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Flowering, fruit production and quality of passion fruit hybrids in Minas Gerais, Brazil

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Abstract

The aim of this work was to characterize flowering aspects, as well as to evaluate the agronomic performance and fruit quality of the main sour passion fruit hybrids. The experimental design was randomized blocks with four replicates and five treatments, consisting of the following commercial hybrids: 'FB300-Araguary', 'FB200-Yellow Master', 'BRS Gigante Amarelo, 'BRS Sol do Cerrado' and 'BRS Rubi do Cerrado' and the experimental unit consisted of three plants. Phenological characterization and the aspects related to flowering were performed through visual observations of the beginning and duration of the events. Hybrid production was determined by weighing all fruits harvested during the production period. For physical and physicochemical variables such as fruit mass, peel mass, seed mass, pulp mass, peel yield, seed yield, pulp yield, peel thickness, number of seeds, longitudinal diameter, transverse diameter, fruit shape, were evaluated, peel firmness, peel and pulp color, pH, total soluble solids, total titratable acidity and TSS/TTA ratio were evaluated. The beginning of flowering and harvesting was 02/22/19 and 04/22/2019, respectively. All studied hybrids had similar production and yield responses, with ideal physical characteristics for processing or fresh consumption.

Keywords: degree-days, *Passiflora edulis*, post-harvest

Introduction

The fruit growing activity has productive chain that includes inputs and production, trade and industry sectors, enabling employment and income in the countryside and city, with estimated generation of three to five job opportunities per cultivated hectare (Faleiro et al., 2019). Among fruit trees, passion fruit is a profitable option for producers and of great social and economic importance for the country, with wide market potential in the various producing regions and high expansion capacity, mainly because the activity offers fast economic returns (Botelho et al., 2019).

Currently, Brazil is the world's largest passion fruit producer and in 2017, production was concentrated mainly in the states of Bahia, Ceará and Santa Catarina, and in Minas Gerais, the harvested area was 1,488 ha, being the sixth state with the largest area destined to passion fruit activity in the country, with production of 19,100 t (IBGE, 2018).

Among passion fruit species commercially exploited in the country, *Passiflora edulis* Sims (sour passion fruit) is the most cultivated because it offers fruits with good acceptance in the fresh consumption and industry markets (Silva et al., 2016). In addition, it has several commercial hybrids, 'BRS's Gigante Amarelo', 'Rubi do Cerrado' and 'Sol do Cerrado', 'FB 200' and 'FB 300' being the most planted today (Junqueira et al., 2016).

Despite being produced from north to south of the country, passion fruit cultivation in Cerrado regions has been highlighted, especially by the existence of commercial hybrid cultivars developed for this region. However, for the state of Minas Gerais, there are only two hybrids developed by Flora Brazil (FB 200-Yellow Master and FB 300-Araguary), and there is no record of studies with these and other commercial hybrids for the

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edaphoclimatic conditions of the central region of Minas Gerais.

Passion fruit cultivation is considered to be long days, as it requires more than 11 hours of light for flowering (Cobra et al., 2015) and grows better in tropical regions, with average monthly temperature from 20 to 32°C (Almeida et al., 2015). The opening of the flower bud is diurnal, starting around 01:00 pm, and may be later on cloudy days (Siqueira et al., 2009). Reproductive development such as flowering, fertilization, fruiting, ripening and consequently fruit quality is temperature dependent (Nave et al., 2010).

Regarding the final destination of fruits, the characteristics required for fruits destined for industry are good pulp yield and high soluble solids content and acidity, in addition to intense juice pigmentation and for fresh consumption market, larger and heavier fruits with homogeneity, facilitating their classification (Meletti, 2011).

Studies related to fruit production and quality carried out in the central region of Minas Gerais are scarce, and highlighting the importance of studies of this nature, the aim of this study was to characterize flowering aspects, as well as to evaluate the agronomic performance and fruit quality of the main sour passion fruit hybrids.

Materials and Methods

The experiment was conducted from October 2018 to July 2019, and the planting done in 10/22/2018 in the orchard of the Federal University of São João del Rei, Campus of Sete Lagoas (UFSJ/CSL), which has geographic coordinates 19°28'36"S and 44°11'53"W and 769 m a.s.l. According to the Köppen classification, the climate of the region is Aw type, tropical climate with dry winter and hot summer (Martins et al., 2018). The average temperature of the region is 22.6°C, and average annual rainfall of 1,335 mm.

The experimental design was randomized blocks with four replicates and five treatments, consisting of the following commercial passion fruit hybrids: 'FB300-Araguary' and 'FB200-Yellow Master' from Flora Brasil/MG and 'BRS Gigante Amarelo', 'BRS Sol do Cerrado' and 'BRS Rubi do Cerrado', developed by Embrapa Cerrados. The experimental unit consisted of three plants and the response, the average effect among the three.

Before planting, the soil in the cultivation area was analyzed (Table 1) in order to correct it, increasing the base saturation to 70% and the necessary planting fertilization, formation and production as appropriate, according to recommendations for the culture proposed by Dias & Rodrigues (2012).

