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Agronomic Performance of Passion Fruit Genotypes in the Federal District, Brazil

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Abstract

Brazil stands out as the largest producer and consumer of passion fruit in the world. However, this fruit specie still faces some production problems such as lack of genetic materials with high yield, disease resistance and fruit quality, due mainly to the lack of research work in the breeding area. In order to contribute to the development of new passion fruit cultivars, this study aimed to evaluate the agronomic performance of passion fruit genotypes in the Federal District, Brazil, as well as to estimate genetic parameters for use in breeding programs. The experiment was carried out with 48 genotypes, in a simple layout (arrangement) of randomized block, with four replications and six plants per plot. The following characteristics were evaluated during fifty-four crops: fruit yield (kg/ha), number of fruit per hectare, average fruit weight (g) and sorting fruit on the equatorial diameter (mm) in five categories (1st, 1B, 1A, 2A and 3A). Higher fruit yields and number were observed in the genotypes MAR 20 # 41, MAR 20#41 pl 1, Gigante Amarelo pl 1 and MAR 20 # 39. Consdering fruits of 1st, genotype MAR 20 # 39 pl 2 produced the highest number of fruits per hectare. High values of heritability and CVg/Cve ratio were observed for total number of fruits per hectare in the first classification.

Keywords: *Passiflora edulis*, fruit yield, genetic parameters.

1. Introduction

Fruit production is increasing in Brazil, specially in recent years, and passion fruit has an important role in this scenario.This fruit is produced in all Brazilian states and in the Federal District in order to supply the internal market demand for frozen concentrated juice and fresh fruit.

The area destinated to passion fruit production in Brazil was 56,825 ha in 2014 (IBGE, 2016), approximately 30% higher than in 2005, when passion fruit was produced on 36,000 hectares (IBGE, 2012). The Northeast Region was the main passion fruit producer of the country in 2014, with 43,045 hectares and 583,636 tons of fruits produced, which corresponded to a productivity of 13.55 t/ha, or 71% of the national production of this fruit. In the same year, Federal District produced 3,766 tons of fruits in 125 hectares (30.13 t/ha), which was equivalent to just over 6.63% of national passion fruit production (IBGE, 2016).

The Brazilian average productivity of passion fruit is approximately 14 t/ha, which is considered low compareted to the crop´s potential. Phytosanitary problems are the main responsibles for low productivity, but other factors also contribute to this scenario, such as plant genotype, edaphic and environmental conditions, biotic agents, use of inappropriate strains and inadequate agricultural practices. The average productivity of passion fruit in recent years in Brazil has ranged from 12 to 15 tons per hectare, with a production potential of 30 to 35 tons per hectare (Silva et al., 2009). Elite genotypes, developed in research activities, can produce more than 50t/ha/year (Faleiro et al., 2011).

The need for improved genetic cultivars with high productivity, fruit quality and resistance to phytopathogens is mainly due to the lack of research studies in the fruit production area and especially in the genetic improvement of passion fruit. The use of pesticides is very high in passion fruit production in Brazil, due to the low pathogen resistance of the current cultivars in the market.

According to Faleiro et al. (2011), the genetic improvement of passion fruit should consider the parts of the plant to be used, the purpose of use and the region of cultivation. In addition, fruit characteristics such as size, shape, appearance, resistance to the transportation, maintenance of quality during storage and marketing preferences must also be observed. Agronomic performance and resistance to fungal, bacterial and viral diseases that affect the crop require continuous studies of genetic improvement, since there are few passion fruit cultivars available to Brazilian producers and their productivity is considered low (Faleiro et al., 2011).

Thus, there is a need for studies that provide greater passion fruit yields with diseases resistance. The University of Brasília, in partnership with Embrapa Cerrados, has been developing new passion fruit varieties to meet the expectations of Brazilian producers. In this sense, the main objective of this study was to evaluate the agronomic performance of 48 passion fruit genotypes in the Federal District region.

2. Material and Method

2.1 Local

The experiment was carried out in Fazenda Água Limpa (FAL) at the University of Brasília (UnB). FAL is located in Nucleo Rural Vargem Bonita, Federal District, 15°56' latitude South, 47°55' longitude West and altitude of 1100 m. The climate is AW type, according to Köeppen's classification, characterized by rainfall concentration during summer, from October to April, and dry winters from May to September (Kottek et al., 2006).

2.2 Experimental description

The soil is classified as Red-Yellow Latosol in the experiment area. Lime (according to the soil analysis) and 1 kg of simple superphosphate were incorporated to each hole in pre-planting. The soil analysis showed the following results: Al (0.05 meq); Ca+Mg (1.9 meq); P (4.5 ppm); K (46 ppm); pH 5.4 and 4% Al saturation. Top dressings were carried out monthly with urea and potassium chloride on the soil surface, at a distance of 0.50 m from the plant, while simple superphosphate (1 kg/hole) was incorporated into the soil. In 2014, topdressing was carried out using 20 grams of potassium chloride and 40 grams of ammonium sulfate, every 30 days. In 2015 and 2016, monthly top dressings were carried out using 40 grams of potassium chloride and 80 grams of ammonium sulfate per plant.

The experimental design used was randomized blocks, with 48 treatments (genotypes), four replications and six plants per plot. The genotypes tested in the experiment were developed in a research partnership between UnB in partnership with Embrapa Cerrados. They were originated from intraspecific and interspecific hybridizations and also from materials from masal selections carried out in commercial orchards in southeastern Brazil, followed by recurrent selections.

