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Fruit yield and quality of wild passion fruit cultivars

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Abstract

Wild *Passiflora* species have considerable economic potential; however, they remain underexplored due to limited research. This study evaluated productive and physicochemical parameters of four passion fruit cultivars—Roxinho (*Passiflora edulis*), BRS Mel do Cerrado (*P. alata*), BRS Pérola do Cerrado (*P. setacea*), and BRS Sertão Forte (*P. cincinnata*)—and assessed fruit yield and quality throughout the annual cycle. The experiment was conducted at the Mato Grosso State University (UNEMAT), Tangará da Serra, Mato Grosso, Brazil, using a randomized complete block design with five replications and five plants per plot. The variables measured were fruit yield, number of fruits, fruit mass, fruit length, fruit diameter, peel thickness, pulp percentage, fruit shape index, total soluble solids (TSS), titratable acidity (TA), the TSS-to-TA ratio, and pH. Significant differences were observed among cultivars for all variables except pH. Roxinho showed the highest fruit yield (18,653.41 kg ha^{-1}), whereas BRS Mel do Cerrado exhibited the highest fruit mass (184.74 g) and TSS (20.25 °Brix), but the lowest pulp percentage. BRS Sertão Forte exhibited the highest TA and yield stability, which are desirable characteristics for industrial processing. Thus, diversified cultivation of wild passion fruit species may be an efficient strategy to reduce production seasonality throughout the year and meet the demands of different market segments.

Keywords: *Passiflora spp.*, physicochemical characteristics, seasonality, wild species

Introduction

The family Passifloraceae comprises 36 genera and approximately 930 species, distributed throughout North and South America. The genus *Passiflora* is the largest in the family, encompassing approximately 525 species distributed predominantly tropical regions. The countries with the highest species diversity are Brazil and Colombia (Farias et al., 2016). Currently, Brazil is the world's largest producer and consumer of passion fruit, with a production of 711,278 Mg cultivated over an area of 45,761 hectares in 2023 (IBGE, 2025).

In Brazil, most areas under passion fruit cultivation are occupied by sour passion fruit and purple passion fruit, both belonging to the species *Passiflora edulis* Sims, which is the most widely cultivated species in the genus. However, other species have been investigated for their agronomic potential and fruit quality, with emphasis on commercial exploitation aimed at improved quality and resistance to diseases and pests (Faleiro et al., 2021). The Brazilian Agricultural Research Corporation (Embrapa) has contributed to expanding the use of native species by developing cultivars of wild species, such as BRS Mel do Cerrado (*Passiflora alata* Curtis), BRS Sertão Forte (*P. cincinnata* Mast.), and BRS Pérola do Cerrado (*P. setacea* DC.) (Braga et al., 2006).

Wild *Passiflora* species have significant economic potential for fresh consumption, industrial processing, ornamental use, and medicinal applications; however, they remain understudied, requiring further research to more comprehensively evaluate their potential (Junghans et al., 2022). BRS Mel do Cerrado is the first released cultivar of *P. alata* Curtis, developed to meet market demand for sweet passion fruit; it features sweet pulp suitable for fresh consumption and is rich in dietary fiber (Faleiro et al., 2021). BRS Sertão Forte was developed for rainfed cultivation due to its tolerance to water stress.

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Its pulp contains a high citric acid concentration, making it suitable for the processing of jams, juices, and sweets (Araújo et al., 2019). BRS Pérola do Cerrado has been increasingly cultivated due to its rusticity and resistance to pests and diseases (Embrapa, 2015).

The purple passion fruit (*P. edulis*) is characterized by small, purple fruits, making it a promising alternative for the specialty fruit market and for ornamental cultivation (Faleiro et al., 2019).

Cultivars derived from wild *Passiflora* species exhibit substantial research potential and represent an important source of income for smallholder farmers. Therefore, studies that expand knowledge of these species, including fruit characterization, are essential.

In this context, the objective of this study was to evaluate the physicochemical and productive parameters of four passion fruit cultivars (Roxinho – *Passiflora edulis*, BRS Mel do Cerrado, BRS Pérola do Cerrado, and BRS Sertão Forte) and to assess fruit yield and quality throughout the annual cycle.

