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Number of carpels in the pollination efficiency of sour passion fruit

Danilo Akio de Sousa Esashika[1], Fábio Gelape Faleiro[2], Nilton Tadeu Vilela Junqueira[3]

Abstract - Passion fruit flowers usually have three carpels, but there are individuals with greater amount of carpels in their reproductive structures and little is known about the influence of this characteristic on this crop. Sour passion fruit (*Passiflora edulis* Sims, 'BRS Sol do Cerrado' cultivar) plants presenting flowers with three, four and five carpels were evaluated regarding the following characteristics: manual and natural pollination efficiency; frequency of different types of flowers in the orchard; and inclination of styles. Frequencies of flowers with three, four and five carpels were also evaluated in 'BRS Sol do Cerrado' genitors. There were no statistically significant differences in pollination efficiency among the different types of flowers, which presented averages above 90%, especially flowers with five carpels, with 100% efficiency. Flowers with three carpels are predominant in 'BRS Sol do Cerrado' cultivar, representing 88.93%, but flowers with four and five carpels did not show styles without inclination, whereas flowers with three carpels presented rate of 11.83%. Only the male genitor stands out for the rate of flowers with four and five carpels, being 37.33% and 7.33%, respectively. Thus, flowers with four and five carpels represent important characteristics for passion fruit breeding programs.

Index terms: manual pollination, *Passiflora edulis*, fruit set.

Número de carpelos na eficiência da polinização do maracujazeiro-azedo

Resumo – As flores do maracujazeiro-azedo normalmente apresentam três carpelos, porém há indivíduos com maior quantidade de carpelos em suas estruturas reprodutivas e pouco se sabe da influência dessa característica na cultura. Plantas de maracujazeiro-azedo (*Passiflora edulis* Sims, cultivar BRS Sol do Cerrado), que apresentam flores com três, quatro e cinco carpelos, foram avaliadas quanto: à eficiência de polinização manual e natural; à frequência dos diferentes tipos de flores no pomar; à inclinação dos estiletes. As frequências de flores com três, quatro e cinco carpelos também foram avaliadas nos genitores da referida cultivar. Não foram observadas diferenças estatísticas significativas na eficiência de polinização entre os diferentes tipos de flores, as quais apresentaram médias acima de 90%, destacando-se a média de 100% das flores com cinco carpelos. As flores com três carpelos são predominantes na cultivar estudada, representando 88,93%, porém flores com quatro e cinco carpelos não apresentaram estiletes sem inclinação, enquanto flores com três carpelos apresentaram taxa de 11,83%. Apenas o genitor masculino da cultivar destaca-se quanto à taxa de flores com quatro e cinco carpelos, sendo de 37,33% e 7,33%, respectivamente. Assim, flores com quatro e cinco carpelos representam importantes características para o melhoramento genético do maracujazeiro.

Termos para Indexação: polinização manual, *Passiflora edulis*, vingamento.

Corresponding author:
danilo.esashika@ifto.edu.br

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[1]Doutor, Professor do Instituto Federal do Tocantins. Lagoa da Confusão-TO, Brasil. E-mail: danilo.esashika@ifto.edu.br (ORCID 0000-0002-9442-9478)

[2]Doutor, Pesquisador Embrapa Cerrados. Planaltina-DF, Brasil. E-mail: fabio.faleiro@embrapa.br (ORCID 0000-0001-8901-6428)

[3]Doutor, Pesquisador Embrapa Cerrados. Planaltina-DF, Brasil. E-mail: nilton.junqueira@embrapa.br (ORCID 0000-0001-9814-7104)

Most passion fruit trees (Passiflora spp.) have flowers with three styles that start at the upper center of a unilocular superior ovary with three parietal placentas (CERVI, 1997). However, there are *P. edulis* Sims accessions that present flowers with four and five sets of parietal placentas, styles and stigmas (SIQUEIRA et al., 2009).

Studies correlating floral morphology and pollination efficiency of passion fruit are still incipient. In *P. edulis* Sims, Ruggiero et al. (1976) identified that passion fruit styles can be classified as with total curvature (TC), partial curvature (PC) or without curvature (SC), and there is no fruit set on those without style inclination after anthesis. In *P. cincinnata*, Freire et al. (2015) observed manual pollination efficiency of 77% in flowers with styles below the anthers and 0% pollination efficiency for flowers with styles above the anthers line.

The aims of this work were: to identify relationships between number of carpels and pollination efficiency of sour passion fruit; to evaluate the frequency of flowers with three, four and five carpels in *P. edulis* Sims 'BRS Sol do Cerrado' cultivar (BRS SC1) (EMBRAPA, 2018) and its genitors, and to evaluate the inclination of the styles of flowers with three, four and five carpels.

Two experiments were carried out on March and April 2018 in a property located at "Núcleo Rural Lamarão", Federal District, in a region with AW Tropical climate according to the Köppen classification.