The following genotypes were evaluated: AP1, AR 2, AR 2 pl 1, EC3-0, EC3-0 pl 1, ECL 7, ECL 7 pl 1, ECL 7 pl 2, ECRAM 3, FB 200, FB 200 pl 1, Yellow Giant, Yellow Giant pl 1, MAR 20#10, MAR 20#100, MAR 20#12, MAR 20#15, MAR 20#2005, MAR 20#2005 pl 1, MAR 20#21, MAR 20#24, MAR 20#24 pl 1, MAR 20#24 pl 2, MAR 20#24 pl 3, MAR 20#24 pl 4, MAR 20#24 pl 5, MAR 20#24 pl 6, MAR 20#24 pl 7, MAR 20#34, MAR 20#34 F2, MAR 20#39, MAR 20#39 pl 1, MAR 20#39 pl 2, MAR 20#41, MAR 20#41 pl 1, MAR 20#41 pl 2, MAR 20 #44, MAR 20#46, MAR 20#46 pl 1, MSCA, MSCA pl 1, Rosa Claro, Rosa Claro pl 1, Rosa Intenso, Rosa Intenso pl 1, Rosa Intenso pl 2 and Rubi Gigante.

Seeds were sowed in trays with 72 cells filled with 125 ml of vermiculite substrate in a protected environment located at the Experimental Biology Station of UnB. The seedlings were transplanted to the field in May 2014. Row spacing was 2.8 meters and 3 meters of space between plants, totaling 1190 plants per hectare. Irrigation was carried out as follows: 7 hours of irrigation and a two-day shift with an average of 3 liters per linear meter per hour. Weed control in the rows was undertaken manually with hoe and between rows with a mechanical mower. No chemical or biological pesticides were sprayed during the experimental period. The control of Juno Longwing (*Dione juno juno*) was carried out with two aplications of Deltamethrin (DecisR) directed to the caterpillars.

The crop was conducted using a vertical espalier support system, with 6 meters apart posts and two strands of smooth wires (1.50 and 2.00 meters above the ground). The plants were conducted in a single stem system, supported by a string up to the wire, leaving two lateral shoots opposite each other for the wire. The sprouts, from then on, grew freely, and no renewal pruning was carried out.

Fruit harvests took place only for fully matured fruits picked up over the ground. Each fruit category was collected separately in plastic boxes identified according to the sketch of the experimental area. The boxes were taken to a shed for post-harvest evaluation, for the weighing procedure, which was followed weekly throughout the analysis period. The weekly harvests and performance evaluations took place from January 2015 to May 2016, totaling 15 months of evaluation and 54 harvests. Artificial pollination was not carried out to increase fruiting.

2.3 Evaluations

The following parameters were evaluated: estimated yield (Kg/ha), number of fruits per hectare, average fruit mass (g), in all fruit categories according to Rangel (2002) classification, which considers five classifications (First, 1B, 1A, 2A and 3A), according to the fruit diameter, ranging from 55 mm for First fruit to above than 90 mm for fruit classified as 3A.

The experimental data was transformed by the square root of x + 1 formula, and submitted to analysis of variance and grouped by the Tukey's mean test at 5% probability using the Genes software (Cruz, 2016).

Estimates of genotypic variances between accessions ($\hat{\sigma}_g^2$), phenotypic at mean ($\hat{\sigma}_f^2$) and mean environmental ($\hat{\sigma}_e^2$), broad-sense heritability (h^2), experimental (CVe) and genetic (CVg) variation coefficients for total yield characteristics were obtained, using the Genes software (Cruz, 2016). Using estimates of phenotypic, genotypic and environmental variances and covariances, CVg/CVe ratios and phenotypic correlations were determined with the help of the GENES software (Cruz, 2016). Linear correlation analysis (Pearson) was performed between all variables evaluated, based on the significance of their coefficients. The intensity of the correlation for $0.05 \leq p \geq 0.01$ is considered very strong (r ± 0.91 to ±1.00), strong (r±0.71 to ±0.90), medium (r±0.51 to ±0.70) and weak (r±0.31 to ±0.50), according to Guerra and Livera (1999).

3. Results and Discussion

Three groups of genotypes were distinguished according to the fruit yield (Table 1). MAR20#41 showed the highest yield (17,405 kg/ha), followed by MAR 20#41 pl 1 (17,158 kg/ha), Yellow Giant pl 1 (16,583 kg/ha), MAR 20#39 (16,371 kg/ha) and MAR 20#24 pl 5 (14,768 kg/ha), differing statistically from the genotype MAR20#24 pl 3 which presented the lowest fruit yield (1,636 kg/ha).

Campos (2015) concluded that, between 35 genotypes and 32 harvests, the highest fruit yields (10,876 kg/ha) was obtained with MSCA passion fruit genotype. Castro (2015) in his work with 48 progenies over 32 harvests, observed that one of the highest fruit yields occurred in the genotype MAR20#24 pl 2 (10,234 kg/ha).

In the present study, the highest fruit yields overcame the national average of 14 t/ha. In addition to the crop management practices, other factors may affect the response of the genotypes in different studies, such as climate, diseases, artificial polinnation, which can increase fruit yield. The present study was undertaken in adverse conditions, which is more prevalent for small farmers, in order to select genotypes appropriate to these conditions. In addition, fruit yield in the present study was also affected by the absence of pesticides use, which is often largely used in this crop. Therefore, the use of procedures such as artificial pollination and phytosanitary control presumably would have substantially increased fruit yields (Junqueira et al., 2003).

