of Cerrados, with average maximum, average and minimum temperatures of 29.8, 23.7 and 17.5°C and mean annual rainfall of 1,318 mm during the evaluation period. The soil of the experimental area is a dystrophic Red Latosol, A moderate, medium texture, alic, presenting the following chemical properties (0-20 cm): pH in $CaCl_2$ 5.9; Ca 40; Mg 15; K 2; H + Al 18; T 75 ($mmol_c$ dm^{-3}); V 76%; O.M. 22 g dm^{-3}; P 48, Fe 130, Cu 6.6; Zn 6.6; Mn 1.8; B 0.2; S 9 (mg dm^{-3}).

Seedlings were cultivated in a nursery with insect-proof screens in 2 L plastic bags containing commercial pine-bark substrate. Transplanting to the field was performed on March 2015, 90 days after sowing, at 3.0 m x 2.0 m tree spacing (1,667 plants ha^{-1}). Cultivation was conducted in espalier on wire threads # 12 fixed at 1.80 m above the ground. Wooden posts were fixed every 6.0 m on the row. Drip irrigation was performed with flow drippers of 4 L $hour^{-1}$ $plant^{-1}$, being activated in periods of prolonged drought. Pits (0.4 m x 0.4 m x 0.4 m) were fertilized with 60 g of single superphosphate, 60 g of dolomitic limestone and 5 L of corral manure. After planting, cover fertilizations were carried out every 45 days with potassium chloride (60 g $seedling^{-1}$) and calcium nitrate (100 g $seedling^{-1}$) or 20-05-20 formulation (100 g $seedling^{-1}$), in addition to boric acid every 90 days (10 g $seedling^{-1}$). Pollination was naturally performed by bumblebees (*Xylocopa* spp.).

Control of spontaneous vegetation was performed by weeding when necessary. There was no previous or concomitant cultivation of passion fruit in the experimental area and in its vicinity. Pest control measures were used during the evaluation period when necessary, using insecticide (deltamethrin 5 ml 10 L^{-1}), and copper hydroxide (2.5 g L^{-1}) was sprayed every 20 days for the control of bacteriosis (*Xanthomonas axonopodis* pv. *passiflorae*).

Five *P. edulis* Sims yellow passion fruit cultivars were evaluated (FB200 Yellow Master, Isla Redondo Amarelo, BRS Rubi do Cerrado, BRS Sol do Cerrado and BRS Gigante Amerelo), as well as six intraspecific *P. edulis* hybrids (GP09-02, GP09-03, H09-09, H09-14, HFOP-08 and HFOP-09) and two selections of sweet passion fruit *P. alata* Curtis (BGP-DP and BGP-DG), obtained by Embrapa Cassava & Tropical Fruits in Cruz das Almas-BA.

The number of fruits per plant (NF) was counted weekly from the first flowering of plants until March 2017, two years after planting, and accumulated productivity (PR), in t ha^{-1}, estimated as a function of the planting density (PD) and the average fruit mass (FM), in grams, by PR = NF x PD x FM x 10^{-6}. Mature fruits were counted and weighed after falling from plants. Six fruits were collected per plot in two production periods, in November 2015 and March 2016, and evaluated by fruit mass (FM) in g and seedless pulp mass (SM) in g, length (FL) in cm, diameter (FD) in mm, number of seeds (NS), bark thickness (BT), juice yield (JY) given by SM / FM in%, soluble solids (SS) in °Brix, titratable acidity in % (TA) and soluble solids / acidity ratio (SS / TA).

The experimental design was in randomized blocks, with 13 treatments, five replicates and three plants per plot. The results were submitted to analysis of variance and the means were grouped by the Scott-Knott test ($p \leq 0.05$), after normality and variance homogeneity assumptions were verified.

Results and discussion

The lowest fruit mass was observed for BGP-DP and HFOP-08, on average 132 g, while the other hybrids and cultivars were grouped with mass ranging from 173 to 243 g (Table 1). However, for the seedless pulp mass, BGP-DP, BGP-DG, HFOP-08, HFOP-09 and BRS Rubi do Cerrado also presented lower average values (19 to 41 g), almost half of that presented by the other passion fruit cultivars. For the size of fruits, larger fruits were observed for BGP-DG compared to BGP-DP, but without differences from yellow passion fruits, except for the smaller fruits observed for HFOP-08 and HFOP-09 (Table 1).

Sweet passion fruits (*P. alata*), which are aimed at the fresh market, presented the lowest juice yield (13.1 and 17.4%) in relation to yellow passion fruit hybrids (Table 1). As the number of seeds per fruit was the same for both sweet passion fruit and for the group with the lower average of yellow passion fruits (mean of 191 seeds), possibly the lowest juice yield of sweet passion fruit selections also results from the aryl characteristics and greater bark mass and thickness (Table 1).

