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Yield capacity of six superior pitaya genotypes under edaphoclimatic conditions of the Federal District

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Abstract - The Embrapa Cerrados pitaya breeding program developed five superior genotypes of different species. The objective of this work was to evaluate the yield capacity of these five pitaya genotypes under the edaphoclimatic conditions of the Federal District. The experiment was carried out at the Embrapa Cerrados in Planaltina, DF. The five selected pitaya genotypes were evaluated, as well as a parent genotype used in the breeding program. Length (CF), diameter (DF) and mass (MF) of all fruits were evaluated, as well as the length/diameter ratio ($CF.DF^{-1}$), number of fruits per plant ($NF.PL^{-1}$), production per plant ($kg.PL^{-1}$) and estimated productivity ($t.ha^{-1}$). BRS Luz do Cerrado and BRS Lua do Cerrado presented larger and heavier fruits, while BRS Minipitaya do Cerrado presented the smallest fruits. CPAC Roxa and BRS Granada do Cerrado presented more rounded fruits. BRS Granada do Cerrado had the highest yield capacity in the two evaluated crops. The results obtained prove the importance of genetic breeding and the selection of superior genotypes more adapted to the region of cultivation, in order to guarantee greater profitability and products of better quality to rural producers and consumers.

Index terms: *Selenicereus* spp.; *Hylocereus* spp.; Cactaceae; fruit quality; yield.

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Capacidade produtiva de seis genótipos superiores de pitaia sob as condições edafoclimáticas do Distrito Federal

Resumo - O programa de melhoramento genético de pitaia da Embrapa Cerrados desenvolveu cinco genótipos superiores de diferentes espécies. O objetivo deste trabalho foi avaliar a capacidade produtiva destes cinco genótipos de pitaia sob as condições edafoclimáticas do Distrito Federal. O experimento foi conduzido na Unidade de Apoio da Fruticultura da Embrapa Cerrados, no município de Planaltina-DF. Foram avaliados os cinco genótipos selecionados de pitaia, bem como um genótipo progenitor utilizado no programa de melhoramento. Avaliaram-se o comprimento (CF), o diâmetro (DF) e a massa (MF) de todos os frutos, bem como a relação comprimento/diâmetro ($CF.DF^{-1}$), número de frutos por planta ($NF.PL^{-1}$), produção por planta ($kg.PL^{-1}$) e produtividade estimada ($t.ha^{-1}$). A BRS Luz do Cerrado e a BRS Lua do Cerrado, apresentaram frutos maiores e mais pesados, enquanto a BRS Minipitaia do Cerrado apresentou os menores frutos. A CPAC Roxa e a BRS Granada do Cerrado apresentaram frutos mais arredondados. A BRS Granada do Cerrado apresentou a maior capacidade de produção nas duas safras avaliadas. Os resultados obtidos comprovam a importância do melhoramento genético e da seleção de genótipos superiores mais adaptados para a região de cultivo, a fim de garantir maior rentabilidade e produtos de melhor qualidade ao produtor rural e aos consumidores.

Termos para indexação: *Selenicereus* spp.; *Hylocereus* spp.; Cactaceae; qualidade de frutos; produtividade.

Introduction

Because the population has been searching for a more nutritious and healthy diet, rural producers have been looking for alternative species of fruits to be cultivated in order to diversify their production (LEE, 2021). Therefore, the production of exotic fruits has increased in recent years since it is an attractive and promising market, becoming an important alternative for the diversification in the consumption of healthy products (RAMOS et al., 2018).

Included in this group we have different species of pitaya (*Hylocereus* spp. and *Selenicereus* spp.) commonly referred to as “dragon fruit” which being considered as promising species in the world market (CHEOK et al., 2018; FALEIRO e JUNQUEIRA, 2022a). This fact is mainly explained by the fact that the pitaya plants present tolerance to arid environments and high resistance to pathogens, as well as the organoleptic, nutritional, and functional quality of the fruits (GENGATHARAN et al., 2015; LE BELLEC et al., 2006).