Material and Methods

The experiment was conducted in the experimental area of the State University of Mato Grosso (UNEMAT), Tangará da Serra, Mato Grosso, Brazil (14°39'S, 57°25'W; altitude of 321 m). The region has a humid tropical climate with well-defined rainy and dry seasons and a mean annual rainfall of 1,774 mm (Viana et al., 2025). The soil in the experimental area was classified as a Typic Hapludox (Latossolo Vermelho Distrófico) (Soil Survey Staff, 2022; Santos et al., 2025).

The experiment was established in July 2022 to evaluate four cultivars derived from wild passion fruit species: Roxinho (*Passiflora edulis*), BRS Mel do Cerrado (*P. alata*), BRS Sertão Forte (*P. cincinnata*), and BRS Pérola do Cerrado (*P. setacea*) (**Figure 1**). A randomized complete block design was used, with five replications and five plants per plot.

The planting spacing was 3 m between rows and 2 m between plants. Seedlings were produced in a protected arched structure (7 m wide × 21 m long, with a central arch height of 4 m), covered with 120-µm transparent polyethylene film and fitted with 50% shading screen on the sides. The containers used were 180-cm^3 tubes. The substrate consisted of three parts soil (subsoil) and one part commercial vegetable substrate, with the addition of the following amendments per 1000 L of mixture: 360 g dolomitic limestone, 180 g single superphosphate, and 90 g potassium chloride (Krause et al., 2021). Two seeds were sown per tube, and thinning was performed after 30 days to leave one seedling per tube. Seedlings were transplanted to the field 65 days after sowing, in July 2022.

Plants were trained on a vertical trellis system consisting of treated eucalyptus posts 2.5 m in height, spaced 6 m apart, with two No. 12 wires positioned 2 m above the soil surface. Training was performed as follows: the main stem was guided upward with string until it reached the upper wire, and all emerging lateral shoots were removed to maintain a single main stem. Once the main stem reached the upper wire, it was topped, and two secondary branches were selected and trained horizontally in opposite directions along the wire, each to a length of 1 m. Emerging tertiary branches were trained to form the fruiting curtain. Thereafter, maintenance pruning was conducted every 15 days.

Irrigation was supplied using sprinklers with a flow rate of 40 L h^{-1}, applied three times per week during dry periods.

Soil fertilizers were applied at planting and as topdressing following the specific recommendations for each cultivar, as described by Araújo et al. (2019) for BRS Sertão Forte, Sanzonowicz & Junqueira (2005) for BRS Mel do Cerrado, Guimarães et al. (2013) for BRS Pérola do Cerrado, Costa et al. (2008) for the cultivar Roxinho.

The following productive parameters were evaluated: fruit yield (kg ha^{-1}), determined by weighing all fruits harvested from the plots; number of fruits (fruits ha^{-1}), obtained by counting the fruits harvested in each plot; and fruit mass (g), calculated as the ratio of total fruit yield to the total number of fruits.

Physicochemical parameters were assessed using nine selected fruits randomly selected per cultivar per plot.

The following physical parameters were measured: pulp percentage, calculated by weighing the pulp (seeds plus aril), dividing by the total fruit mass, and multiplying by 100; fruit length (mm), measured as the longitudinal dimension using a digital caliper; fruit diameter (mm), measured as the transverse dimension using a digital caliper; fruit shape index, calculated as the fruit length-to-diameter ratio; and peel thickness (mm), determined as the arithmetic mean of measurements taken at four points on the outer peel using a digital caliper.

The chemical parameters evaluated in the pulp were: total soluble solids (TSS; °Brix), determined using a digital benchtop refractometer (model RTD-45) with readings in the range of 0–45 °Brix; pH, measured by direct reading using a digital potentiometer, according to AOAC (2010); titratable acidity (TA; g citric acid 100 mL^{-1}),