Regarding the chemical variables of fruits (Table 1), sweet passion fruits presented higher concentration of soluble solids (20 °Brix) and lower titratable acidity (mean of 1.55 %), whereas yellow passion fruits had means of 14.28 °Brix and 5.12%, respectively. As a consequence, there were three groupings regarding SS / TA, in which BGP-DP showed SS / TA of 13.95, followed by 11.90 for BGP-DG, whereas yellow passion fruits did not differ from each other with SS / TA ranging from 2.56 to 3.04 (Table 1).

Fruits destined for the juice industry must present pulp yield higher than 35%, high acidity to guarantee post-harvest shelf life, yellow-gold juice color and soluble solids content above 13 °Brix (FARIAS et al., 2005). The fresh fruit market prefers large fruits, with mass greater than 200 g, with good appearance, yellowish color and free of pests, diseases and physical injuries (AGUIAR et al., 2015). In the present study, the majority of yellow passion fruits evaluated met these parameters, according to the Brazilian standards of quality classification of passion fruit (BRASIL, 2003).

Regarding the number of fruits evaluated, the selection of sweet passion fruit BGP-DG accumulated the highest amount in 18 months of production (August 2015 to March 2017), with 137 fruits, followed by the group formed by BGP-DP (103 fruits) and GP09-02 yellow passion fruit (89 fruits), and the third group formed by the other yellow passion fruits, with the lowest number of fruits accumulated, on average 59 fruits (Table 1). Accumulated productivity was estimated from the density of plants (1,667 plants ha^{-1}), number of accumulated fruits and average fruit mass, resulting in two groups, BGP-DG being the most productive, with 52.7 t ha^{-1}, while the second group, with mean yield of 19.9 t ha^{-1}, was formed by sweet passion fruit BGP-DP, which did not differ from yellow passion fruit hybrids and cultivars.

The production and fruit quality results presented are similar to previous studies evaluating the agronomic performance of these hybrids and other yellow passion fruit trees, with variations also resulting from the edaphoclimatic and cultivation conditions in the different regions of the country (AGUIAR et al., 2015; COSTA et al., 2009; FORTALEZA et al., 2005; FREITAS et al., 2011; GRECO et al., 2014; MARTINS et al., 2003; MELETTI, 2000; MELO et al., 2001; NEGREIROS et al., 2008; ZACCHEO et al., 2012; NEVES et al., 2013; VALE et al., 2013). Similar results are also reported for production and fruit quality of sweet passion fruit selections in other studies (ALVES et al., 2012; MELETTI et al., 2003).

The evaluation of yellow passion fruit in three municipalities of Bahia (Lençóis, Dom Basílio and Rio de Contas) presented higher production values for FB200, HFOP-09, HFOP-08, H09-14, H09-09, GP09 -03, BRS Rubi do Cerrado and BRS Gigante Amarelo cultivars, ranging from 22.55 t ha^{-1} to 30.24 t ha^{-1} (Cruz Neto et al., 2016). These results demonstrate the great potential of yellow passion fruit evaluated in this work and, probably because the experiments mentioned were carried out in a tropical and warm climate region, with continuous production throughout the northeastern region of Brazil.

In this experiment, the annual yellow passion fruit harvest was only nine months (Figure 1), since production was concentrated between the months of October and June, that is, at the warmer time of the year and without reduction in the photoperiod, conditions necessary to yellow passion fruit, but not restrictive to sweet passion fruit (VASCONCELLOS; DUARTE FILHO, 2000). This explains in part the lower average productivity of *P. edulis* in relation to that observed in experiments conducted in the northeastern region in general. On the other hand, sweet passion fruit selections BGP-DG and BGP-DP (*P. alata*) were earlier in relation to yellow passion fruit, showing beginning of harvest at 161 and 181 days after planting, respectively, and increasing during the study, with peaks at 390 and 229 days, respectively (Figure 1). Yellow passion fruit started fruit production only at 229 days after planting, with increasing and marked production starting at 329 days. Transplanting performed in March 2015 contributed to the development of *P. edulis* plants by October, when production began, and productivity could be reduced if planting occurred in the second half of the year. On the other hand, seedlings had only 90 days, thus requiring a longer period to grow in the field after transplanting.

Sweet passion fruit BGP-DP, despite its high number of fruit per plant, was not considered to have good performance in the northern state of São Paulo, due to the lower fruit mass in relation to BGP-DG, resulting in lower productivity per area (Table 1). On the other hand, yellow passion fruit hybrids GP09-02 and H09-09 and BRS Sol do Cerrado, Isla Redondo Amarelo and FB200 cultivars stood out for the higher juice yield, on average 32.3%, in addition to the greater number of fruits of the first hybrid.