To this date there are few cultivars of pitayas registered with the Ministry of Agriculture, Livestock and Food Supply (MAPA), recommended for commercial planting in Brazil (FALEIRO et al., 2021; LIMA, 2013). In order to make available to rural producers more adapted to Brazilian soil and climate conditions genotypes of pitaya, a genetic breeding program carried out at Embrapa Cerrados developed five superior pitaya genotypes of different species.

In 2021 the first five cultivars were sent to the Ministry of Agriculture, Livestock and Food Supply (MAPA) and today they are registered: BRS Lua do Cerrado, BRS Luz do Cerrado, BRS Minipitaya do Cerrado, BRS Granada do Cerrado and BRS Âmbar do Cerrado (FALEIRO e JUNQUEIRA, 2022b). These genotypes have been cultivated and validated in all Brazilian regions with exciting results concerning their

agronomical performance. The aim of the present study was to evaluate the yield capacity of these five pitaya genotypes by Embrapa Cerrados under the edaphoclimatic conditions of the Federal District.

Material and Methods

The experiment was carried out in the experimental area of pitayas located at the Unidade de Apoio da Fruticultura (Unity of Fruit Cultivation Support) at Embrapa Cerrados in the city of Planaltina, Federal District, located in the Central Brazilian Plateau at 15º35'30" S latitude, 47º42'30" W longitude and 1.007 m altitude. According to Köppen climate classification, the weather is defined as Seasonal Tropical (Aw) with two well defined seasons: a dry season from May to September and a wet season from October to April, where the average annual precipitation is 1500 mm and the mean temperature ranged from 15.9°C in the coldest months to 26.4°C in the hottest months (SILVA et al., 2009).

The orchard was developed in March 2018 using cladodes with the five superior genetically developed genotypes: BRS Lua do Cerrado (BRS LC) (*Selenicereus undatus*); BRS Luz do Cerrado (BRS LZC) (*S. undatus*); BRS Granada do Cerrado (*S. undatus* x *S. costaricensis)* (BRS GC); BRS Minipitaya do Cerrado (*Selenicereus setaceus*) (BRS MPC; and BRS Âmbar do Cerrado (*S. megalanthus*) (BRS AC). A witness (CPAC Roxa from the *S. costaricensis* species*)* that is one of the parental genotypes used in the interspecific crossings was also evaluated.

The experiment was performed using the randomized block design with two repetitions and ten plants by repetition. As seedlings were conducted by staking of a single stem. After reaching the top of the post, the cladodes were supported on a motorcycle tire sustained by an iron cross, allowing the formation of the plants canopy. The spacing used was four meters between lines and three meters among plants.

Six pitaya genotypes were studied in the 2019/2020 and 2020/2021 cycles. In order to get the measurements all fruits produced by the plants of two repetitions were harvested using knives and scissors. Only the fruits totally matured presenting a characteristic color of the peel were harvested.

After each daily harvest, the fruits were sent to the lab so their length (CF), diameter (DF) and mass (MF) were evaluated. As soon as the data were distributed to tables, the number of fruits by plant ($NF.PL^{-1}$), average production per plant ($kg.PL^{-1}$) and the estimated productivity ($t.ha^{-1}$) were calculated.

The analysis of variance was made using the statistic software SISVAR® and following the randomized blocks design with two repetitions. The means were submitted to the Tukey Test, 1% of probability.

Results and Discussion

Significant differences among the six pitaya genotypes were found concerning all features evaluated, regardless the year the analysis was performed. There were also significant differences at a 1% of probability for the $NF.PL^{-1}$, $kg.PL^{-1}$ and $t.ha^{-1}$ variables and the years of evaluation and the genotype X year interaction (Tables 1 and 2).