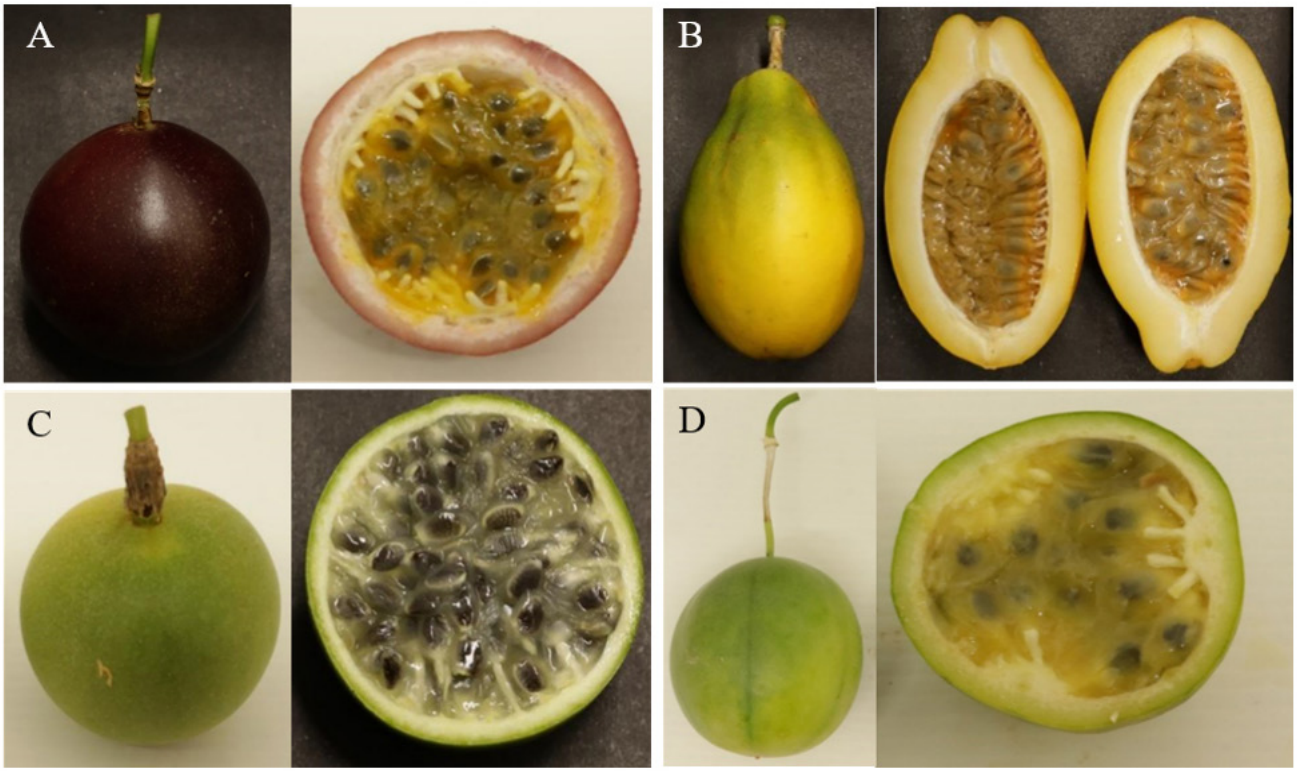

Figure 1. Representative passion fruits of four cultivars derived from wild species: (A) Roxinho (Passiflora edulis), (B) BRS Mel do Cerrado (P. alata), (C) BRS Sertão Forte (P. cincinnata), and (D) BRS Pérola do Cerrado (P. setacea).

determined by titration with 0.1 mol L^{-1} NaOH , using 5 mL of passion fruit juice diluted in 50 mL of distilled water, with three drops of phenolphthalein added to an Erlenmeyer flask, followed by agitation until a persistent pink endpoint was observed (IAL, 2008); and the TSS-to-TA ratio.

Data were subjected to analysis of variance, and means were compared using Tukey's test at the 5% probability level with the SISVAR software (Ferreira, 2019). **Figure 2** was created using the ggplot2 package in the R software.

Results and Discussion

Significant differences were observed among the passion fruit cultivars for all evaluated parameters except pH (**Table 1**). Roxinho and BRS Mel do Cerrado exhibited the highest mean fruit yields, with values of 18,653.41 and 16,529.58 kg ha^{-1}, respectively. The highest mean number of fruits was recorded for BRS Pérola do Cerrado (234,833.33 fruits ha^{-1}) and Roxinho (201,500.00 fruits ha^{-1}). However, BRS Pérola do Cerrado exhibited the lowest mean fruit mass (46.74 g) among the cultivars evaluated (**Table 2**). Similarly, Ataíde et al. (2012) reported a mean fruit mass of 46.10 g.

BRS Mel do Cerrado exhibited high mean values for fruit yield (16,529.58 kg ha^{-1}) and number of fruits (91,333.33 fruits ha^{-1}) and showed the highest mean fruit mass (184.74 g) among all cultivars (Table 2). This fruit mass value was consistent with those reported by D'Abadia et al. (2020), who evaluated eight genotypes of BRS Mel do Cerrado in Planaltina, Distrito Federal, Brazil, and obtained mean values ranging from 151.21 to 239.17 g. Larger and heavier fruits are generally associated with higher consumer acceptance. However, pulp percentage (17.64%) was lower than that observed for the other cultivars.

