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Anticipated selection for intrapopulation breeding of passion fruit

Natan Ramos Cavalcante[1*], Willian Krause[2], Alexandre Pio Viana[3], Celice Alexandre Silva[2], Keithi Karla Xavier Porto[1] and Roberto Antonio Savelli Martinez[1]

*[1]Universidade do Estado de Mato Grosso, Rod. MT-358, Km 7, Jardim Aeroporto, 78300-000, Tangará da Serra, Mato Grosso, Brazil. [2]Programa de Pós-graduação em Genética e Melhoramento de Plantas, Universidade do Estado de Mato Grosso, Tangará da Serra, Mato Grosso, Brazil. [3]Programa de Pós-graduação em Genética e Melhoramento de Plantas, Universidade Estadual do Norte Fluminense, Campos dos Goytacazes, Rio de Janeiro, Brazil. *Author for correspondence. E-mail: natancavalcante2@hotmail.com*

ABSTRACT. The aim of this work was to verify the efficiency of the anticipated selection of superior plants in intrapopulation breeding of passion fruit. The experiment was conducted at the Mato Grosso State University experimental area. Eight populations were evaluated. Planting was carried out in August 2010 following the randomized blocks experimental design, with ten repeats and ten plants per plot. The production characteristics of mass and number of fruits were evaluated from data obtained from two cultivation periods, the first year and the full two-year cycle of culture. Estimates of genetic parameters indicate the possibility of selection gains. The accuracies of fruit production, fruit number and fruit mass characteristics had high magnitude, independent of the selection cycle. Coincidence index estimates were high for all characteristics. Based on the results, early selection (first year) was efficient and reduced the time of selection for the best plants and can be used for passion fruit breeding.

Keywords: selection gain, *Passiflora edulis* Sims, productivity.

Seleção antecipada no melhoramento intrapopulacional do maracujazeiro azedo

RESUMO. Este trabalho tem como objetivo verificar a eficiência da seleção antecipada de plantas superiores no melhoramento intrapopulacional do maracujazeiro azedo. O experimento foi conduzido na área experimental da Universidade do Estado de Mato Grosso. Foram avaliadas oito populações e o plantio foi realizado em agosto de 2010, com delineamento experimental em blocos ao acaso, dez repetições e dez plantas por parcela. As características de produção, massa e número de frutos foram avaliadas a partir de dados obtidos em dois períodos de cultivo, sendo no primeiro ano e no ciclo completo da cultura, que nesse caso foi de dois anos. As estimativas dos parâmetros genéticos indicam a possibilidade de ganhos com a seleção. Os valores de acurácia para as características de produção de frutos, número de frutos e massa de frutos foram de alta magnitude, independente do ciclo de seleção. As estimativas do índice de coincidência foram altas para todas as características. Baseado nos resultados, a seleção antecipada (primeiro ano) se mostrou eficiente por reduzir o tempo de seleção das melhores plantas, podendo ser utilizada no melhoramento do maracujazeiro azedo.

Palavras-chave: ganho de seleção, *Passiflora edulis* Sims, produtividade.

Introduction

The passion fruit originated in Tropical America and currently has more than 150 native species in Brazil, including the most commercially important, the sour passion fruit (*Passiflora edulis* Sims). It represents 95% of the country's orchards and is the most widely planted species in the world (Araújo et al., 2006; Bernacci, Soares-Scott, Junqueira, Passos, & Meletti, 2008; Meletti, 2011).

However, the sour passion fruit crop in Brazil has low productivity due to phytosanitary problems, inadequate farming techniques and low use of bred cultivars. The small number of cultivars and commercial hybrids available hinders the access of producers to high-agronomic quality propagation materials (Gonçalves, Viana, Bezerra Neto, Pereira, & Pereira, 2007).

Therefore, genetic breeding programs have emerged as basic tools in the search for productive genotypes, providing greater competitiveness in the domestic market (Gonçalves et al., 2008). Various methods of genetic breeding for plants exist, including intrapopulation recurrent selection that allows the accumulation of favorable alleles at each selection cycle, thus obtaining real profits for the improved characters (Silva, Ramalho, & Abreu, 2007).

To help the breeder in the work of obtaining and selecting superior genotypes, estimates of genetic parameters, such as heritability, are very useful in the planning of breeding programs (Sebbenn, Vilas Boas, Max, 2008a; 2008b; Rosado, Rosado, Resende, Bhering, & Cruz, 2009; Miranda et al., 2013).

One of the steps of recurrent intrapopulation selection is the evaluation of progeny for a certain period in the field. Thus, alternatives to reduce the time to complete a bred generation are needed, and it is advantageous for breeding programs to practice superior genotype selection based on the initial year of production. One of the alternatives is the use of early selection (Massaro, Bonine, Scarpinati, & Paula, 2010). In the case of perennial and semi-perennial species, the number of years to complete a selective cycle is the main obstacle for breeding programs (Rezende, Bertolucci, & Ramalho, 1994). In this case, as the sour passion fruit has a two-year cycle, early selection plays a relevant role.