Table 1. Chemical and physical analysis of soil (0 - 20 and 20 - 40 cm deep) in the experimental area performed by the Laboratory of Soil Fertility and Plant Nutrition.

	pH	MO	P	K	Ca	Mg	Al	H+Al	SB	T	T
Soil depth	H_2O	%	.... mg dm^{-3}		.... cmolc dm^{-3}						
0 – 20	5.5	2.4	6.2	80.4	2.4	0.4	0.3	6.3	3.0	3.3	9.3
20 – 40	5.2	1.9	4.5	48.3	1.3	0.1	0.8	6.6	1.5	2.3	8.1
	V	M	B	Cu	Fe	Mn	S	Zn	Argila	Silte	Areia
Soil depth	.... %		.... mg dm^{-3}						..........dag kg^{-1}..........		
0 - 20	32	9	0.2	0.9	47.6	49.9	4.3	0.9	64	17	19
20 - 40	19	35	0.1	0.9	50.6	37.1	3.8	0.5	66	16	18

MO = soil organic matter; P = phosphorus (Melhich-1); K = potassium Ca = calcium; Mg = magnesium; Al = aluminum; H + Al = potential acidity; SB = sum of bases; t = effective CTC; T = potential CTC; V = base saturation; m = Al saturation; B = boron; Cu = copper; Fe = iron; Mn = manganese; S = sulfur; Zn = zinc.

Seedlings were produced by 'Viveiro Flora Brazil', located in Araguari-MG, being acquired with approximately at 70 days, 40 cm of shoot height and 10 to 11 leaves. Transplant was performed in October 2018, with 4 x 3 m spacing, 40 x 40 x 40 cm pits in previously prepared and corrected soil. The conduction of plants was in vertical cordon with flat wire at 1.8 m above the ground, with distance of 6 m between eucalyptus posts.

During formation, lateral buds were eliminated, leaving only the most vigorous, guided by tutoring to the supporting wire. When reaching the wire height, plants were pruned and two upper lateral branches were left, which were carried at 1.5 m from the main one on each side of the plant, forming the lateral branches. From these, productive tertiary branches emerged and were evaluated in the present experiment, and to avoid contact with the soil, tertiary branches were cut approximately 15 cm from it.

Cultural treatments were carried out following recommendations of Dias & Rodrigues (2012), with control of weeds, diseases and pests when demanded, as well as fertilization for formation and production (values > 35 t ha^{-1} of expected productivity). Water requirement was supplied by localized irrigation, performed with static micro sprinkler and fruits were obtained through natural pollination by *Xylocopa* bees.

Climatic variations occurred during the experiment period were obtained from the National Institute of Meteorology (INMET) through records of the Automatic Meteorological Station, installed at Embrapa

Milho e Sorgo, approximately 3 km from the experimental site, and from solar radiation data, it was also possible to calculate the photoperiod duration (Figures 1A and 1B).

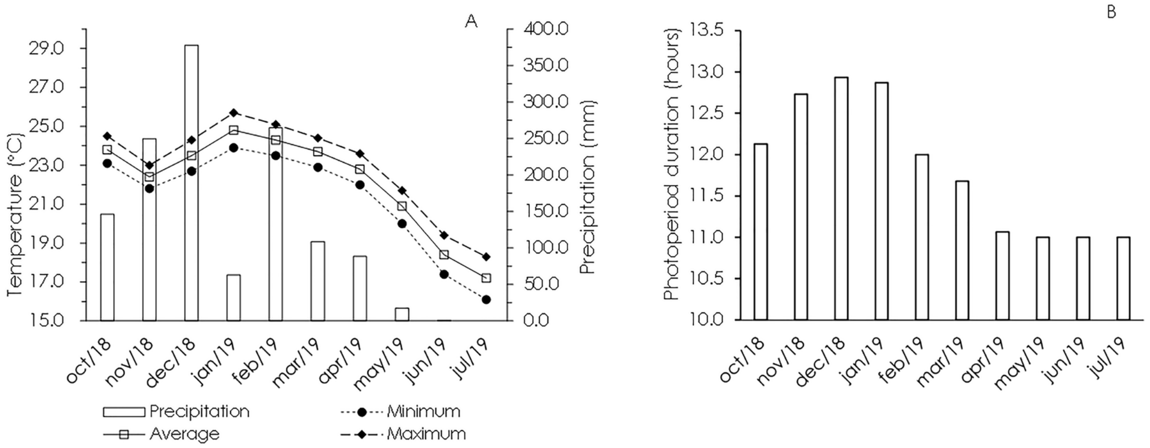

Figure 1. Minimum, average and maximum temperatures; accumulated monthly precipitation (A) and photoperiod duration (B) during sour passion fruit cultivation in Sete Lagoas –MG. Source: Embrapa Milho e Sorgo Automatic Weather Station.

Phenological characterization was performed through daily visual observations of the beginning and duration of flowering and fruiting phenological events of hybrids. To this end, from the emergence of the first floral bud, which took place on February 22, two branches of the middle third of tertiary branches were marked on each plant, recording dates of emergence (SGF) and development of floral buds (DGF), developed flower bud (BFD), anthesis (A), initial fruit development (DIF), developed fruit (FD) and ripe fruit (FM), accounting for all structures that appeared in each branch. For better evaluation, a phase scale adapted from the characterization proposed by Souza et al. (2012) was determined (Figure 2).