With regard to the number of fruits per area, there was a statistical difference between the evaluated genotypes. The genotypes that stood out for the highest amount of fruits also showed the highest fruit yield – MAR20#41 (175,990 fruits/ha), followed by MAR 20#39 (137,647 fruits/ha), MAR 20#41 pl 1 (137,597 fruits/ha), Gigante Amarelo pl 1 (132,835 fruits/ha) and MAR 20#24 pl 5 (126,288 fruits/ha). The genotype MAR 20#24 pl 3, which showed the lowest fruit yield, also produced the lowest amount of fruits (12,004 fruits per hectare) (Table 1).

Castro (2015) observed 88,035 fruits/ha with the genotype MAR20#24 pl 2, one of the highest values between genotypes. This author observed the highest amount of fruits in the genotype MSCA (102,777 fruits/hectare).

From the data analyzed, it was possible to observe that the variables number of first and 3A fruits had significant differences from the others categories (Table 2). That happened to weight of first and 3A fruits (Table 3) and average weight of 2A fruits (Table 4) too.

It is noteworthy here that the first and 1B fruits are considered ideal for the industry, as they are not accepted in fresh markets due to their small size. The other classes 1A, 2A and 3A are destined for commercial fresh fruit markets (Coimbra, 2010).

In the present study, the genotypes MAR 20#39 pl 2 and MAR 20#44 showed the highest yield of 1st fruits, with 1,317.69 kg/ha and 1,043.835 kg/ha, respectively. The lowest 1st fruit yield was observed in the genotypes MAR 20#34 F2 pl 1 (98.957 kg/ha), MAR 20#24 pl 2 (102.677 kg/ha) and MAR 20#41 pl 2 (125.246 kg/ha) (Table 3). Campos (2015) reported the MSCA genotype (7,383 kg/ha) as one of the most productive of 1st fruit in their study. Castro (2015) observed that the genotypes MAR20#10 (6,489 kg/ha) and MAR20#24 pl 2 (6,489 kg/ha) had the highest yields of this category of fruit.

The MAR 20#39 pl 2 genotype showed one of the highest fruit yields and stood out with the highest yield of 1st fruits (1,317kg/ha) followed by MAR 20#44 (1,043 kg/ha).

There was a statistical difference in the number of the 1st fruits between genotypes (Table 2). The largest amount of 1st fruits was observed in the genotype MAR 20#39 pl 2 (27,976 fruits/ha) and the lowest one in the Rubi Gigante genotype (1,984 fruits/ha). Campos (2015) observed the highest number of 1st fruits for the MSCA genotype (83,581 fruits/ha), while Vilela (2013) observed the highest estimated yield and the highest number of fruits in the genotype MAR 20#21 (3,601 kg/ha and 55,226 fruits/ha) and Gigante Amarelo (3,482 kg/ha and 59,050 fruits/ha), and the smallest one in MSC (290 kg/ha and 5,330 fruits/ha). Castro (2015) observed the highest numbers of fruits in MAR20#24 pl 2 (66,249 fruits/ha) and in MAR20#34 (65,416 fruits/ha).

Considering the average mass (in grams) per equatorial diameter category, the studied genotypes showed statistically significant differences in the F test at 5% significance only in the average mass 2A classification (Table 4). For the 2A classification, statistical difference was observed between the genotypes. The highest average mass was observed for ECL-7 (1,687 g/fruit) and the lowest one for Ruby Gigante (291 g/fruit).

Significant differences were observed between genotypes for the category of 3A fruits (Table 3). The highest yield were found in the genotypes Gigante Amarelo pl 1 (1,384 kg/ha), Gigante Amarelo (1,244 kg/ha), MAR 20#34 F2 (1,138 kg/ha), EC3-0 p11 (1,078 kg/ha) and ECL-7 p12 (1,021 kg/ha). The MAR 20#34 F2 pl 1 obtained the lowest productivity (181kg/ha).

The highest amount of 3A fruits was observed in the genotypes Gigante Amarelo pl 1 (5,109 fruits/ha), Gigante Amarelo (4,811 fruits/ha) and Rosa Intenso pl 2 and EC3-0 pl 1 (4,167 fruits/ha). The genotypes MAR 20#100 (446 fruits/ha), MAR 20#34 F2 pl 1 (694 fruits/ha) and FB 200 pl 1 (744 fruits/ha) showed the lowest amounts of 3A fruits.

The differences in the performance of the genotypes are explained by the various recurrent selections that were undertaken over time, climate and different managements.

Table 1. Estimated fruit yield and number of 48 passion fruit genotypes cultivated at Fazenda Água Limpa, University of Brasília. Brasilia, DF, Brazil, 2016