The soil of the region is a Red Yellow Latosol with high phosphorus and potassium levels and adequate Ca / Mg ratio. Planting and top-dressing fertilization was carried out according to technical recommendations for sour passion fruit cultivation in the Midwestern region of Brazil. The micro sprinkler irrigation system was triggered at least four days depending on weather conditions and soil water saturation. The photoperiod of the region during the study period is longer than 11 hours and 20 minutes, which favors sour passion fruit flowering. The spacing used was 2.5 meters between rows and 3 meters between plants, which were conducted with vertical cordon with one wire thread at 1.8 meters high.

The first experiment was conducted in a completely randomized design with five replicates of seven flowers for each treatment. Treatments were: flower type (three, four or five carpels) and pollination type (manual or natural). Flowers from healthy plants close to anthesis were selected. Manual pollination was performed in a crosswise manner and in natural pollination, pollinators had free access to flowers. Pollinators of the genus *Xylocopavis* were observed visiting passion fruit flowers more often in the afternoon. Manual pollination was performed by collecting pollen in a row opposite to the one that would be pollinated in order to avoid pollination of a plant with its own pollen.

Fruit set was evaluated three days after the experiment was installed, considering positive results flowers whose ovary were swollen and greenish, indicating the phenological phase of initial fruit development (MACHADO et al., 2012), and negative results, those in which ovaries did not increase in size and were darkened in color.

The frequency of flowers with three, four and five carpels and the inclination degree of styles of these flowers were evaluated in the same experimental area. For this, five replicates of 50 open flowers each were evaluated. Flowers were randomly evaluated during walk between rows. These characteristics were evaluated after 90 minutes of anthesis (approximately at 02:30 p.m.) of flowers to allow the inclination of styles, which were classified as total curvature (TC), partial curvature (PC) or without curvature (SC) (RUGGIERO et al., 1976).

The second experiment was carried out in another location to evaluate the frequency of flowers with three, four and five carpels of 'BRS Cerrado Sol' cultivar (*P. edulis* Sims) grown in greenhouse in the city of Planaltina - DF, which is AW tropical climate region according to the Köppen classification. This experiment was carried out in a completely randomized design with 5 replicates for each treatment (male and female genitors) composed of 50 flowers each replicate. Genitors were vegetatively propagated and cultivated in greenhouse with antiphid screen in drip irrigation system. Planting and top-dressing fertilization was carried out according to technical recommendations for sour passion fruit cultivation in the Midwestern region of Brazil. The spacing used was 2 meters between rows and vertical cordon with two wire threads at heights of 1.8 and 1.4 meters.

Experimental data were submitted to analysis of variance and Tukey mean comparison test at 5% of significance using the BIOSTAT v. 5.0 statistical software (AYRES et al., 2007).

No statistically significant differences in flower pollination efficiency were identified with three, four and five carpels of 'BRS Sol do Cerrado' cultivar. Flowers with three carpels presented average set of 91.43 ± 7.82 and flowers with four and five carpels presented average set of 97.14 ± 6.39 and 100.00 ± 0.00 respectively (Table 1). Such averages are high considering the manual pollination efficiencies found in other studies with *P. edulis* Sims, in which Yamashiro (1981) found value of 50.8%, Siqueira et al. (2009) of 74.0% and finally Carvalho and Teófilo (1973) of 85%.

When naturally pollinated, flowers with three and four carpels presented average set of 83.33% and 93.33%, respectively, and did not differ statistically from results obtained with manual pollination of flowers with three and four carpels (Table 1). The results of natural pollination differ from those found by other authors, which ranged from 0% to 12% (OAK; THEOPHY, 1973;

YAMASHIRO, 1981; SIQUEIRA et al., 2009). This high natural pollination efficiency is certainly a characteristic of 'BRS Sol do Cerrado' cultivar in small orchards with high presence of natural pollinators and in suitable climate conditions for pollination.

Table 1. Manual pollination efficiency of passion fruit flowers 'BRS Sol do Cerrado' cultivar with three, four and five carpels, "Núcleo Rural Lamarão" - DF, 2018.

Type of Pollination	No. of Carpels		
	3	4	5
Natural (%)	83.33 ± 15.05 Aa	93.33 ± 10.33 Aa	-
Manual (%)	91.43 ± 7.82 Aa	97.14 ± 6.39 Aa	100.00 ± 0.00 a

* Means followed by the same lowercase letter in the row and uppercase in the column do not differ from each other by the Tukey mean comparison test at 5% significance.

Although the average pollination efficiency did not present statistically significant difference, the result of 100% pollination efficiency of flowers of five carpels is agronomically important because it represents possible gains in the number of fruits produced that could have a positive impact on fruit productivity, since the fruit set is directly related to pollination (AKAMINE; GIROLAMI, 1959).

This high fruit set presented by flowers with four and five carpels may be related to the inclination of their styles. It is noteworthy that flowers with total curvature of styles (CT) show the best pollination probabilities because they present stigmas near the anthers height, facilitating pollination by pollinators; while the opposite occurs with flowers without curvature (SC), which do not provide fruits even when manually pollinated (RUGGIERO et al., 1976).