The differences between the physical characteristics and the yield capacity of the pitaya analyzed in the present study are explained by their genetic differences. The different species of pitaya present a huge diversity as for the physical features of the fruits as for example, the shape, peel and pulp colors and presence or absence of torn (JUNQUEIRA et al., 2002), as well as the diameter, length, and mass (JIANG et al., 2011; LIMA et al., 2013).

S. undatus genotypes show larger fruits compared to the other evaluated samples, including the diameter (DF) and length (CF). BRS Lua do Cerrado had fruits that were in average 11.96 cm and 12.53 cm long in the first and second year of production, while BRS Luz do Cerrado presented mean values

equal to 12.05 cm in 2019/2020 and 12.00 cm in the 2020/2021 cycle. In relation to the variable "diameter of the fruit", BRS Lua do Cerrado showed an average of 8.85 cm and 9.14 cm in the first and second year of evaluation, respectively (Table 1). These results are like the ones observed by other authors when studying physico-chemical features of *H. undatus* (CHIK et al., 2011; CORDEIRO et al., 2015; FERNANDES et al., 2018; LIMA et al., 2014; MAGALHÃES et al., 2019; MENEZES et al., 2015b; YAH et al., 2008).

CPAC Roxa and BRS Minipitaya do Cerrado had the lowest fruit length. In the present study no statistical differences were found among themselves concerning this feature. The average fruit lengths of the *S. costaricensis* genotype were 5.65 cm and 6.01 cm for the first and second year of cultivation, respectively. As for the *S. setaceus*, the average lengths were 6.64 cm in 2019/2020 and 6.55 cm in 2020/2021 crop (Table 1).

Statistically significant fruit diameters were found between CPAC Roxa and BRS Minipitaya do Cerrado. The average diameters of CPAC Roxa were 5.99 cm for the 2019/2020 crop and 6.47 for the 2020/2021 crop, while the average diameters of BRS Minipitaya do Cerrado were 4.74 cm and 4.39 cm in the first and second year of evaluation, respectively (Table 1).

Sato et al. (2014), after studying the pysico-chemical characteristics of the *S. costaricensis* in three cities in the state of Pará, found higher average length and diameter compared to the results found in the same species analyzed in the present experiment. These authors reported average values ranging from 8.2 cm to 8.9 cm for the fruit length and 9.12 cm to 9.36 cm for the fruit diameter in the three locations where the study was performed.

Besides the significant interspecific diversity reported by Junqueira et al. (2002), within the same species of the pitaya genotypes, there might also exist a high intraspecific genetic variability between the same species of pitaya genotypes. Lima et al. (2014) studying the physico-chemical features of 15 accessions of *S. setaceus*, observed the existence of a high intraspecific genetic variability. The genotypes researched by these authors showed values of CF and DF that ranged from 6.8 cm to 9.0 cm (length) and from 4.0 cm to 4,7 cm, respectively.

BRS Granada do Cerrado had intermediary values for CF and DF. In terms of fruit length, an average ranging from 7.52 cm and 7.44 cm was noted in the 2019/2020 and 2020/2021 cycle, respectively. As for the DF variable, the average of the interspecific hybrid was 6.92 cm in the first year and 6.90 cm in the second year of evaluation, not showing statistical differences from CPAC Roxa in the crop of 2020/2021 (Table 1).

S. megalanthus genotype showed statistical differences from the other genotypes concerning the CF variable, with an average of

Table 1 – Average length (CF) (cm), diameter (DF) (cm), length/diameter ratio ($CF.DF^{-1}$) and fruit mass (MF) (g) of six pitaya genotypes (*Hylocereus* spp. and *Selenicereus* spp.). Planaltina – DF, 2022.