Genotype	Yield (kg/ha)	Number /ha
AP1	6.812,457 ab	60.168 ab
AR 2	10.874,505 ab	98.461 ab
AR 2 pl 1	13.431,117 ab	111.655ab
EC3-0	10.309,880 ab	90.277 ab
EC3-0 pl 1	14.515,378 ab	118.550 a
ECL 7	10.051,451 ab	73.610 ab
ECL 7 pl 1	11.544,288 ab	91.368 ab
ECL 7 pl 2	13.008,107 ab	112.746 ab
ECRAM pl 3	9.899,915 ab	86.259 ab
FB 200	10.977,033 ab	103.520 ab
FB 200 pl 1	4.943,385 ab	42.361 ab
Gigante Amarelo	12.954,338 ab	102.528 ab
Gigante Amarelo pl 1	16.583,257 a	132.835 a
MAR 20#10	7.429,760 ab	64.682 ab
MAR 20#100	7.298,264 ab	67.707 ab
MAR 20#12	11.156,594 ab	102.032 ab
MAR 20#15	8.561,044 ab	84.175 ab
MAR 20#2005	13.391,435 ab	107.141 ab
MAR 20#2005 pl 1	11.510,508 ab	96.179 ab
MAR 20#21	5.995,454 ab	49.057 ab
MAR 20#24	12.804,340 ab	111.060 ab
MAR 20#24 pl 1	7.865,221 ab	67.261 ab
MAR 20#24 pl 2	5.882,609 ab	47.023 ab
MAR 20#24 pl 3	1.636,387 b	12.004 b
MAR 20#24 pl 4	9.588,412 ab	76.785 ab
MAR 20#24 pl 5	14.768,202 a	126.288 a
MAR 20#24 pl 6	6.580,268 ab	63.739 ab
MAR 20#24 pl 7	7.463,986 ab	59.473 ab
MAR 20#34	6.138,558 ab	65.376 ab
MAR 20#34 F2	11.400,044 ab	101.834 ab
MAR 20#39	16.371,553 a	137.647 a
MAR 20#39 pl 1	9.065,601 ab	86.308 ab
MAR 20#39 pl 2	12.248,742 ab	114.483 ab
MAR 20#41	17.405,071 a	175.990 a
MAR 20#41 pl 1	17.158,993 a	137.597 a
MAR 20#41 pl 2	7.457,488 ab	66.765 ab
MAR 20#44	9.303,842 ab	72.816 ab
MAR 20#46	11.121,823 ab	108.332 ab
MAR 20#46 pl 1	9.863,953 ab	89.136 ab
MSCA	6.716,675 ab	61.457 ab
MSCA pl 1	10.907,491 ab	97.171 ab
Rosa Claro	7.552,527 ab	74.503 ab
Rosa Claro pl 1	12.439,811 ab	102.578 ab
Rosa Intenso	10.054,675 ab	79.711 ab
Rosa Intenso pl 1	10.028,534 ab	81.646 ab
Rosa Intenso pl 2	12.404,841 ab	97.072 ab
Rubi Gigante	9.176,959 ab	64.334 ab
MAR 20#34 F2 pl 1	6.032,408 ab	50.991 ab

Note. Means followed by the same letters in the columms do not differ from each other by Tukey's test at the 5% level.

Table 2. Fruit number (fruits/ha) according to the classification of the equatorial fruit diameter of 48 genotypes of sour passion fruit cultivated at Fazenda Água Limpa, University of Brasília. Brasilia, DF, Brazil, 2016

Genotype	1[a]	1B	1A	2A	3A
AP1	4.315 c	22.916 a	23.214 a	8.383 a	1.339 b
AR 2	8.780 b	45.734 a	30.406 a	11.161 a	2.381 a
AR 2 pl 1	4.563 c	46.230 a	44.245 a	14.038 a	2.579 a
EC3-0	7.044 c	43.353 a	29.067 a	9.077 a	1.736 b
EC3-0 pl 1	7.589 c	39.285 a	48.759 a	18.750 a	4.167 a
ECL 7	6.796 c	24.404 a	26.091 a	13.641 a	2.679 b
ECL 7 pl 1	6.300 c	40.426 a	30.307 a	12.103 a	2.232 b
ECL 7 pl 2	11.458 b	54.910 a	29.067 a	13.492 a	3.819 a
ECRAM pl 3	3.720 c	37.301 a	32.787 a	10.069 a	2.381 b
FB 200	11.210 b	45.386 a	33.581 a	11.409 a	1.934 b
FB 200 pl 1	6.101 c	16.617 a	14.881 a	4.018 a	744 b
Gigante amarelo	3.919 c	34.127 a	43.849 a	15.823 a	4.811 a
Gigante amarelo pl 1	5.952 c	52.579 a	54.116 a	15.079 a	5.109 a
MAR 20#10	5.803 c	27.480 a	22.569 a	7.292 a	1.538 b
MAR 20#100	7.093 c	30.605 a	24.156 a	5.407 a	446 b
MAR 20#12	9.524 b	44.890 a	32.390 a	13.839 a	1.389 b
MAR 20#15	8.680 b	41.765 a	24.256 a	8.680 a	794 b
MAR 20#2005	4.117 c	41.468 a	40.426 a	17.559 a	3.571 a
MAR 20#2005 pl 1	6.498 c	41.567 a	30.952 a	14.335 a	2.827 a
MAR 20#21	5.555 c	18.551 a	15.476 a	7.242 a	2.232 b
MAR 20#24	11.557 b	46.279 a	40.674 a	11.309 a	1.240 b
MAR 20#24 pl 1	6.647 c	29.166 a	22.718 a	6.994 a	1.736 b
MAR 20#24 pl 2	1.835 c	19.643 a	16.914 a	7.093 a	1.538 b
MAR 20#34 F2 pl 1	992 c	4.563 a	3.919 a	1.835 a	694 b
MAR 20#24 pl 3	4.315 c	32.093 a	29.960 a	8.780 a	1.637 b
MAR 20#24 pl 4	9.623 b	57.241 a	43.105 a	13.789 a	2.530 a
MAR 20#24 pl 5	3.770 c	34.920 a	17.609 a	6.399 a	1.042 b
MAR 20#24 pl 6	5.704 c	23.611 a	19.196 a	8.532 a	2.431 b
MAR 20#24 pl 7	8.780 c	31.646 a	17.262 a	5.704 a	1.984 b
MAR 20#34	5.605 c	41.815 a	37.499 a	13.492 a	3.423 a
MAR 20#34 F2	5.952 c	54.166 a	58.382 a	14.930 a	4.216 a
MAR 20#39	8.482 b	36.607 a	28.323 a	10.565 a	2.331 b
MAR 20#39 pl 1	11.954 b	49.156 a	42.162 a	10.516 a	694 b
MAR 20#39 pl 2	27.976 a	85.713 a	45.585 a	13.889 a	2.827 a
MAR 20#41	6.796 c	51.487 a	54.860 a	21.279 a	3.175 a
MAR 20#41 pl 1	3.621 c	34.523 a	22.371 a	5.307 a	942 b
MAR 20#41 pl 2	2.083 c	30.704 a	25.545 a	11.855 a	2.629 b
MAR 20#44	16.766 b	51.091 a	29.166 a	9.077 a	2.232 a
MAR 20#46	11.111 b	39.930 a	28.819 a	8.036 a	1.240 b
MAR 20#46 pl 1	5.803 c	24.702 a	22.817 a	6.399 a	1.736 b
MSCA	6.052 c	45.783 a	29.910 a	12.549 a	2.877 a
MSCA pl 1	5.010 c	39.930 a	20.436 a	8.284 a	843 b
Rosa Claro	3.720 c	36.507 a	43.997 a	14.831 a	3.522 a
Rosa Claro pl 1	5.555 c	32.242 a	27.331 a	11.061 a	3.522 a
Rosa Intenso	3.373 c	27.529 a	31.994 a	14.633 a	4.117 a
Rosa Intenso pl 1	4.811 c	37.748 a	39.434 a	12.450 a	2.579 a
Rosa Intenso pl 2	2.629 c	18.700 a	25.000 a	13.839 a	4.167 a
Rubi Gigante	1.984 c	23.065 a	18.254 a	6.498 a	1.190 b