BRS Mel do Cerrado exhibited the highest mean values for fruit length (112.64 mm) and fruit diameter (73.78 mm) (Table 2). This cultivar exhibits promising traits for commercial exploitation, including fruit length and diameter, fruit mass, total soluble solids, and yield. BRS Pérola do Cerrado exhibited the lowest fruit diameter (44.48 mm). The lowest fruit length values were observed for BRS Sertão Forte (50.19 mm) and BRS Pérola do Cerrado (51.07 mm), which did not differ significantly from each other. Rangel Junior et al. (2018) reported similar fruit diameter for BRS Pérola do Cerrado (46 mm), with fruit length of 49 mm, fruit mass of 55 g, and pulp percentage of 48.5%.

BRS Sertão Forte and BRS Pérola do Cerrado exhibited the thinnest peel, with mean values of 2.18 and 2.30 mm, respectively (Table 2). Roxinho showed an intermediate peel thickness (3.75 mm), whereas BRS

Table 1. Analysis of variance for productive and physicochemical parameters of passion fruits of cultivars derived from wild species: fruit yield, number of fruits (NF), fruit mass (FM), fruit length (FL), fruit diameter (FD), peel thickness (PT), pulp percentage (PP), shape index (SI), total soluble solids (TSS), titratable acidity (TA), TSS-to-TA ratio (TSS/TA), and pH.

Source of variation	DF	Mean squares											
		Fruit yield (kg ha^{-1})	NF (fruits ha^{-1})	FM (g)	FL (mm)	DF (mm)	PT (mm)	PP (%)	SI	TSS (°Brix)	TA (g 100 mL^{-1})	TSS/TA	pH
Cultivar	3	123493677.01**	2.73548587×10^{10}**	13213.53**	3460.32**	631.91**	712.21**	1731.96**	0.33**	43.67**	5.97**	25.40**	0.07ns
Replication	3	15490738.41	583451349.30	200.94	23.38	10.32	18.23	58.19	0.003	0.06	0.42	1.38	0.03
Error	9	14246956.48	1.82	208.21	27.23	15.09	25.83	18.79	0.003	0.65	0.15	1.00	0.04
Total	15	-	-	-	-	-	-	-	-	-	-	-	-
Overall mean		13138.27	148145.83	106.81	69.69	60.73	33.04	48.22	1.12	16.66	3.58	5.37	2.81
CV (%)		28.73	28.83	13.51	7.49	6.40	15.38	8.99	5.51	4.85	11.08	18.67	7.82

CV = coefficient of variation; DF = degrees of freedom; ** and ns = significant at the 1% probability level and not significant by the F-test, respectively.

Table 2. Mean values for productive and physicochemical parameters of passion fruits of cultivars derived from wild species: fruit yield, number of fruits (NF), fruit mass (FM), fruit length (FL), fruit diameter (FD), peel thickness (PT), pulp percentage (PP), shape index (SI), total soluble solids (TSS), titratable acidity (TA), TSS-to-TA ratio (TSS/TA), and pH.

Cultivar	Fruit yield (kg ha^{-1})	NF (fruits ha^{-1})	FM (g)	FL (mm)	FD (mm)	PT (mm)	PP (%)	SI	TSS (°Brix)	TA (g 100 mL^{-1})	TSS/TA	pH
Roxinho	18.653.41a	201.500.00a	91.98b	64.91b	66.47ab	3.75b	52.57a	0.97c	15.72c	3.93b	4.15b	2.71a
BRS Mel do Cerrado	16.529.58a	91.333.33b	184.74a	112.64a	73.78a	5.00a	17.64b	1.53a	20.25a	2.60c	7.84a	2.92a
BRS Sertão Forte	6.335.58b	64.916.66b	103.79b	50.19c	58.18b	2.18c	61.87a	0.86c	12.56d	5.16a	2.44b	2.69a
BRS Pérola do Cerrado	11.034.49ab	234.833.33a	46.74c	51.07c	44.48c	2.30c	60.81a	1.14b	18.14b	2.63c	7.05a	2.94a

Means followed by the same letter in the column do not differ significantly by Tukey's test at the 5% probability level.