Under the conditions of this experiment, flowers with three carpels of 'BRS Sol do Cerrado' cultivar presented 11.84% of flowers without curvature (SC), 13.10% of flowers with partial curvature (PC) and 75.06% of flowers with total curvature (CT). There were no flowers without curvature of styles in four-carpel reproductive structures, and 17.80% of flowers presented partial inclination of styles and 82.20% of flowers presented total inclination. All flowers with five carpels showed total curvature of styles (Table 2), which may have contributed to the high pollination efficiency of this treatment observed in Table 2

Table 2. Inclination frequency of sour passion fruits flowers 'BRS Sol do Cerrado' cultivar with three, four and five carpels, "Núcleo Rural Lamarão" - DF, 2018.

	No. of Carpels		
	3		
Inclination	SC	PC	TC
Frequency (%)	11.84 ± 6.54 b	13.10 ± 6.93 b	75.06 ± 5.96 a
	4		
Inclination	SC	PC	TC
Frequency (%)	0.00 ± 0.00 c	17.80 ± 6.01 b	82.20 ± 6.00 a
	5		
Inclination	SC	PC	TC
Frequency (%)	0.00 ± 0.00 b	0.00 ± 0.00 b	100.00 ± 0.00 a

* Means followed by the same letter do not differ from each other by the Tukey mean comparison test at 5% significance. * SC = without curvature, PC = partial curvature, CT = total curvature.

It is verified in literature that the frequency of flowers with different style inclination is variable. Siqueira et al. (2009) identified that 40% of passion fruit flowers presented flowers without curvature (SC) or partial curvature (PC) of styles, while Siqueira and Kill (2009) found frequencies of 30% (4.8% for SC and 25.2% for PC). Hoffman et al. (2000) identified values of 76.86% for TC flowers, 21.22% for PC flowers and 1.92% for SC flowers, values similar to those obtained by Ruggiero et al. (1976). Matsumoto and São Sojé (1991) reported that from 57.7% to 87.0% of sour passion fruit flowers are TC type and from 10.0% to 28.8% are SC type.

Junqueira et al. (2001) point to cultivar and time of year as factors of variation in the frequency of different types of flowers regarding style inclination, reporting that in cold night periods, SC and PC rates tend to increase. Siqueira and Kill (2009) reported that the Passiflora species is also a factor of variation of this frequency, identifying *P. alata* and *P. cincinnata*, with 68.7% and 72.6% of PC and SC flowers, respectively.

In fact, the experimental data for flowers with three carpels fall within the range of values found by the authors above, but for flowers with four and five carpels, the frequency of SC flowers differ from those observed by the authors. This is an expressive result, since SC flowers do not produce fruits (AKAMINE; GIROLAMI, 1957; RUGGIERO et al., 1976), as the megaesporophyte does not have an oosphere, which makes embryo formation impossible and consequently impairs fruit formation (HOFFMAN , 1997).

The frequencies of flowers with three, four and five carpels of 'BRS Sol do Cerrado' passion fruit cultivar showed significant statistical differences, and flowers with three carpels were numerically higher, representing 88.93%, well above the amount of flowers with four and five carpels, which presented averages of 9.11% and 1.96%, respectively (Table 3). The female genitor of the cultivar did not have flowers with five carpels and the frequencies of flowers with four carpels were below 15%. The male genitor presented 7% of flowers with five carpels and 37% of flowers with four carpels (Table 4), being a promising material for the generation of a new cultivar with higher proportion of flowers with more than three carpels.

Table 3. Frequency of passion fruit flowers 'BRS Sol do Cerrado' cultivar with three, four and five carpels, "Núcleo Rural Lamarão" - DF, 2018.

	No. of Carpels		
	3	4	5
Frequency (%)	88.93 ± 6.35 a	9.11 ± 4.21 b	1.96 ± 4.38 b

* means followed by the same letter on the row do not differ from each other by the Tukey mean comparison test at 5% significance.

Table 4. Frequency of flowers 'BRS Sol do Cerrado' cultivar with three, four and five carpels, "Núcleo Rural Lamarão" - DF, 2018.

Frequency (%)	No. of Carpels		
	3	4	5
Male	55.33 ± 10.95 a	37.33 ± 13.62 a	7.33 ± 7.23 b
Female	85.50 ± 3.09 a	14.49 ± 3.09 b	0.00 ± 0.00 c

* means followed by the same letter on the row do not differ from each other by the Tukey mean comparison test at 5% significance.

The pollination efficiency of flowers with four and five carpels represents an important trait for the genetic improvement of passion fruit. BRS Sol do Cerrado cultivar shows predominance of flowers with three carpels, with higher frequency of flowers with four and five carpels in its male genitor. The proportion of styles with total curvature increases with the increase of carpels, with no styles without curvature (SC) in flowers with four and five carpels.

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