Note. Means followed by the same letters in the columms do not differ from each other by Tukey's test at the 5% level.

Table 3. Fruit yield (kg/ha) according to the classification of the equatorial fruit diameter of 48 genotypes of sour passion fruit cultivated at Fazenda Água Limpa, University of Brasília. Brasilia, DF, Brazil, 2016

Genotype	1[a]	1B	1A	2A	3A
AP1	262.149 c	1883.209 a	2838.751 a	1515.108 a	313.24 b
AR 2	486.849 c	3866.763 a	3864.779 a	2053.792 a	602.323 a
AR 2 pl 1	245.532 c	3992.257 a	5847.639 a	2658.198 a	687.491 a
EC3-0	386.9 c	3726.14 a	3682.986 a	1981.868 a	531.987 a
EC3-0 pl 1	385.411 c	3398.019 a	6045.751 a	3607.838 a	1078.358 a
ECL 7	293.647 c	2050.071 a	3513.345 a	3477.879 a	716.508 a
ECL 7 pl 1	337.545 c	3727.876 a	4280.001 a	2590.739 a	608.127 b
ECL 7 pl 2	575.935 b	4360.804 a	4099.696 a	2950.605 a	1021.067 a
ECRAM pl 3	167.408 c	2977.39 a	4043.844 a	2051.559 a	659.713 a
FB 200	681.538 b	3548.811 a	4103.615 a	2135.14 a	507.93 b
FB 200 pl 1	461.303 c	1534.453 a	2007.661 a	770.079 a	169.889 b
Gigante amarelo	245.284 c	2928.532 a	5488.269 a	3047.33 a	1244.924 a
Gigante amarelo pl 1	355.948 c	4884.457 a	7037.603 a	2921.091 a	1384.158 a
MAR 20#10	300.839 c	2149.921 a	2971.587 a	1648.787 a	358.626 b
MAR 20#100	359.37 c	2842.719 a	2946.389 a	1030.492 a	119.294 b
MAR 20#12	538.435 b	3526.49 a	3959.024 a	2752.691 a	379.955 b
MAR 20#15	414.33 c	3349.161 a	2856.856 a	1722.695 a	218.003 b
MAR 20#2005	241.564 c	3576.836 a	5174.037 a	3450.598 a	948.34 a
MAR 20#2005 pl 1	389.38 c	3509.377 a	3922.07 a	2856.856 a	832.826 a
MAR 20#21	311.008 c	1689.957 a	2071.896 a	1356.876 a	565.717 b
MAR 20#24	638.335 b	3938.19 a	5443.874 a	2412.666 a	371.275 b
MAR 20#24 pl 1	380.947 c	2578.586 a	2968.462 a	1415.407 a	521.818 b
MAR 20#24 pl 2	102.677 c	1731.623 a	2308.5 a	1338.771 a	401.036 b
MAR 20#34 F2 pl 1	98.957 c	411.205 a	540.915 a	403.764 a	181.545 b
MAR 20#24 pl 3	228.42 c	2965.485 a	4165.618 a	1789.906 a	438.982 b
MAR 20#24 pl 4	524.794 b	5160.694 a	5641.044 a	2721.937 a	719.732 a
MAR 20#24 pl 5	170.385 c	2350.414 a	2401.753 a	1348.444 a	309.272 b
MAR 20#24 pl 6	336.553 c	2125.219 a	2538.21 a	1776.018 a	687.987 a
MAR 20#24 pl 7	403.02 c	1907.216 a	2175.814 a	1090.015 a	562.492 b
MAR 20#34	280.006 c	3481.847 a	4432.975 a	2512.515 a	692.699 a
MAR 20#34 F2	278.27 c	4536.892 a	7414.334 a	3003.679 a	1138.377 a
MAR 20#39	425.589 c	2868.017 a	3233.339 a	1982.116 a	556.54 b
MAR 20#39 pl 1	682.282 b	3866.763 a	5327.06 a	2134.544 a	238.092 b
MAR 20#39 pl 2	1317.69 a	6846.335 a	5745.954 a	2769.556 a	725.536 a
MAR 20#41	322.664 c	4393.045 a	7261.558 a	4298.801 a	882.925 a
MAR 20#41 pl 1	195.434 c	2905.218 a	2963.997 a	1108.616 a	284.222 b
MAR 20#41 pl 2	125.246 c	2705.767 a	3420.092 a	2337.964 a	714.772 a
MAR 20#44	1043.835 a	4055.5 a	3645.04 a	1747 a	630.448 b
MAR 20#46	551.828 b	3520.289 a	3789.135 a	1697.15 a	305.551 b
MAR 20#46 pl 1	268.102 c	1906.72 a	2821.638 a	1242.543 a	477.672 b
MSCA	390.372 c	3563.195 a	3661.161 a	2504.331 a	788.432 a
MSCA pl 1	269.838 c	3042.022 a	2599.816 a	1437.48 a	203.37 b
Rosa Claro	196.922 c	3077.091 a	5267.041 a	2949.613 a	949.144 a
Rosa Claro pl 1	258.925 c	2784.932 a	3774.254 a	2282.707 a	953.856 a
Rosa Intenso	155.504 c	2139.604 a	4030.947 a	2672.98 a	1029.5 a
Rosa Intenso pl 1	342.009 c	3130.166 a	5342.189 a	2867.769 a	722.708 a
Rosa Intenso pl 2	176.585 c	1655.235 a	3369.25 a	2800.805 a	1175.083 a
Rubi Gigante	100.941 c	2003.693 a	2407.209 a	1237.086 a	283.478 b