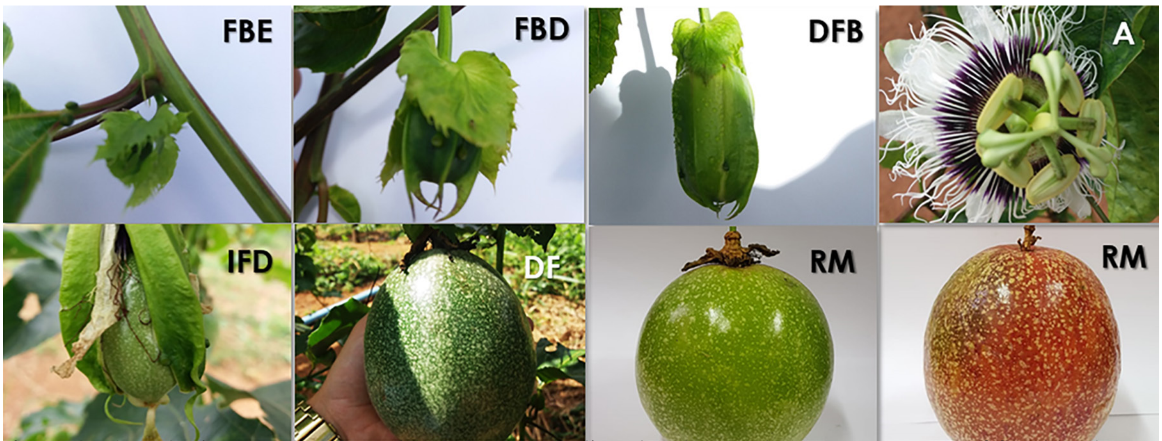

Figure 2. Phenological stages of passion fruit reproductive development: FBE: emergence of floral bud; FBD: floral bud development; DFB: developed floral bud; A: Anthesis (flowering); IFD: initial fruit development; DF: developed fruit and FM: ripe fruit.

The duration in days of the reproductive cycle was calculated from the change dates of each phenological event, counting the days from the emergence of buds until ripe fruits.

For the calculation of accumulated degree-days (thermal sum) in the various phenological events, the minimum basal temperature of 10 °C is recommended by Neves et al. (1999) for the culture, being calculated from the difference between the average daily temperature and the lower basal temperature (10 °C), according to the following equation:

$$GDA = \sum(Tmd - 10) \quad \text{Eq. (1)}$$

Where,

GDA = sum of accumulated degree-days (°C),

Tmd = average daily temperature (°C).

In order to account for the average time spent for floral opening (anthesis) and fillet and stylet deflection, 20 random flowers of each hybrid were observed between March and April 2018, during which time there was little variation in temperature and rainfall in the region (Figure 1). The curvature movements of fillets and stylets were classified as totally curved, considering stigmas at the same level as anthers, partially curved or without curvature.

Stigma receptivity was tested on 12 random flowers per hybrid per hour between 01:00 pm and 06:00 pm. Hydrogen peroxide (H_2O_2) drops were applied at 10 vol on the stigmatic surface, forming intense bubbles in the presence of the peroxidase enzyme (Cobra et al., 2017), thus confirming receptivity. Subsequently, the average number of receptive stigmas was determined in each interval evaluated, also determining the viability of flowers for pollination.

Floral longevity was determined from observations in the same period in 20 flowers per random hybrid from 11:30 am to 06:00 pm, with 30-minute intervals, in which the number of completely open flowers and senescent flowers was counted, considering the beginning of the senescence period from wilting and loss of corolla brightness, which becomes opaque at this stage, according to Cobra et al. (2015). Based on data above, the percentage of completely open and senescent flowers at different evaluation times was calculated.

Production of hybrids in kilograms per plant (kg plant^{-1}) was determined by weighing all the fruits daily harvested (considering as harvest point when there was abscission when fruit was touched and fruits that were already on the ground) between months from April to July. From these production data, the estimated yield was calculated by multiplying the average production per hybrid by the number of plants per hectare (833 plants ha^{-1}).

For physical characterization, 10 fruits of each hybrid were harvested by plot, taking into consideration the phytosanitary aspect. The physical characteristics evaluated were: fresh fruit mass (FM) in grams, obtained by individual weighing of fruits on a digital scale; longitudinal diameter (LD) in mm, measured from the peduncle insertion to the stigma scar using a digital caliper; transverse diameter (TD) in the equatorial region of the fruit in mm, with the aid of a digital caliper; fruit shape (FS), through the LD/TD ratio, dimensionless; exocarp color (EC) with the use of a Konica Minolta colorimeter, model Spectrophotometer CM - 700 d, with direct reading of the luminosity coordinate “L”, Chroma saturation index “C” and the Hue angle “h°”; and peel firmness (PF), expressed in kilogram-force (kgf), measured by a manual penetrometer.