Mel do Cerrado exhibited the thickest peel (5.0 mm). Fortaleza et al. (2005) reported that passion fruits with thinner peel are preferred because of their greater pulp content. This observation supports the results for BRS Mel do Cerrado, which exhibited the lowest pulp percentage and the greatest peel thickness.

The highest mean pulp percentages were observed for BRS Sertão Forte (61.87%), BRS Pérola do Cerrado (60.81%), and Roxinho (52.57%), which did not differ significantly from each other (Table 2). BRS Mel do Cerrado exhibited the lowest pulp percentage (17.64%).

The length-to-width ratio is commonly used to calculate the fruit shape index, with a value of 1 indicating round fruits and values greater than 1 indicating oval fruits (Fortaleza et al., 2005). BRS Mel do Cerrado and BRS Pérola do Cerrado exhibited oval fruit shape, whereas Roxinho and BRS Sertão Forte exhibited round fruits. D'Abadia et al. (2021) also described fruits of BRS Sertão Forte as round.

Total soluble solids (TSS) differed significantly among the cultivars, ranging from 12.56 to 20.25 °Brix (Table 2). The highest mean TSS (20.25 °Brix) was observed for BRS Mel do Cerrado, which is consistent with the range reported by Borges et al. (2020), from 15.8 to 21.0 °Brix. Faleiro et al. (2021) reported that fruits of BRS Mel do Cerrado are highly attractive for the pharmaceutical industry and fresh consumption due to their high sugar concentrations. °Brix is commonly used as an indicator of fruit quality for industrial processing, and fruits with TSS values above 13 °Brix are generally preferred (Bruckner et al., 2002).

Rangel Junior et al. (2018) evaluated physicochemical parameters of fruits of BRS Pérola do Cerrado and reported a mean TSS of 13.31 °Brix, with values reaching up to 17.5 °Brix, which are similar to those obtained in the present study. Consequently, only BRS Sertão Forte (*Passiflora cincinnata*), with 12.56 °Brix, fell below the preferred TSS standard compared with the other cultivars.

Titratable acidity (TA) differed significantly among the cultivars, with BRS Sertão Forte exhibiting the highest mean value (5.16 g 100 mL^{-1}), which is close to the 4.91 g 100 mL^{-1} reported by Sousa et al. (2024). Pulp with a high citric acid content is suitable for processing into jams, juices, and sweets (Araújo et al., 2019). High TA in fruit pulps is desirable for industrial processing because it reduces the need for acidulants (Rocha et al., 2001).

According to Nagato et al. (2003), TA for industrial processing should range from 2.7 to 3.9 g 100 mL^{-1}. Thus, Roxinho (*P. edulis*), with 3.93 g 100 mL^{-1}, exhibited a value slightly above the upper limit for industrial processing, whereas BRS Mel do Cerrado and BRS Pérola do Cerrado (2.60 and 2.63 g 100 mL^{-1}, respectively) fell below this range.

The TSS-to-TA ratio (TSS/TA) ranged from 2.44 to 7.84 among the cultivars (Table 2). In general, higher the TSS/TA values are associated with greater juice or pulp palatability due to high TSS and low TA. BRS Sertão Forte exhibited the lowest TSS/TA (2.44), indicating low sugar content and high acidity in the fruits. BRS Mel do Cerrado and BRS Pérola do Cerrado exhibited the highest ratios (7.84 and 7.05, respectively), which did not differ significantly from each other, indicating high sugar content and low acidity. The market-accepted range for TSS/TA in passion fruits is 2.9 to 4.9 (Costa et al., 2008), with only Roxinho falling within this range (4.15).

The cultivars did not differ significantly in pH (Table 2), with all values within the range established by Brazilian regulations for passion fruit pulp (2.7–3.8) (Brasil, 2018).

All evaluated passion fruit cultivars exhibited distinct patterns among species, with clear variations in physicochemical and productive traits. The cultivars showed different fruit yield performance, with distinct peaks observed throughout the year (**Figure 2**). BRS Sertão Forte exhibited a distinct yield pattern compared with the other cultivars, characterized by high yield at the onset of harvest and stability throughout the remaining months until the end of the production cycle, coinciding with the offseason for sour passion fruit. These results are consistent with those reported by D'Abadia et al. (2021) in experiments conducted under overhead and vertical trellis systems.