Note. Means followed by the same letters in the columms do not differ from each other by Tukey's test at the 5% level.

Table 4. Average fruit weight (g/fruit) according to the classification of the equatorial fruit diameter of 48 genotypes of sour passion fruit cultivated at Fazenda Água Limpa, University of Brasília. Brasilia, DF, Brazil, 2016

Genotype	1st	1B	1A	2A	3A	TOTAL
AP1	113.59 a	167.16 a	242.56 a	354.66 b	479.16 a	224.70 a
AR 2	94.74 a	175.59 a	252.48 a	378.96 b	498.51 a	222.22 a
AR 2 pl 1	104.66 a	172.62 a	258.43 a	378.96 b	533.72 a	242.06 a
EC3-0	105.16 a	170.63 a	254.96 a	413.68 b	629.95 a	226.19 a
EC3-0 pl 1	96.23 a	171.62 a	241.07 a	368.05 b	518.84 a	243.05 a
ECL 7	85.32 a	164.68 a	283.23 a	1687.48 a	508.92 a	330.35 a
ECL 7 pl 1	106.15 a	176.58 a	261.90 a	413.19 b	528.27 a	239.08 a
ECL 7 pl 2	100.69 a	158.73 a	275.29 a	419.64 b	533.72 a	225.69 a
ECRAM pl 3	85.81 a	160.22 a	253.47 a	410.71 b	680.55 a	237.10 a
FB 200	117.06 a	160.22 a	240.08 a	383.43 b	519.83 a	214.28 a
FB 200 pl 1	147.82 a	174.10 a	243.05 a	381.44 b	471.72 a	228.17 a
Gigante amarelo	125.49 a	177.58 a	257.93 a	380.95 b	511.40 a	257.44 a
Gigante amarelo pl 1	118.55 a	181.05 a	261.90 a	397.81 b	567.45 a	245.04 a
MAR 20#10	98.21 a	152.78 a	263.89 a	436.50 b	517.35 a	228.17 a
MAR 20#100	103.17 a	192.46 a	245.04 a	404.76 b	525.29 a	214.28 a
MAR 20#12	122.02 a	170.14 a	242.06 a	398.31 b	538.68 a	232.64 a
MAR 20#15	98.21 a	157.24 a	247.02 a	393.35 b	543.15 a	199.40 a
MAR 20#2005	112.10 a	165.67 a	252.48 a	382.44 b	500.49 a	242.06 a
MAR 20#2005 pl 1	124.50 a	173.11 a	254.96 a	407.24 b	621.52 a	247.02 a
MAR 20#21	111.11 a	179.56 a	280.75 a	377.97 b	565.96 a	231.15 a
MAR 20#24	115.08 a	176.09 a	270.83 a	442.45 b	629.95 a	234.12 a
MAR 20#24 pl 1	113.59 a	181.55 a	261.41 a	395.83 b	513.88 a	229.16 a
MAR 20#24 pl 2	113.59 a	193.45 a	281.74 a	423.11 b	542.65 a	273.31 a
MAR 20#34 F2 pl 1	204.86 a	192.46 a	271.33 a	449.40 b	526.78 a	286.21 a
MAR 20#24 pl 3	104.17 a	182.54 a	276.29 a	402.28 b	532.73 a	251.48 a
MAR 20#24 pl 4	110.61 a	176.09 a	259.42 a	401.28 b	577.37 a	231.64 a
MAR 20#24 pl 5	83.33 a	143.35 a	270.33 a	404.76 b	519.83 a	206.84 a
MAR 20#24 pl 6	107.14 a	199.40 a	250.49 a	408.72 b	533.23 a	256.44 a
MAR 20#24 pl 7	90.77 a	136.90 a	240.57 a	373.01 b	538.19 a	207.34 a
MAR 20#34	97.22 a	169.14 a	239.08 a	377.97 b	456.84 a	230.16 a
MAR 20#34 F2	99.21 a	163.69 a	249.00 a	386.90 b	534.22 a	246.52 a
MAR 20#39	97.22 a	159.22 a	224.70 a	359.62 b	496.03 a	208.33 a
MAR 20#39 pl 1	109.13 a	155.26 a	250.00 a	414.68 b	739.57 a	211.31 a
MAR 20#39 pl 2	91.76 a	159.72 a	250.00 a	396.32 b	506.44 a	196.92 a
MAR 20#41	98.71 a	172.12 a	260.41 a	396.82 b	555.05 a	251.48 a
MAR 20#41 pl 1	111.11 a	170.14 a	270.83 a	394.34 b	520.83 a	226.68 a
MAR 20#41 pl 2	72.42 a	169.64 a	269.84 a	395.83 b	543.15 a	249.50 a
MAR 20#44	125.00 a	160.71 a	249.50 a	397.81 b	561.50 a	207.34 a
MAR 20#46	95.73 a	174.10 a	266.37 a	411.20 b	517.35 a	215.77 a
MAR 20#46 pl 1	85.32 a	157.74 a	254.46 a	396.82 b	554.06 a	223.71 a
MSCA	137.89 a	155.26 a	238.09 a	396.82 b	556.54 a	227.18 a
MSCA pl 1	107.14 a	155.75 a	257.93 a	356.15 b	487.10 a	208.83 a
Rosa Claro	102.18 a	166.66 a	240.57 a	394.84 b	525.79 a	241.56 a
Rosa Claro pl 1	80.85 a	173.11 a	271.33 a	407.24 b	561.50 a	249.50 a
Rosa Intenso	92.26 a	153.27 a	252.97 a	369.54 b	524.30 a	242.06 a
Rosa Intenso pl 1	139.38 a	162.20 a	266.37 a	453.86 b	560.01 a	253.96 a
Rosa Intenso pl 2	134.42 a	176.09 a	259.92 a	417.16 b	566.96 a	261.41 a
Rubi Gigante	72.42 a	129.96 a	199.90 a	291.17 b	357.63 a	172.62 a