The variation coefficient for fruit yield was high (Table 1), even if using improved hybrids and cultivars, and in the same group, there was an average production variation from 8.6 to 33.0 t ha^{-1} among experimental plots. The only pollination used was natural, and the fruit set is usually one-third of that after artificial pollination (KRAUSE et al., 2012). It was also observed in the experimental area the presence of honey bees intensively competing with bumblebees and, during the rainy periods, especially from 460 days after planting, there was incidence of bacteriosis in all hybrids, selections and cultivars, in spite of the preventive chemical control, causing intense symptoms of disease, fall of leaves and dieback of branches. All these factors may have contributed to reduce or vary the productive potential (Table 1, Figure 1). Even so, with the exception of HFOP-08 and HFOP-09, all passion fruits studied showed estimated productivity above the national average for an annual harvest.

Table 1. Fruit mass (FM), seedless pulp mass (SM), juice yield (JY, SM / FM), number of seeds per fruit (NS), fruit diameter (FD), fruit length (FL), bark thickness (BT), total soluble solids (SS), titratable acidity (TA), soluble solids / acidity ratio (SS / TA), number of fruits produced per plant (NF) and estimated cumulative productivity (PR) of yellow and sweet passion fruits in the northern state of São Paulo, Bebedouro-SP, 2015-2017.

Genotype	FM (g)	SM (g)	JY (%)	NS	FD (cm)	FL (cm)	BT (mm)	SS (°Brix)	TA (%)	SS/TA	NF	PR (t ha^{-1})
FB200	198 a	64 a	31.6 a	244 a	8.2 a	8.9 a	6.8 c	15.0 b	4.92 a	3.03 c	63 c	20.7 b
Isla Redondo	207 a	61 a	29.6 a	255 a	8.6 a	9.0 a	6.8 c	14.4 b	5.16 a	2.81 c	68 c	23.1 b
BRS Rubi do Cerrado	179 a	44 b	24.6 b	192 b	8.1 a	8.3 b	6.5 c	14.0 b	4.75 a	3.04 c	59 c	17.6 b
BRS Gigante Amarelo	215 a	61 a	28.4 b	201 b	8.1 a	8.8 a	6.2 c	13.2 b	5.21 a	2.58 c	37 c	13.9 b
BRS Sol do Cerrado	210 a	72 a	36.7 a	257 a	8.7 a	8.7 a	7.1 c	14.0 b	5.50 a	2.56 c	76 c	26.7 b
GP09-02	228 a	74 a	32.2 a	310 a	8.5 a	9.0 a	7.0 c	15.0 b	4.79 a	3.04 c	89 b	33.0 b
GP09-03	192 a	53 a	27.0 b	191 b	8.1 a	8.6 a	6.2 c	14.5 b	5.38 a	2.73 c	56 c	17.5 b
H09-09	190 a	62 a	31.5 a	281 a	8.2 a	8.7 a	6.3 c	14.5 b	5.21 a	2.79 c	73 c	22.6 b
H09-14	195 a	56 a	27.6 b	189 b	8.6 a	8.6 a	7.3 c	14.0 b	5.42 a	2.60 c	75 c	24.2 b
HFOP-08	155 b	41 b	26.1 b	208 b	7.3 b	7.5 b	7.3 c	14.4 b	4.96 a	2.94 c	50 c	12.4 b
HFOP-09	173 a	40 b	23.0 b	151 b	7.7 b	8.1 b	8.0 c	14.1 b	5.06 a	2.81 c	30 c	8.6 b
BGP-DP (sweet)	109 b	19 b	17.4 c	206 b	5.7 c	7.9 b	9.2 b	20.0 a	1.44 b	13.95 a	103 b	18.5 b
BGP-DG (sweet)	243 a	32 b	13.1 c	190 b	7.7 b	8.8 a	12.0 a	20.0 a	1.67 b	11.90 b	137 a	52.7 a
Mean	191	52	26.8	221	7.9	8.5	7.4	15.0	4.47	4.37	70	22.4
F value	4.5**	4.6**	7.3**	2.4*	12.4**	2.9**	7.6**	22.8**	34.0**	148.2**	4.5**	6.5**
VC (%)	16.6	28.9	25.6	25.6	5.64	6.2	15.6	5.7	10.2	14.3	37.3	38.6

Averages followed by the same letter in the column belong to the same group by the Scott Knott test, * significant at 5% probability and ** significant at 1% probability.