Thus, the aim of this study was to evaluate the efficiency of early selection in intrapopulation breeding of the sour passion fruit to reduce the evaluation time of the plants in the field.

Material and methods

The experiment was conducted at the Universidade do Estado de Mato Grosso, located in the municipality of the city of Tangará da Serra, Mato Grosso State, at 14º37'10"S and 57º29'09"W and an altitude of 321 m. The regional climate, is classification, as an Aw, a tropical humid megathermal, with two distinct seasons: a rainy season from October to March and a dry season from April to September. The annual rainfall average varies from 1300 to 2000 mm year^{-1}, and the annual temperature varies from 16 to 36°C (Martins et al., 2010).

The soil is classified as Distroferric Red Latossoil, with a clay content above 40%, varying from light undulation to plain landscape. Liming and fertilization were made according to soil analysis, following the recommendations of Borges, Caldas, and Lima (2006).

The studied populations were composed of eight crossings between the commercial cultivars: BRS Gigante Amarelo x BRS Rubi do Cerrado, BRS Sol do Cerrado x BRS Rubi do Cerrado, BRS Ouro Vermelho x BRS Rubi do Cerrado, FB 100 x BRS Rubi do Cerrado, FB 200 x BRS Rubi do Cerrado, IAC 275 x BRS Rubi do Cerrado, IAC 275 x BRS Sol do Cerrado and IAC 275 x BRS Ouro Vermelho. The experimental design was a randomized block with ten replications and ten plants per plot. Planting was carried out in August 2010, with a spacing of 4.0 m between plants and 3.5 m between planting lines to enable machinery mobilization within the experiment. The conduction system of plants was with a vertical support, in stakes of 2.5 m, spaced of 6.0 m and with a flat wire number 12, 2.0 m above the ground. Cropping practices, such as irrigation, fertilization, pruning, pests and disease control, followed the recommended procedures for the passion fruit plant.

All plants were evaluated within each plot, with fruit harvested weekly. The features, fruit production and fruit number were obtained by the sum of the total harvests during the experiment. Fruit mass was obtained by directly weighing the fruits with the aid of a Marte brand (model MS 30 k1 model) digital scale. The arithmetic mean of the total weight of the fruits compared to the total number of fruits was calculated. Analyses of predictive genetic gains and the estimation of variance components by residual maximum likelihood (REML)- best linear unbiased prediction (BLUP) were performed using the genetic statistical software Selegen-Computarized Genetic Selection, as outlined by Resende (2016). The model used was as follows: $y = Xr + Zg + Wp + \varepsilon$; where: y is the data vector; r is the vector of repetition effects (assumed to be fixed) added to the overall average; g is the vector of genotypic individual effects (assumed to be random); p is the vector of plot effects; and ε is the vector of errors or residues (random). X, Z and W are matrices of known incidence formed by 0 and 1 values, which associate r, g and p nonentities to the y data vector, respectively. This model enables evaluation of full siblings with multiple observations per plot assessed in one place in a randomized block design, with several plants per plot.

To evaluate the efficiency of early selection, the following methodologies were used: estimates of genetic parameters, individual heritability in the narrow sense (h^2_a %), selection gain in percentage GS (%), annual average selection gain in percentage ($GS_{annual\ average}$), accuracy ($r_{\hat{a}a}$) and coincidence index.

Estimates of individual heritability in the narrow sense were obtained by dividing additive genetic variance by phenotypic variance, of which the results are interpreted as heritability of high magnitude ($h^2_a \geq 0.50$), heritability of average magnitude ($0.15 \leq h^2_a < 0.50$) and heritability of low magnitude ($h^2_a < 0.15$) (Resende, 2002). To estimate the values of accuracy, the square root of the individual heritability in the narrow sense was calculated and classified according to the following magnitudes: high accuracy (râa ≥ 0.70), medium or moderate (0.40 ≤ râa < 0.70) and low (râa < 0.40) (Resende, 2002).

From the linear mixed model methodology, REML/BLUP, the top 30 plants were selected, and selection gains were estimated as percentages by $GS\,\% = \frac{GS}{MO} \times 100$, in which GS is the selection gain, and MO is the original average. The annual genetic gain in percentage was estimated by $GS_{\text{annual average}} = \frac{GS}{a}$, where GS is the selection gain, and a is the number of years by selection cycle (Cruz & Carneiro, 2003).

All analyses of the characteristics described above were made from data obtained during the two periods of cultivation, the first year of cultivation and the complete cycle of the sour passion fruit crop.