Note. Means followed by the same letters in the columms do not differ from each other by Tukey's test at the 5% level.

Table 5. Estimates of broad-sense heritability (ha^2), coefficient of genetic variation (CVg) and ratio between genetic and environmental coefficient and variation (CVg/CVe), of 48 passion fruit genotypes in field. Brasilia, DF, Brazil, 2016

Genetic Parameters	NF 1[a]	NF 1B	NF 1A	NF 2A	NF 3A	TOTAL NF
ha^2 (average family)	72.56%	36.31%	20.29%	23.11%	36.32%	28.69%
Cvg	54.89%	21.80%	16.87%	17.85%	30.49%	17.92%
CVg/CVe	0.813	0.378	0.256	0.274	0.378	0.317
Genetic Parameters	P 1[a]	P 1B	P 1A	P 2A	P 3A	TOTAL P
ha^2 (average family)	68.91%	37.28%	20.01%	27.49%	36.88%	24.98%
Cvg	51.13%	22.01%	16.64%	19.81%	30.50%	16.60%
CVg/CVe	0.744	0.386	0.250	0.308	0.382	0.289
Genetic Parameters	AW 1[a]	AW 1B	AW 1A	AW 2A	AW 3A	TOTAL AW
ha^2 (average family)	46.05%	23.78%	12.94%	*	6.81%	49.04%
Cvg	13.46%	4.03%	1.86	*	2.46%	7.02%
CVg/CVe	0.462	0.279	0.193	*	0.135	0.491

Note. NF: Number of fruits, P: Productivity (yield), AW: Average weight, 1[a]: first fruits, 1B: 1B fruits, 1A: 1A fruits, 2A: 2A fruits, 3A: 3A fruit.

It is important to emphasize that no induded pollination was undertaken in the passion fruit flowers in this study. Therefore, only natural crosses occurred, resulting in natural hybridization in the field (half-sib family).

The heritability observed for estimated total yield was low (24.98%), as well as the CVg/CVe ratio which was 0.289, well below 1, which reflects an unfavorable condition for selection, since the genetic variance was lower than the environmental variance. According to Alves (2004), these values indicate that the use of simple improvement methods will not provide significant gains during the selection process. The breeding methods based on the performance of families are more suitable than those based on the performance of individual plants.

Considering the number of fruits, the values of heritability and the CVg/CVe ratio were 28.69% and 0.317, respectively, and for total average mass the values were 49.04% (heritability) and 0.491 (CVg/CVe ratio) (Table 5), which are considered as low, as occurred for total yield.

Among the classes, the number of fruits and yield of 1st fruits showed medium to high heritability values (72.56% and 68.91%, respectively). Furthermore, in fruits classified as First, the CVg/CVe ratio values for these characteristics were close to 1. These results indicate favorable conditions for future selections and that simple methods of genetic improvement, such as mass selection, could be used for the achievement of superior materials (Vencovsky, 1987).

Pio Viana et al. (2003), studying 20 passion fruits genotypes in two locations in Rio de Janeiro, observed heritability values for fruit weight between 39.18% and 80.42%. These heritability values indicate differences between the locations, suggesting that the environment has an influence on heritability values for this trait.

According to the data evaluated, there was a positive and very strong phenotypic correlation between the response variables estimated yield and number of fruits (rf = 0.96) (Table 7). The variables estimated yield and number of fruits for categories 1B, 1A and 2A also showed positive strong and very strong phenotypic correlations (1B, rf = 0.82; 1A, rf = 0.95; 2A, rf = 0.87). A similar result was observed by Vilela (2013), working with 32 genotypes, who observed very strong phenotypic correlations between estimated yield and number of fruits of all categories (1st, rf = 0.98; 1B, rf = 0.96; 2A, rf = 0.82; 3A, rf = 1.00). Values of this magnitude indicate that these parameters are directly related to the increase in the amount of fruits, and yield observed in the experimental field. Gonçalves (2011) also observed a strong positive correlation between the number of fruits and the estimated yield (rf = 0.88).