Genotype	CF		DF		CF/DF		MF	
	2019/2020 crop	2020/2021 crop	2019/2020 crop	2020/2021 crop	2019/2020 crop	2020/2021 crop	2019/2020 crop	2020/2021 crop
CPAC Roxa	5.65 a*	6.01 a	5.99 b	6.47 b	0.95 a	0.94 a	130.51 a	161.55 B
BRS MPC	6.64 ab	6.55 ab	4.74 a	4.39 a	1.41 b	1.50 b	81.61 a	66.93 A
BRS GC	7.52 b	7.44 b	6.92 c	6.90 b	1.10 a	1.08 a	219.92 b	212.73 B
BRS AC	8.63 c	9.10 c	4.55 a	5.00 a	1.96 c	1.83 c	142.32 ab	137.06 Ab
BRS LC	11.96 d	12.53 d	8.85 d	9.14 c	1.36 b	1.38 b	557.84 c	602.16 C
BRS LZC	12.05 d	12.00 d	9.04 d	8.99 c	1.36 b	1.34 b	566.34 c	556.49 C

*The means followed by the same letter in the column did not show statistical differences according to the Tukey Test, 1% of probability

8.63 cm in the cycle of 2019/2020 and 9.10 cm in the 2020/2021 cycle. As for the fruit diameter, BRS Âmbar do Cerrado showed the lowest diameter along with the BRS Minipitaya do Cerrado. With averages equal to 4.55 cm in the first year and 5.00 cm in the second year of evaluation, the DF means were similar to the ones found in other experiments using the same species (CHIK et al., 2011; JIANG et al., 2011) (Table 1).

Although the values for fruit length and diameter of the *S. undatus* in the present work were similar to the ones found in other papers, the total mass was higher than most of the studies available (CHIK et al., 2011; FERNANDES et al., 2018; MAGALHÃES et al., 2019; MENEZES et al., 2015a; MENEZES et al., 2015b; ORTIZ e TAKAHASHI, 2015; CORDEIRO et al., 2015; PATWARY et al., 2013; YAH et al., 2008). The average fruit mass for BRS Lua do Cerrado was 557.84 g and 602.61 g in the first and second year of evaluation, respectively, while the average values for BRS Luz do Cerrado regarding the MF was 566.34 g in the crop of 2019/2020 and 556.49 g in the crop of 2020/2021 (Table 1). These results prove the importance of the plants genetic breeding and selection of superior and more adjusted genotypes for the area they are cultivated.

BRS Minipitaya do Cerrado had the lowest fruit masses, where the means were 81.61 g and 66.93 g in the first and second year of evaluation, respectively, not showing any statistically significant differences when compared to CPAC Roxa in the crop of 2019/2020 and BRS Âmbar do Cerrado in the two crops that were studied (Table 1). Lima et al. (2014) observed similar means when studying the different accessions of *S. setaceus*, where the means ranged from 67 g and 91 g between genotypes.

The average fruit masses for BRS Âmbar do Cerrado were 142.32 g in the first and 137.06 g in the second year of evaluation (Table 1). These figures were similar to the results found by Jiang et al. (2011) in Taiwan (175,3 g) and larger than the findings from Weiss et al. (1994) in studies performed in Israel (108 g).

The length/diameter ratio is used as a reference in the fruit cultivation for the definition of the standard pattern of fruits of a certain species or variety. Fruits are considered ovoid or oblong when their length/diameter ratio is superior to 1.0 and are called round when close to 1.0 (MEDEIROS et al., 2009).

When analyzing the $CF.DF^{-1}$ of CPAC Roxa and BRS Granada do Cerrado, the values were different from the others, being too close to 1, showing more rounded fruits (Table 1). In a study performed in the State of Pará, Sato et al. (2014) observed that *S. costaricensis* fruits had a globular shape and that they were moderately flat. On the other side, Chik et al. (2011) after evaluating the *H. polyrhizus* fruits, another species of pitaya with red pulp, noticed that the fruits were round.