The coincidence level of 30 selected plants was evaluated in the first year of cultivation with plants selected in the full cycle of the crop for the evaluated characteristics. To estimate the coincidence index, the method of Hamblin and Zimmermann (1986) was used: $IC = \frac{A\text{-}C}{B\text{-}C} \times 100$, where A is the number of plants that coincide in both selection seasons, B is the number of selected plants, in this case 30, and C is the number of random coincidences assigned-in this case, 10% of B.

Results and discussion

Among the most important genetic parameters for the selection of plants is the variance component, especially the genotypic variance (Cruz & Carneiro, 2003). The estimated value of the genetic variance for the fruit production characteristic was 4.19 during the first year of cultivation and 5.99 for the full cycle of the crop (Table 1). For the fruit number characteristic, the genetic variance for the first year of cultivation was 121.63, and for the complete cycle, was 149.81, values that indicate the possibility of obtaining gains from the practice of selection.

For the fruit mass feature, the highest values obtained were 242.23 for the first cultivation year and 218.99 for the complete crop cycle. Knowledge of genotypic variance is very important in the breeding program for indicating the extent of genetic variation of a character (Cruz & Carneiro, 2006).

The estimated individual phenotypic variance was smaller for the fruit production characteristic in the first selection cycle (37.04) than in the complete cycle (42.16) (Table 1). Higher values for the number of fruits were found in the full cycle than in the first year of cultivation (1,598.08 compared with 1,441.43). The value of phenotypic variance for fruit mass was higher for selection in the first year than for selection in the whole cycle (530.98 and 502.19, respectively). Silva and Viana (2012) evaluated 140 full-sib progenies of sour passion fruit from the second recurrent selection cycle in the Norte Fluminense and obtained phenotypic variance estimates of 1,789.00 and 328.25 for the number and weight of fruits, respectively.

The average heritability (h^2m) for fruit production characteristics, fruit number and fruit mass was high both in the first year of cultivation and for the full cycle. Oliveira et al. (2008) evaluated 16 progenies of half-siblings and observed that the values of the estimates of heritability coefficients in the narrow sense (h^2m) varied from 0.11 to 0.57 and that the highest heritability was found in number of fruits per plant (0.54) and fruit weight (0.57). Silva, Viana, Amaral Júnior, Gonçalves, & Reis (2012) evaluated 140 full sibling families and obtained heritability based on progeny averages of 39.19% for the characteristic fruit number, 28.04% for production and 71.38% for fruit mass.

The determination coefficient of the environmental effects between plots (c^2parc) quantifies the variability within the blocks. Thus, the higher the coefficient, the higher the environmental variability between plots. For all features and periods of cultivation, low environmental variability was found (less than 1%) (Table 1), verifying good experimental precision in relation to the data analysis. According to Farias Neto et al. (2008), good perennial plant experiments have coefficient values of approximately 10%.

Table 1. Estimates of genetic parameters of the population for the characteristics of fruit yield, fruit number and fruit mass in the population of sour passion fruit for the first year of cultivation and the complete cycle of the crop. Tangará da Serra, Mato Grosso State, 2016.

Parameters	Cropping period	Fruit production	Number of fruits	Mass of fruits
Vg	First year	4.19	121.63	242.23
	Complete cycle	5.99	149.81	218.99
Vf	First year	37.04	1,441.43	530.98
	Complete cycle	42.16	1,598.08	502.19
h^2m	First year	0.9255	0.8956	0.9829
	Complete cycle	0.9411	0.8967	0.9803
c^2parc	First year	0.0027	0.0075	0.0275
	Complete cycle	0.0035	0.0192	0.0344
Acprog	First year	0.9620	0.9463	0.9914
	Complete cycle	0.9701	0.9469	0.9901

Vg: genetic variance; Vf: individual phenotypic variance; h^2m: average heritability of progeny; c2parc: determination coefficient of plot effects; Acprog: accuracy of progeny selection.

Accuracy (Acprog) refers to the correlation between the true genotypic value of the analyzed material and the estimated or predicted one (Resende, 2002). The accuracies obtained were of high magnitude, ranging from 0.94 to 0.99, for all features and cropping periods, indicating reliability in the selection.

Based on estimates of genetic parameters, the effectiveness of selection in the first year can be observed compared to the full cycle of the crop. Therefore, our results suggest that early selection is another tool for genetic breeding of the sour passion fruit.

Table 2 shows that individual heritability in the narrow sense had an average magnitude for the production characteristics and the number of fruits in the two cropping periods. However, the fruit mass showed high heritability for the two cropping periods. The average and high magnitude heritability indicates favorable situation to improve this feature and to use simpler breeding methods (Viana et al., 2004).

Table 2. Estimated parameters for the characteristics of fruit yield, fruit number and fruit mass in 30 sour passion fruit plants for the first year of cultivation and the complete cycle of the crop. Tangará da Serra, Mato Grosso State, 2016.