Subsequently, fruits were cut in the equatorial region, extracting the juice to perform analyses such as: juice color evaluation (JC), measured by the Spectrophotometer CM - 700 d colorimeter expressed by the "L" lightness coordinate "L", chroma “C” saturation index and hue angle, Hue “h°”; and peel thickness (exocarp plus mesocarp) (PT) in mm, with a digital caliper, measuring three equidistant points and calculating their average; and peel mass (PeM) in grams on a digital scale. Through the difference between fruit mass (FM) and peel and seed masses, pulp mass (PM) was estimated. Seeds were extracted using lime for aryl removal, which were weighed on a digital scale to obtain seed mass (SM), and number of seeds (NS) was obtained from the weighing of five subsamples of 100 seeds, calculating the average weight of 100 seeds and related to seed mass (SM). Masses were used to determine peel (PeelY), seed (SY) and pulp (PY) yield, expressed as percentage.

The physicochemical characteristics evaluated were: hydrogen potential (pH), by direct reading in digital potentiometer and results expressed in absolute numbers; total soluble solids content (TSS), expressed in °Brix by means of portable digital refractometer; and total titratable acidity (TTA) determined by titration of 5 mL of juice and three drops of phenolphthalein diluted in 45 mL of distilled water, titrated with 0.1 mol L^{-1} NaOH and results expressed as percentage of citric acid, according to methodology of the Adolfo Lutz Institute (2008) and ratio was obtained through the TSS/TTA ratio.

Flowering data were descriptive and for the comparison of results for production, yield, physical and physicochemical characteristics, the assumptions of the model were observed, which were met, following analysis of variance through the 5% F test, and data averages compared by the Tukey test at 5% error probability, with the aid of the SISVAR® software (Ferreira, 2011), version 5.6.

Results and Discussion

The flowering of sour passion fruit began on February 22, 2019, with ‘Gigante Amarelo’ hybrid beginning its reproductive cycle 123 days after transplanting (Table 2). A similar 120-day interval was also found for ‘FB 200’ hybrid in studies conducted within a protected environment in Viçosa-MG (Salazar et al., 2016). For this hybrid, flowering at 129 days after transplantation was recorded under the conditions of the present study.

The latest hybrid to enter this phase was ‘Sol do Cerrado’, with 136 days, consequently it was also the one that presented shorter flowering duration, with phase of only 28 days, with 14 days less flowering than ‘FB 300’ hybrid, of longer duration of this period.

Table 2. Duration in days of the flowering and harvesting period of different passion fruit hybrids.

Hybrid	Flowering			Harvesting		
	Begin	End	Duration (days)	Begin	End	Duration (days)
	Cycle 2018/2019					
Gigante Amarelo	22/02	05/04	41	29/04	05/07	67
Rubi do Cerrado	02/03	11/04	40	29/04	05/07	67
Sol do Cerrado	07/03	05/04	28	22/04	05/07	74
FB200	28/02	05/04	36	22/04	05/07	74
FB300	28/02	11/04	42	29/04	05/07	67

The end of flowering occurred in the first weeks of April, a month in which a decrease in temperature and photoperiod was observed, with average of 11.1 hours of sunshine per day in the region (Figure 1), which is in agreement with Nave et al. (2010), who reported that the development of passion fruit flowers is interrupted with photoperiod days less than 11.5 h.

Flowering interruption in colder and low photoperiod months was also observed in Araponga (Brazil), with flowering resumption in September, with reduced number of flowers and after December, with significant flowering (Cordeiro et al., 2019).

The beginning of the harvest period was marked by the first fruits obtained from 'Sol do Cerrado' and 'FB 200' hybrids, on April 22. Despite the short flowering duration, 'Sol do Cerrado' had longer harvest time, 74 days, together with 'FB 200' hybrid.

Within the flowering and harvest periods, there are phenological events used to characterize phenological stages. Such characterization, combined with the calculation of accumulated degree-days, can help in crop planning and maturation season estimates (Souza et al., 2012), becoming an important tool for producers. In this context, the duration of the phenological reproduction events in days was obtained (Table 3), in which it was possible to verify synchrony among hybrids during the interval between flower bud emergence (FBE) and beginning of fruit development (IFD) where all hybrids needed 21 days. Montero et al. (2013) observed an interval of 12-15 days for flower bud development for *Passiflora edulis* in a greenhouse experiment with different *Passiflora* species, value similar to that found in the present work (14 days), also emphasizing the 19-day requirement from bud emergence to flower opening for all hybrids.

Table 3. Duration in days of phenological events of different passion fruit hybrids.

Phenological Events	Duration (Days)				
	Hybrid				
	Gigante Amarelo	Rubi do Cerrado	Sol do Cerrado	FB200	FB300
FBE/FBD	2	5	5	5	5
FBD/DFB	12	9	9	9	9
DFB/A	5	5	5	5	5
A/IFD	2	2	2	2	2
IFD/DF	19	26	19	19	15
DF/RF	13	6	6	6	18
FBE/RF	53	53	46	46	54

FBE: Floral bud emergence; FBD: Floral bud development; DFB: Developed floral bud; A: Anthesis; IFD: Initial fruit development; DF: Developed fruit and RF: Ripe fruit.