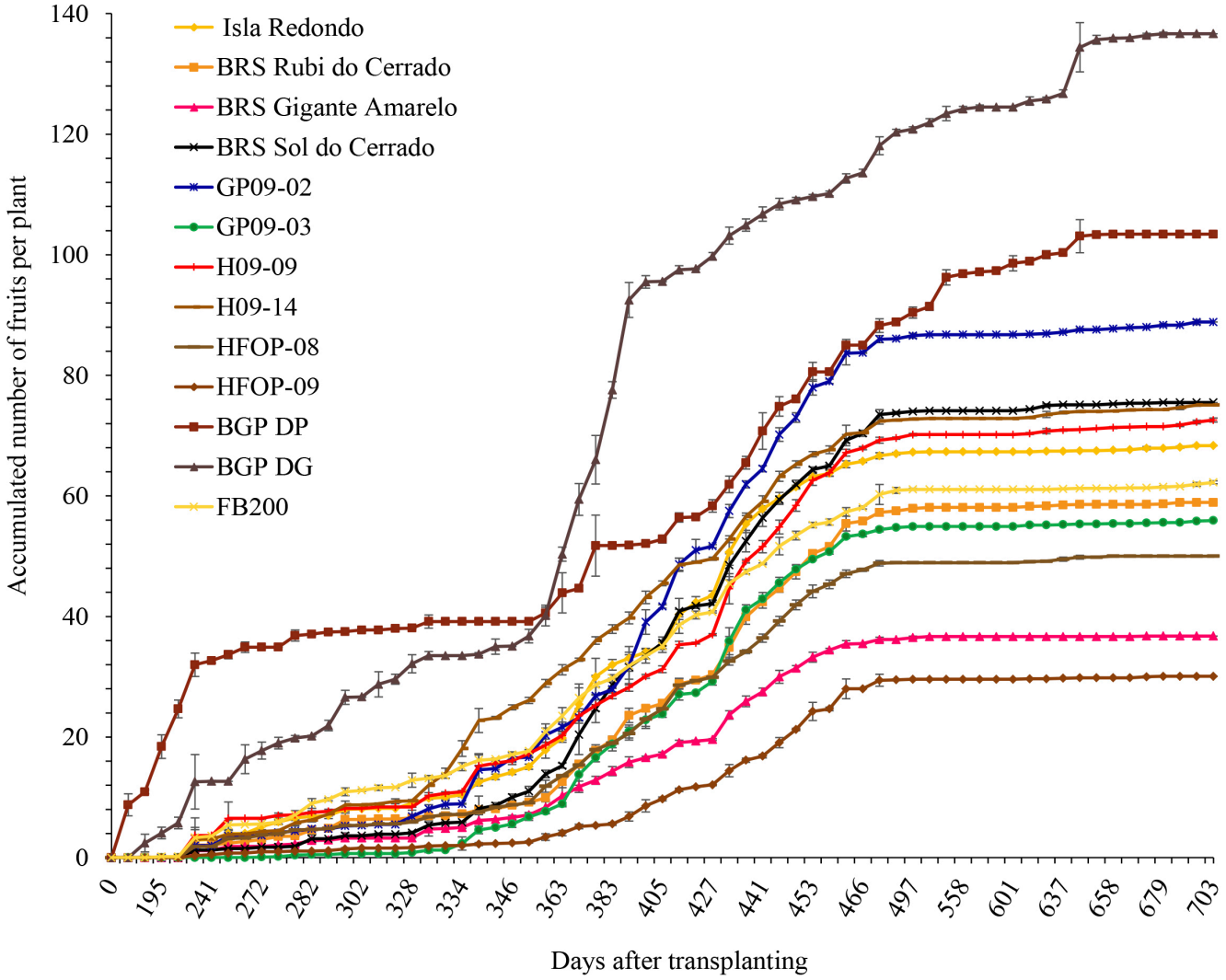

Figure 1. Accumulated number of fruits per plant up to 703 days after transplanting of yellow and sweet passion fruit harvest in northern state of São Paulo, Bebedouro-SP, from March / 2015 to March / 2017. Bar represents the standard error of the average on each day of harvest.

Conclusions

Under the conditions evaluated in this study, sweet passion fruit BGP-DG was selected for the fresh market by combining higher productivity, mass and fruit size.

Among yellow passion fruit, GP09-02 hybrid was highlighted by the highest accumulated number of fruits per plant in two years of cultivation, although GP09-02, H09-09, BRS Sol do Cerrado, Isla Redondo Amarelo and FB200 presented higher juice yield and similar accumulated productivity per area.

These cultivars, hybrids and selections have potential for commercial cultivation in the northern state of São Paulo and in regions with similar soil and climatic conditions.

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