Parameters	Cropping period	Fruit production	Number of fruits	Mass of fruits
h_a^2 (%)	First year	22.65	16.87	91.24
	Complete cycle	28.45	18.74	87.21
GS (%)	First year	12.59	9.51	29.79
	Complete cycle	15.74	9.39	27.55
GS (%)	First year	12.59	9.51	29.79
	Complete cycle	7.87	4.70	13.78
Râa	First year	0.47	0.41	0.95
	Complete cycle	0.53	0.43	0.93

h_a^2 %: individual heritability in the narrow sense; GS (%): selection gain in percentage; GS annual average: annual selection gain in percentage; and râa: accuracy.

Silva, Munõz, Vincent, and Viana (2015) evaluated a population with 81 full sibling families belonging to the third recurrent selection cycle in the Universidade Estadual do Norte Fluminense Darcy Ribeiro. They obtained proportions of narrow heritability for fruit number (41%), production (24%) and fruit mass (14%). The heritability values for the number of fruits and production were classified as average, and for fruit mass, as low. However, estimates of heritability are influenced by many factors, such as the endogamy level of the population and the experimental precision and therefore should not be extrapolated to other populations (Borém & Miranda, 2005; Silva & Viana, 2012).

For the fruit production characteristic, the selection gain was higher in the complete cycle of the crop (15.74%) than in the first cycle (12.59%). However, for the mass and number of fruits, the larger selection gains were in the first cropping year (9.51 and 29.79%, respectively vs. the full cycle values of 9.39 and 27.55%, respectively). Pinto, Resende, Mesquita, Rosado, & Cruz (2014) evaluated early selection for growth traits in clonal trials of *Eucalyptus urophylla* and found that at the age of six years, the selection gain was 39.61% for diameter and 30.86% for height. The prediction gains using early selection was 38.79% for diameter at the age of three years and 29.55% for height, obtaining an early selection efficiency of 97.94% for diameter and 95.73% for height. The authors concluded that early selection can be used efficiently in the breeding of clones because the individual plants identified as superior at early ages were the same as those that would be selected at later ages, as well.

When applying the annual genetic gain for the two periods of cultivation, the gain for the full crop cycle reduces by half, while the gain for the first year of cultivation remains the same. Thus, the annual genetic gain in the first year of cultivation compared to the full cycle is 37.5% higher for the production of fruits, 50.6% higher for the number of fruits and 53.77% higher for fruit mass. These results demonstrate the efficiency of early selection in the first cultivation year. Similar results were found in a study conducted by Rezende et al. (1994) on eucalyptus clones, when it was observed that the gain realized by year increased when the age of selection was decreased. In the same study, early selection was efficient; therefore, the second year of cultivation was the recommended age for the selection of eucalyptus clones.

The accuracy values for both cultivation periods for the production and number of fruits are between 41 and 53% (Table 2). The accuracy aims to inform the correct ordering of genotypes for plant selection purposes. According to Resende (2002), accuracy higher than 50% indicates that there will be a good precision in the selection of genotypes. For fruit weight, the accuracy was of high magnitude for the two periods of cultivation. These results demonstrate that early selection maintained good precision for the plants selected via REML/BLUP. According to Pimentel, Stenzel, Cruz, and Bruckner (2008), evaluating different harvest times found similar accuracy values for fruit mass, indicating a good percentage of success in the selection of this trait.

It was observed that of the 30 plants that were selected in the first cultivation year, 25 were also selected in the full course of the crop for fruit yield and fruit number characteristics, corresponding to a coincidence rate of 81.48% (Table 3). Giordani, Fernandes, Titon, and Santana (2012), evaluating genetic parameters for growth traits in pequizeiro (*Caryocar brasiliense*) at an early stage, noted that the estimation of efficiency of selection performed by the Hamblin and Zimmermann method (1986) is a promising tool and can be used to assist in the early selection of superior plants.

The coincidence index between the cultivation periods was 74.07% for fruit mass. Thus, for all traits, a high coincidence rate between the selected plants in the two cropping periods was observed, demonstrating the efficiency of early selection for the first year of cultivation.

Table 3. Coincidence index according to Hamblin and Zimmermann (1986) of the 30 best plants of sour passion fruit selected based on fruit production characteristics, fruit number and fruit mass at the first year of cultivation for those selected for the complete cycle of culture. Tangará da Serra, Mato Grosso State, 2016.

Evaluated Characteristics	Coincidence Index (%)
Fruit Production	81.48
Numbers of Fruits	81.48
Fruit Mass	74.07

Conclusion

The early selection of sour passion fruit plants in the first cropping year is recommended for the progeny evaluation stage within the intrapopulation recurrent selection method to improve the efficiency of breeding programs by reducing cultivation time and consequently providing lower costs due to hand labor and agricultural inputs.

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