Roxinho exhibited the highest fruit yield from February to June, followed by a marked reduction during the remaining months of the year. Similar seasonal patterns for this cultivar were reported by Medeiros et al. (2009). BRS Mel do Cerrado exhibited its highest yield peak from February to April at the onset of fruiting, followed by reduced production from May to June, a period characterized by lower rainfall, and a subsequent peak in August, September, and October.

BRS Pérola do Cerrado maintained relatively stable yield during the initial phase of the first harvest, with a trend of increasing production in November and December, when it reached its peak near the end of the evaluation period, corresponding to the offseason for commercial sour passion fruit cultivars.

These results indicate an effective strategy for diversifying passion fruit production throughout the year. Rather than cultivating a single cultivar (*P.*

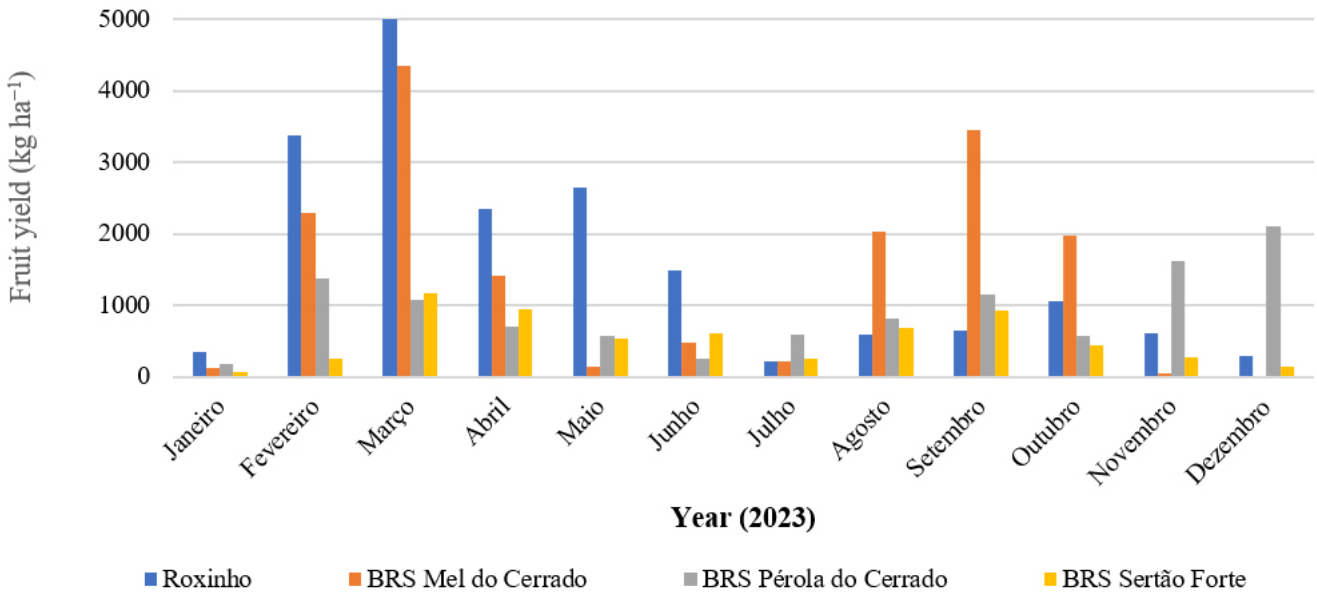

Figure 2. Variation in fruit yield (kg ha^{-1}) throughout the annual production cycle for four passion fruit cultivars derived from wild species: Roxinho (Passiflora edulis), (B) BRS Mel do Cerrado (P. alata), BRS Pérola do Cerrado (P. setacea), and BRS Sertão Forte (P. cincinnata).

edulis), producers can plant a combination of different cultivars or *Passiflora* species to achieve more consistent production and mitigate the effects of seasonality during specific periods of the year.

Conclusion

The cultivars derived from wild *Passiflora* species exhibited productive potential and fruit quality attributes that make them viable alternatives to commercial cultivars, capable of meeting market demand for specialty fruits. Roxinho showed the highest fruit yield and a high pulp percentage. BRS Mel do Cerrado produced the largest fruits with the highest total soluble solids content, making it attractive due to its visual appeal and sweetness. BRS Pérola do Cerrado, despite its smaller fruits, demonstrated yield stability throughout the annual production cycle.

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