The duration between phenological events of fruit formation and ripening was similar only for 'Sol do Cerrado' and 'FB 200' hybrids, with 19 days between IFD/DF and 6 days between DF/RF, which also presented the shortest reproductive phase duration (46 days between FBE/RF). The others required a total of 53 days, from bud formation to fruit ripening, with development and ripening events varying among them. These values are within the time variation observed in a study conducted in Campos dos Goytacazes (Brazil), in 2010 (Souza et al., 2012), where the authors reported duration of floral bud emergence to fruit ripening in the months of February and March of 39 and 59 days, respectively.

The sum of degree-days (Table 4) fluctuated according to duration, presenting requirement of 293.2 degree-days for all hybrids during the interval between floral bud emergence (FBE) until the beginning of fruit development (IFD).

During fruit formation (IFD/DF), higher sum of degree-days was observed for 'Rubi do Cerrado' (334.9) and lower for 'FB 300' (182.8). For 'FB 300' in the fruit ripening process, the highest thermal requirement of 226.4 degree-days was identified. The thermal sum between anthesis and fruit ripening observed under the conditions of this experiment was 435.8 degree-days for 'Gigante Amarelo', 'Rubi do Cerrado' and 'FB 300', and 348.9 degree-days for 'Sol do Cerrado' and 'FB 200'.

Table 4. Sum of degree-days (°C) of phenological events of different passion fruit hybrids.

Phenological Events	Sum of degree-days (°C)				
	Hybrid				
	Gigante Amarelo	Rubi do Cerrado	Sol do Cerrado	FB200	FB300
FBE/FBD	30.0	73,6	73.6	73.6	73.6
FBD/DFB	173.0	129.4	129.4	129.4	129.4
DFB/A	63.6	63.9	63.9	63.9	63.9
A/IFD	26.6	26.6	26.6	26.6	26.6
IFD/DF	250.9	334.9	250.9	250.9	182.8
DF RF	158.3	74.3	71.4	71.4	226.4
FBE/RF	702.3	702.3	615.4	615.4	702.3

FBE: Floral bud emergence; FBD: Floral bud development; DFB: Developed floral bud; A: Anthesis; IFD: Initial fruit development; DF: Developed fruit and RF: Ripe fruit.

During the full flowering period (from March 21 to April 5, 2019), it was observed that flowers do not show synchrony regarding floral opening. This process started between 00:30 pm and 01:00 pm, extending until 03:00 pm, when the flowering peak occurred, in which all plants presented 100% of open flowers. The same hybrids, evaluated in Tangará da Serra (Brazil) presented early beginning of opening, compared to those of the present work, being at 11:30 am, and late flowering peak, occurring at 03:30 pm (Cobra et al., 2015). Siqueira et al. (2009) reported that on cloudy days, later opening was observed, highlighting the interference of the photoperiod in this process.

The first hybrids to start the floral opening process were ‘FB 200’ and ‘Rubi do Cerrado’ at 00:30 pm, the latter was also the first to finish opening, with 100% flowers open at 02:30 pm, along with ‘Gigante Amarelo’. The average time for flower opening was 32.4 min, with average between 13 and 60 min for ‘FB 300’ and ‘Gigante Amarelo’, respectively.

After the beginning of flower opening, fillets and stylets begin the downward bending movement, with average time of 33.2 min for this movement. ‘FB 300’ hybrid obtained shorter average curvature duration, performing in 19 min and expressing a behavior similar to that obtained in the floral opening.

‘Gigante Amarelo’ had shorter time for fillet and stylet deflection, 46 min; however, this time was shorter than that described in an experiment in the “Vale do Submédio São Francisco” region, where the authors observed average time of 71.4 min of curvature (Siqueira et al., 2009).

Regarding the curvature of fillets (Figure 3), none was found without curvature; however, only ‘Sol do Cerrado’ presented 100% of fully curved flowers. The lowest percentage was found for ‘Rubi do Cerrado’ hybrid, with only 55%. This bending movement of fillets allows pollen grains to be more easily deposited on the dorsal region of *Xylocopa* bees as they move within flower in search for nectar (Siqueira et al., 2009).

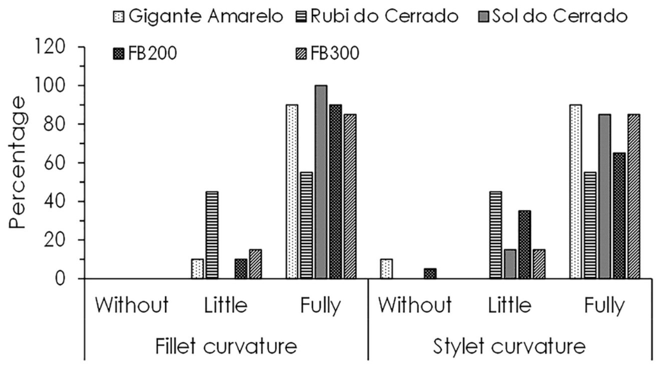

Figure 3. Percentage of flowers with fillet and stylet curvature in different passion fruit hybrids.