Strong positive correlations were observed between the estimated total yield and the estimated total productivity of fruits classified as 1B (rf = 0.87), 1A (rf = 0.95) and as 2A (rf = 0.86). In addition, the estimated total yield was also positively and strongly correlated with the total number of fruits classified as 1B, 1A and 2A (rf = 0.82, 0.95 and 0.87 respectively).

Simple correlations are frequent in long-cycle plants, especially in native species (Degenhardt et al., 2005). This knowledge is useful, especially when the selection of a character is dificult, due to its low heritability or difficulty to measure or to identify (Falconer, 1987). These analyzes are considered sufficient to identify relationships between characters of economic importance for crops in some cases.

In this study, it is observed that in all fruit categories, the estimated total yield showed a higher phenotypic correlation with the number of fruits than with the fruit mass, indicating that for the achievement of high yields necessarily involves the selection of plants with a large number of fruits. Morgado et al. (2010) also observed that the estimated total yield was more correlated with the number of fruits (rf = 0.92) than with the fruit mass (rf = 0.54). Negative and significant correlations were observed between the parameters 1st fruit yield and average total mass (rf = -0.50), 1B fruit yield and total average mass (rf = -0.36), number of 1B fruits and average total mass (rf = -0.42) and average mass of fruits 1A with number of fruits 1B and total number of fruits (both rf = -0.31). Pimentel et al. (2008), studying 111 passion fruit genotypes, observed a negative correlation between the number of fruits and the average fruit mass (rf = -0.62). These results indicate that the greater the amount of fruits, the smaller the individual mass of the evaluated fruits. Moreover, the increase in the number of fruits entails to a reduction in their size. The negative correlation between number of fruits and average fruit weight is an indication that the excessive amount of fruits can lead to the production of fruits with smaller mass, with less commercial value, as occurs with other crops (Scarpare Filho et al., 2000).

Table 6. Estimates of phenotypic correlation values between characters of 48 passion fruit genotypes cultivated at Fazenda Água Limpa. Brasilia, DF, Brazil, 2016.

	P st	P 1B	P 1^a	P 2A	P 3A	TP	NF 1st	NF 1B	NF 1A	NF 2A	NF 3A	TNF	AW 1st	AW 1B	AW 1A	AW 2A	AW 3A	TAW
P st	1	0.65*	0.25	0.11	-0.05	0.41*	0.97*	0.68*	0.27	0.11	-0.06	0.58*	-0.04	-0.24	-0.29*	-0.04	0.14	-0.50*
P 1B		1	0.76*	0.56*	0.33*	0.87*	0.68*	0.97*	0.76*	0.58*	0.32*	0.94*	-0.28	-0.18	-0.20	-0.14	0.19	-0.36*
P 1^a			1	0.82*	0.63*	0.95*	0.27	0.70*	0.99*	0.83*	0.62*	0.89*	-0.24	-0.11	-0.15	-0.04	0.22	0.02
P 2^a				1	0.76*	0.86*	0.15	0.51*	0.80*	0.98*	0.74*	0.74*	-0.24	-0.14	-0.08	0.22	0.12	0.29*
P 3^a					1	0.65*	-0.03	0.28	0.62*	0.77*	0.98*	0.52*	-0.15	-0.07	-0.05	0.02	0.04	0.31*
TP						1	0.44*	0.82*	0.95*	0.87*	0.64*	0.96*	-0.27	-0.16	-0.17	-0.01	0.20	-0.04
NF 1st							1	0.72*	0.29*	0.14	-0.03	0.61*	-0.18	-0.28*	-0.25	-0.00	0.11	-0.50*
NF 1B								1	0.70*	0.53*	0.26	0.93*	-0.31*	-0.30*	-0.22	-0.15	0.20	-0.42*
NF 1A									1	0.83*	0.62*	0.90*	-0.24	-0.14	-0.25	-0.07	0.21	-0.01
NF 2A										1	0.77*	0.76*	-0.24	-0.14	-0.18	0.07	0.08	0.20
NF 3A											1	0.51*	-0.17	-0.07	-0.08	0.02	-0.04	0.29*
TNF												1	-0.31*	-0.27	-0.29	-0.09	0.20	-0.25
AW 1st													1	0.41*	0.04	-0.12	-0.03	0.26
AW 1B														1	0.36*	-0.02	-0.12	0.47*
AW 1A															1	0.35*	0.1	0.52*
AW 2A																1	-0.04	0.62*
AW 3A																	1	-0.03
TAW																		1

Note. P: Productivity (yield), NF: Number of fruits, AW: Average weight, 1^a: first fruits, 1B: 1B fruits, 1A: 1A fruits, 2A: 2A fruits, 3A: 3A fruit.

*Significant at 5% probability.

4. Conclusion

The genotypes MAR 20#41, MAR 20#41 pl 1, Gigante Amarelo pl 1 and MAR 20#39 stood out with the highest estimated fruit yields and also the highest number of fruits.

MAR20#24 pl 3 showed the lowest fruit yield, and also the lowest amount of fruits.

For industrial purposes, the highest yield and the highest amount of first fruits per area occurred in the genotype MAR 20#39 pl 2, while the lowest values of these parameters were observed in the Rubi Gigante genotype.

High values of heritability were observed for the total number of fruits per area in the first classification.

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