Because the $CF.DF^{-1}$ of BRS Minipitaya do Cerrado, BRS Lua do Cerrado and BRS Luz do Cerrado fruits were close to 1.5, their fruits were a little more elongated (Table 1). These results were similar to the ones observed by other authors, who also classified the *S. undatus* fruits as slightly oblong (CHIK et al., 2011; TRAN e YEN, 2014; OSUNA-ENCISO et al., 2016; PATWARY et al., 2013)

The largest $CF.DF^{-1}$ ratio was found in BRS Âmbar do Cerrado fruits (1.96 in the 2019/2020 cycle and 1.83 in the 2020/2021 cycle) presenting fruits typically ovoid (Table 1). These data corroborate with he reported by Chik et al. (2011) in *S. megalanthus* fruits in orchards in Malaysia and by Jiang et al. (2011) in orchards located in Taiwan.

In the cycle of 2019/2020, the highest $NF.PL^{-1}$ variable was found in BRS Granada do Cerrado. With an average of 88.80 fruits per plant, the interspecific hybrid did not show differences when compared to BRS Lua do Cerrado and BRS Luz do Cerrado with 38.60 and 38.40 fruits per plant, respectively. The *S. undatus* genotypes did not show differences where the number of fruits per plants ranged from 10.35 (BRS Âmbar do Cerrado) to 28.05 (BRS Minipitaya do Cerrado). In the

2020/2021 cycle, BRS Granada once again showed the highest NF.PL^{-1}. The average was 234.30, being statistically different from other genotypes studied in this experiment. The values were 45.05 (BRS Lua do Cerrado) to 70.95 fruits per plant (CPAC Roxa), being similar to the results observed by other authors (FERNANDES et al., 2018) (Table 2).

Significant differences were found in the different years of evaluation when the NF.PL^{-1} variable was studied in the six subject genotypes. BRS Granada do Cerrado produced 164% more fruits per plant in the second year of study. CPAC Roxa presented an increase of 272% followed by BRS Âmbar do Cerrado with 530% more fruits per plant (Table 2). These differences might be explained by the superior vegetation growth of the plants from one year to the other, resulting in largest number of cladodes and, consequently largest number of buds capable of developing into flower buds. Another possible explanation is the evolution of noncurrent cladodes maturity because when reaching the ideal height and reserve accumulation, they could better express their yield potential in the second year of study.

Jiang et al. (2011) performed experiments using *S. megalanthus* and found that the cladodes emerged in previous cycles presented the largest number of floral buds by cladode when compared to young floral buds emerged between the crops. These authors also reported that when studying current cladodes, the longer shoots tended to have higher percentage of flowers than shorter ones.

On the other side, Costa et al. (2014) reported that 96% of the cladodes in *S. undatus* plants that had already produced fruits in previous seasons started to produce fruits again, while only 72% of the current cladodes produced fruits. Furthermore, these authors observed that the noncurrent cladodes produced 25% more fruits than the current cladodes.

When studying the production per plant (kg. PL^{-1}), CPAC Roxa, BRS Minipitaya do Cerrado and BRS Âmbar do Cerrado presented the lowest values during the two years of evaluation, not being statistically different from each other. In the 2019/2020 harvest, the lowest kg.PL^{-1} was found in BRS Âmbar do Cerrado (1.45 kg.plant^{-1}) while in the 2020/2021 harvest, the lowest value for this variable was found in BRS Minipitaya do Cerrado fruits (3,57 kg.plant^{-1}). *H. undatus* genotypes showed intermediary values of kg.PL^{-1} which averaged from 21.5 kg and 21.75 kg per plant in the first year and 27.06 kg and 28.95 kg per plant in the second year studying BRS Lua do Cerrado and BRS Luz do Cerrado, respectively (Table 2).

The highest values for kg.plant^{-1} in the two evaluation seasons were obtained with BRS Granada do Cerrado. This genotype presented an average of 19.14 kg.plant^{-1} in the 2019/2020 crop and 49.86 kg.plant^{-1} in the 2020/2021 crop. In addition, a significant increase was observed between the first and

Table 2 – Means of fruits per plant (NF.PL^{-1}), production per plant (kg.PL^{-1}) and estimated productivity (t.ha^{-1}) of six pitaya genotypes. Planaltina – DF, 2022.