In observations of stylet curvature (Figure 3), the lowest percentage related to total curvature was also recorded for ‘Rubi do Cerrado’, 55%, showing greater difficulty to perform artificial pollination in this hybrid. ‘Gigante Amarelo’ flowers showed higher percentage of stylet curvature, with 90% of flowers fully curved. According to Almeida et al. (2015), not all passion fruit flowers show stylet deflection and for this eventuality, the flower is considered functionally male. Only ‘Gigante Amarelo’ and ‘FB 200’ hybrids had flowers with this characteristic, in the percentage of 10 and 5% respectively. It is from this curvature movement of stylets that stigmas are receptive to the germination of pollen grains and the flower is considered functionally female (Ángel-Coca et al., 2011).

The first receptive flowers were observed at 01:00 pm in ‘Gigante Amarelo’, ‘FB 200’ and ‘FB 300’ hybrids (Figure 4A). The others showed receptivity at 02:00 pm, with all flowers 100% receptive only at 04:00 pm, these results suggest that this is the ideal time to practice artificial pollination, improving efficiency and optimizing operation. One hour later, receptivity declined, initially for ‘Rubi do Cerrado’ and ‘FB 300’, from 05:00 pm. These results corroborate those found by Cobra et al. (2017) and according to the authors, this receptivity is considered high.

Flower senescence began at 05:00 pm for all hybrids (Figure 4B), and by the end of observations (06:00 pm), only ‘Gigante Amarelo’and ‘Rubi do Cerrado’ had more than 50% of senescent flowers, indicating that floral longevity would still last longer, in agreement with Montero et al. (2013), under greenhouse conditions in the state of São Paulo, in which flowers remained open until sunset and in disagreement with Siqueira et al. (2009), in a field experiment in the city of Juazeiro-BA, where the authors observed wilting and small changes in the color of petals and sepals only at 06:00 pm.

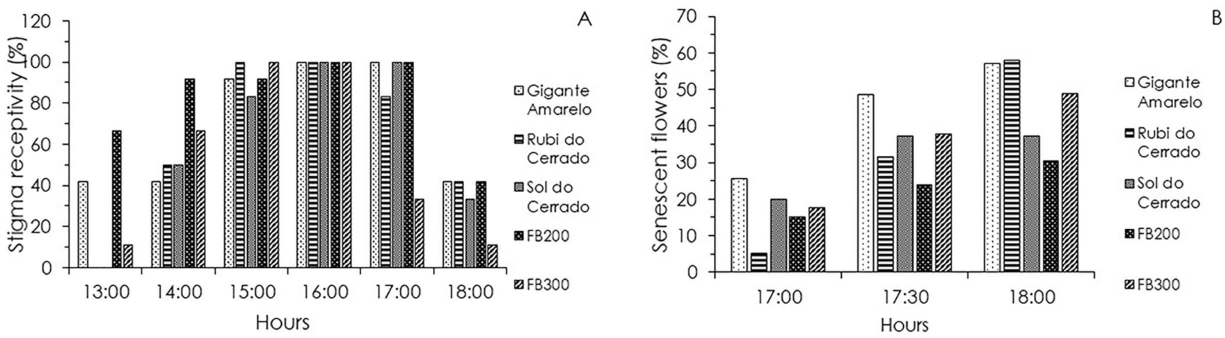

Figure 4. Percentage of receptive (A) and senescent (B) flowers of different passion fruit hybrids.

By comparing the values of opening and senescence times, it is possible to identify 'FB 200' hybrid with longer floral longevity, as it has beginning of floral opening at 00:30 pm and lower percentage of senescent flowers at 06:00 pm.

Considering average production per plant and yield, no significant differences were found among hybrids, with averages ranging from 5.75 to 8.75 kg plant^{-1} for 'Sol do Cerrado' and 'Rubi do Cerrado' respectively. Therefore, these hybrids had lower and higher average yield, 5.00 and 7.50 t ha^{-1}, which values are below the state average of 12.8 t ha^{-1} and national average of 13.5 t ha^{-1} (IBGE, 2018); however, the small harvest interval of only three months should be taken into account. According to Carvalho et al. (2015), planting carried out from October to January has lower production in the first crop cycle, known as off-season. For planting carried out between January to March (summer), production is higher. In the state of Mato Grosso, for planting carried out in December, average of 11.66 t ha^{-1} for 'Gigante Amarelo' and 15.7 6 t ha^{-1} for 'Sol do Cerrado' and 'FB 200' was found, being the highest yield recorded by the authors for 'Rubi do Cerrado', with 27.51 t ha^{-1} (Cavalcante et al., 2016).

In studies evaluating two passion fruit production cycles by Weber et al. (2016) in northern Paraná, the superiority of plants in the second cycle is evident, and according to them, two-year non-manually pollinated plants produced more or in the same proportion as one-year manually pollinated plants. In the same work, the first cycle was also planted in October, obtaining average yield of 16.66 t ha^{-1}, twice the planting density used in the present experiment. In the second year, without manual pollination, yield was 23.26 t ha^{-1}, showing greater adaptation of plants to the environment in the second cycle.

Analyzing mass characteristics (Table 5), significant difference was found for fruit, peel and pulp mass. 'Gigante Amarelo', 'Rubi do Cerrado' and 'FB 200' hybrids had higher fruit mass averages, statistically differing from 'Sol do Cerrado' and 'FB 300' hybrids.

Table 5. Fruit mass (FM), peel mass (PeM), seed mass (SM), pulp mass (PM) of different passion fruit hybrids.

Hybrid	FM (g)	PeM (g)	SM (g)	PM (g)
Sol do Cerrado	199.75 bc	105.25 b	7.50 a	87.00 ab
Rubi do Cerrado	223.00 abc	122.25 ab	8.25 a	92.25 ab
Gigante Amarelo	253.75 a	141.25 a	9.00 a	103.50 a
FB200	240.50 ab	142.50 a	7.75 a	90.25 ab
FB300	182.75 c	99.25 b	8.00 a	75.50 b
Coefficient of variation (%)	10.27	12.59	10.02	13.50

Means followed by the same lower case letter in the column do not differ from each other (Tukey, $p \leq 0.05$).

There was no significant difference for the yields of peel, seed and pulp, with average pulp yield between 37.75 and 43.75% for 'FB 200' and 'Sol do Cerrado', respectively (Figure 5). There was also no difference in peel thickness and number of seeds, with average values from 8.25 to 10.00 mm peel thickness for 'Sol do Cerrado' and 'FB 200' and 294.50 to 345.75 seeds for 'FB 300' and 'Gigante Amarelo', respectively.

For characteristics longitudinal and transverse diameters, fruit shape and peel firmness (Table 6), there was a difference among hybrids only for LD, and the average found for 'FB 200' was 103.50 mm, which is statistically different only from the lowest average of 85.50 mm of 'FB 300' fruits. The tranverse diameter of fruits ranged from 74.50 mm to 83.00 mm, with overall average of 79.70 mm, being within class 4 of the Brazilian Program for the Improvement of Commercial Standards and Packaging of Horticultural Products, which is a value considered good within the numerical scale from 1 to 5, made by measuring the transverse diameter of fruits (Hortibrasil, 2016). Similar LD and TD variations were found in a study with passion fruits marketed in CEASA de Juazeiro - BA (Silva et al., 2016), proving that the hybrids produced in this experiment presented fruit size compatible to those being traded.

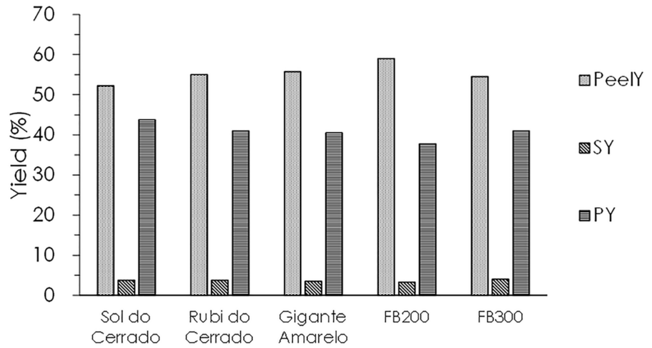

Figure 5. Peel yield (PeelY), seed yield (SY), pulp yield (PY) of different passion fruit hybrids.

Table 6. Longitudinal diameter (LD), transverse diameter (TD), fruit shape (FS) and peel firmness (PF) of different passion fruit hybrids.

Hybrid	LD (mm)	TD (mm)	FS	PF (kgf)
Sol do Cerrado	92.00 ab	76.00 a	1.21 a	4.38 a
Rubi do Cerrado	96.50 ab	82.50 a	1.17 a	4.46 a
Gigante Amarelo	97.75 ab	83.00 a	1.18 a	4.67 a
FB200	103.50 a	82.50 a	1.26 a	4.60 a
FB300	85.50 b	74.50 a	1.15 a	4.49 a
Coefficient of variation (%)	6.43	5.28	4.91	6.52

Means followed by the same lower case letter in the column do not differ from each other (Tukey, $p \leq 0.05$)

Considering shape variable, fruits are classified according to the LD/TD ratio, being round for values smaller than 1 and oval for higher values (Fortaleza et al., 2005). All hybrids evaluated showed values greater than 1, indicating a tendency to more oval fruits. Also, according to Fortaleza et al. (2005), this fruit shape is desired mainly by the industry, as it contains about 10% more juice than rounded fruits.

Regarding fruit firmness, it was observed that there was no significant difference, with averages ranging from 4.38 to 4.67 kgf for 'Sol do Cerrado' and 'Gigante Amarelo', respectively. This feature provides hybrids transport resistance and longer shelf life (Meletti, 2011).