Genotype	NF.PL^{-1}		kg.PL^{-1}		t.ha^{-1}	
	2019.2020 crop	2020.2021 crop	2019.2020 crop	2020.2021 crop	2019.2020 crop	2020.2021 crop
CPAC Roxa	19.05 a A	70.95 a B	4.96 A A	11.43 a A	4.13 a A	9.52 a A
BRS MPC	28.05 a A	53.35 a A	2.40 A A	3.57 a A	2.00 a A	2.97 a A
BRS GC	88.80 b A	234.30 b B	19.14 B A	49.86 c B	15.95 b A	41.55 c B
BRS AC	10.35 a A	65.25 a B	1.45 A A	8.92 a A	1.21 a A	7.44 a A
BRS LC	38.60 ab A	45.05 a A	21.55 B A	27.06 b A	17.96 b A	22.55 b A
BRS LZC	38.40 ab A	52.10 a A	21.75 B A	28.95 b A	18.13 b A	24.12 b A

*Means followed by the same small letter in the column and by the same capital letter within each variable are not statistically significant by the Tukey Test, 1% of probability.

second year of evaluation only for this material, which presented an increase of 517% in the variable kg.plant^{-1} from the first to the second harvest (Table 2). Fernandes et al. (2018), studying the effect of fertilization on two pitaya species, also observed an increase in the production of *S. undatus* and *H. polyrhizus* plants during the first three years after the development of the orchard.

Likewise, BRS Granada do Cerrado presented the highest estimated productivity (t.ha^{-1}) in the two years of evaluation. In the 2019/2020 crop, it presented an average of 15.95 t.ha^{-1} and 41.55 t.ha^{-1} in the 2020/2021 crop, representing an increase of 161% from the first to the second year of evaluation (Table 2).

The lowest t.ha^{-1} in the two years of evaluation were observed for the CPAC Roxa, BRS Minipitaya do Cerrado and BRS Âmbar do Cerrado genotypes, which did not differ statistically from each other. In the 2019/2020 harvest, BRS Âmbar do Cerrado had the lowest average (1.21 t.ha^{-1}) while in the 2020/2021 crop BRS Minipitaya do Cerrado showed the lowest t.ha^{-1} (2.97) (Table 2).

On the other side, *S. undatus* genotypes had intermediary values for estimated productivity (t.ha^{-1}), being statistically different from the others relation to the two years of study. In the 2019/2020 crop, these materials presented in average of 17.96 kg and 18.13 t.ha^{-1}, while in 2020/2021 the estimated productivity was 22,55 t.ha^{-1} and 24,12 t.ha^{-1} for BRS Lua do Cerrado and BRS Luz do Cerrado, respectively (Table 2).

Results of the present experiment demonstrated that the interspecific hybrid (BRS Granada do Cerrado) shows the largest yield capacity when compared to the species that originated the crossing (*S. undatus* and *S. costaricensis*). This fact might be the result of an exploitation of heterosis generated in the crossing among *S. undatus* and *S. costaricensis* genotypes that generated a more productive offspring than the two parents, a fact commonly called hybrid vigor. In passion fruits, the interspecific crossing might be used with the objective of increasing the genotypes yield due to the capacity to exploit hybrid vigor by crossing two contrasting genotypes (JUNQUEIRA et al., 2005).

The results of the present experiment evidenced the importance of the genetic breeding of plants and the selection of superior and more adjusted genotypes for the production area to ensure higher profitability and products of a better quality to the rural producer.

Conclusion

Genotypes of pitaya developed by Embrapa Cerrados showed differences as for their physical features and yield capacity.

On the other hand, genotypes of the *S. undatus* species showed to produce larger and heavier fruits.

As for the genotype of *S. setaceus*, it showed smaller fruits presenting a possible alternative for the market of “baby” fruits.

Finally, BRS Granada do Cerrado showed to produce more fruits per plant, having a larger yield capacity, resulting in an expected larger yield per hectare.

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