Regarding exocarp color, there was significant difference only for hue angle (Table 7); however, all averages were in the second quadrant, with peel color between 104.75° for 'Sol do Cerrado' and 93.50° for 'Rubi do Cerrado', being greener and yellowish colors, respectively, since graphically, the 90° angle is within the yellow predominance range and the 180° angle is within the green predominance range. Similar values were found by Salazar et al. (2015) in fruits from grafted plants and cultivated in protected environment. For the Chroma saturation index, averages ranged from 20.75 to 23.75, indicating low peel saturation since the C index is defined as the radial distance from the center of the L * C * h° space to the color point, being 0 for impure color and 60 for pure color. Finally, for L luminosity, 'Rubi do Cerrado' fruits presented the highest averages, with numerical value of 57.75 and the lowest average was obtained for 'Sol do Cerrado' fruits, 53.50. This coordinate ranges from 0, which corresponds to black, to 100, which is white.

Table 7. Luminosity coordinate (L), chroma saturation index (C), Hue angle (h°) of the exocarp and pulp of different passion fruit hybrids.

Hybrid	Exocarp			Pulp		
	L	C	h°	L	C	h°
Sol do Cerrado	53.50 a	22.50 a	104.75 a	34.00 a	12.75 a	63.50 a
Rubi do Cerrado	57.75 a	20.75 a	93.50 b	33.25 a	13.00 a	63.75 a
Gigante Amarelo	54.00 a	23.25 a	104.25 a	33.25 a	13.00 a	64.50 a
FB200	57.25 a	23.00 a	101.00 ab	34.00 a	12.50 a	63.75 a
FB300	55.00 a	22.75 a	102.25 ab	33.75 a	12.25 a	65.75 a
Coefficient of variation (%)	4.24	13.50	4.27	2.44	5.13	5.19

Means followed by the same lower case letter in the column do not differ from each other (Tukey, $p \leq 0.05$).

For pulp color, there was no statistical difference, with luminosity values recorded between 33.25 for 'Rubi do Cerrado' and 'Gigante amarelo' and 34 for 'Sol do Cerrado' and 'FB 200'. Chroma was between 13.00 and 12.25 which as in exocarp color, also indicates low saturation or low pulp pigmentation. Similar intervals were also found in studies conducted in Viçosa (Brazil) (Salazar et al., 2015). For the hue angle, average values were found in the first quadrant, where 0° represents red color predominance range and 90° yellow color.

For the physicochemical analysis of fruits (Table 8), statistical differences were observed only for variables total titratable acidity (TTA) and ratio and no differences were observed for pH and total soluble solids (TSS). When comparing pH and TSS values obtained in the experiment with limits established by the Brazilian legislation, which are between 2.7 and 3.8 and TSS above 11.00 °Brix for passion fruit pulp (Brazil, 2000), it is clear that only 'Sol do Cerrado' had TSS value below legislation (10.50 °Brix). This value was also similar to that found by Botelho et al. (2017) in Cáceres; however, the authors evaluated hybrids in the municipalities of Terra Nova do Norte and Tanguará da Serra-MT, and in these locations, 'Sol do Cerrado' reached values of 12.24 and 13.08 °Brix, respectively.

TTA values are above the minimum value (2.50% citric acid) established by Brazilian legislation (Brazil, 2000). The highest averages of 4.00% citric acid were found in 'Sol do Cerrado' and 'FB 300' hybrids, which differed from 'Gigante Amarelo' and 'Rubi do Cerrado' hybrids; however, did not differ from 'FB 200', with 3.75%. The lowest average of 2.75% citric acid obtained by 'Rubi do Cerrado' hybrid was also found in a study in Mato Grosso (Botelho et al., 2017).

The high TSS content found for 'Rubi do Cerrado', together with the lower average of this hybrid for TTA, reflected in the final pulp flavor, with higher ratio value, statistically different from all other hybrids. The ratio values obtained in this study were higher than those found in Janauba (Brazil) (Dias et al., 2016) and the overall average of 3.37 was within the range obtained in Tangará da Serra (Brazil) (Cavalcante et al., 2016).

Table 8. Hydrogen potential (pH), total soluble solids (TSS), total titratable acidity (TTA) and TSS/TTA ratio of different passion fruit hybrids.

Hybrid	pH	TSS (°Brix)	TTA (% citric acid)	*Ratio*
Sol do Cerrado	2.85 a	10.50 a	4.00 a	2.54 c
Rubi do Cerrado	2.91 a	12.75 a	2.75 c	4.58 a
Gigante Amarelo	2.88 a	11.50 a	3.25 bc	3.50 b
FB200	2.87 a	11.25 a	3.75 ab	3.08 bc
FB300	2.82 a	12.25 a	4.00 a	3.16 bc
Coefficient of variation (%)	2.80	12.95	9.27	15.88

Means followed by the same lower case letter in the column do not differ from each other (Tukey, $p \leq 0.05$).

Conclusions

In central Minas Gerais, 'Sol do Cerrado' and 'FB 200' hybrids have shorter fruit maturation period.

The highest floral longevity is expressed by 'FB 200' and all flowers are 100% receptive at 04:00 pm, suggesting that this as the ideal time for artificial pollination practice, improving efficiency and optimizing operation.

All hybrids studied obtain similar yield and productivity responses, with physical characteristics ideal for fresh consumption or processing market.

Among the chemical characteristics, 'Sol do Cerrado' and 'FB 300' hybrids stood out, with total acidity indexes more favorable for processing and 'Rubi do Cerrado' hybrid with ratio values that most attract consumers.

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