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GENETIC GAINS VIA CLONAL SELECTION IN PASSION FRUIT *Passiflora edulis* Sims

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ABSTRACT

We selected 110 plants from commercial passion fruit (*Passiflora edulis* Sims) plantings in the region of the Triângulo Mineiro, in the State of Minas Gerais, in the year of 1986. These plants were cloned via stem cuttings and their clones grown out in a completely randomized design in a commercial farm in the county of Araguari-MG, during 1987. Horticultural traits were evaluated in 1988. Broad sense heritability estimates (H^2) were obtained for early and total yield, average fruit weight, soluble solids, and percent pulp. Genetic variation among clones for total and early yield and for average fruit weight was indicated by large values of H^2 obtained for these traits. Heritability estimates for soluble solids were moderately high, but subject to considerable genotype x environmental interaction, as indicated by the poor correlations between samplings at different dates. Heritability estimates for percent pulp were lower than for soluble solids, but less subject to interactions with sampling dates. Considering the magnitudes of the estimates of H^2 and of the genetic coefficients of variation, greater genetic progress is expected from direct selection for total and early yield and for average fruit weight than for soluble solids or for percent pulp. By selection of the 24 highest yielding clones, a genetic gain of +29.1% is expected for total yield and +89.2% for early yield, with minor changes in average fruit weight, soluble solids and percent pulp.

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INTRODUCTION

Passion fruit is an important fruit crop in Brazil, both for fresh consumption and for processing. Yellow passion fruit (*Passiflora edulis* Sims f. *flavicarpa* Deneger) is usually the predominant type grown, even though the purple from (*P. edulis* Sims) can also be found (Suzuki and Lins, 1987), as well as populations with various amounts of introgression between these two types.

The species *P. edulis* Sims is highly variable in fruit size, external and internal fruit color, plant size and development, color of leaves, stems and tendrils (Oliveira, 1980; 1987). Cross pollination is favoured by both flower morphology and the occurrence of self-incompatibility (Knight, Jr. and Winters, 1963; Ruggiero, 1973).

Inheritance of a few genetic traits has been studied. Nakasone *et al.* (1967) reported that wilt resistance was controlled by a single locus; tendril color also had monogenic inheritance, with purple being dominant over green; and external fruit color is also under monogenic control, purple being dominant (or partially dominant) over yellow.

Studies on the genetics of quantitative traits have been scarce. Oliveira (1980) reported that purple passion fruit was lower yielding than the yellow form. Plants originated from a Hawaiian hybrid of purple x yellow passion fruit were slightly higher yielding than the Brazilian yellow passion fruit (selection 'Jaboticabal'). On the other hand, the Brazilian yellow passion fruit was a highly variable population, with a few plants outyielding the best Hawaiian plants. Full-sib progeny of selected parents were superior to open pollinated half-sib progeny. Landgraf (1978) reported yields ranging from 2.5 kg/year/plant to 40.0 kg/year/plant among 245 plants under study. Relative contributions of genetic and environmental components were not recorded.

Because passion fruit is a relatively new crop (i.e., of recent domestication), a wide array of genetic variability is still available for exploitation via mass selection (Oliveira, 1987). At a later stage, Oliveira (1987) suggests full-sib hybrids and clonal selection as potentially useful methods for passion fruit improvement.

The objectives of the present study were: 1) to estimate genetic and environmental variances for economic traits in passion fruit; 2) to estimate potential genetic gains from selection of the superior clones; 3) to establish a suitable breeding strategy to maximize genetic gains. For the study, plants were selected, cloned through stem cuttings, and field tested. The results here reported are based on data from the first year's harvest.

MATERIALS AND METHODS

Base populations

The base populations for individual plant selections belonged to commercial orchards located in the region of the Triângulo Mineiro, in the state of Minas Gerais, Brasil. It is estimated that the region holds ca. 700 thousand plants in commercial production, with ca. 300 commercial growers. We sampled nine commercial orchards, varying in size from 870 to 19400 plants each. The total number of plants in these nine orchards was estimated to be 37500. A total of 110 plants were selected in these orchards, on the basis of phenotypic superiority relatively to the orchard mean as observed on the day of sampling. Stem cuttings of these plants were taken to Paulínia-SP and kept in a clonal bank in the experimental farm of the Bioplanta Tecnologia de Plantas S.A.

Field trial

From mother plants maintained at Bioplanta's clonal bank in Paulínia-SP, cuttings were taken for each of the 110 clones. Rooted plants from these cuttings were taken to a commercial farm in the county of Araguari-MG, where they were transplanted to the field in a randomized complete design layout, with 110 treatments and 2 replications. Spacing was 5 m between rows, with 3 m between plants within a row. Each plot comprised 3 plants of the same clone, totaling 15 m of plot length, of which only the middle 5 m was used for data collection. Standard agronomic practices were used throughout the experiment. Artificial irrigation was not provided for, except during transplanting in February 1987.

Data collection

Data collection was made at weekly intervals during a period of 37 weeks, starting in November 11, 1987 and ending in August 8, 1988. Total number of fruit and total yield were recorded on a plot basis at each of the 37 harvests. The accumulated total of the first 10 weeks was considered as *early yield,* whereas the accumulated total of the 37 weeks was considered as *total yield.* The *average fruit weight* per plot was calculated as the ratio between total yield and the total number of fruit (accumulated over 37 weeks). Percent soluble solids (in degrees Brix) and percent pulp on a plot basis were recorded in the 24th. and in the 31st. week (respectively on May 10 and June 28, 1988). We will hereafter refer to BRIX1 and %PULP1 for the readings of the 24th. week, and to BRIX2 and %PULP2 for those of the 31st. week.

Estimation of variance components

The genotypic (V_G) and environmental (V_E) components of variance were estimated by equating the mean squares of the sources of variation in the ANOVA table to their respective expected mean squares, as described by Becker (1984). These estimates of V_G and V_E were used in the estimation of broad sense heritabilities both on a single-plant basis (H^2) and on a clonal mean basis (H^2_m). The standard errors associated with the estimates of V_G, V_E, H^2 and H^2_m were estimated according to Hallauer and Miranda Filho (1981). Genetic coefficients of variation (CV_G) were calculated as the ratio between the genotypic standard deviation and the mean of all clones. Genetic gains obtained by selection of the 24 highest yielding clones were calculated by the formula:

$$GAIN = (Y_{all} - Y_{24}) \times H^2_m$$

where:

Y_{all} = average of all clones tested.
Y_{24} = average of the 24 highest yielding clones.
H^2_m = broad sense heritability on a clonal mean basis.

Genotypic correlations among the traits under consideration were estimated as indicated by Hallauer and Miranda Filho (1981).

RESULTS AND DISCUSSION

The estimates of values of genotypic (V_G) and environmental (V_e) variances, broad-sense heritabilities, and genotypic coefficients of variation for the traits under study are shown in Table I. There is evidence that the passion fruit populations from the region of the Triângulo Mineiro, of which the 110 selected clones are representatives, have considerable genetic variation for yield (early and total), average fruit weight, soluble solids and percent pulp, as indicated by the significant estimates of V_G obtained.

Broad sense heritabilities, both at the single plant (H^2) and clonal mean (H^2_m) levels, and genetic coefficients of variation were high for early and total yield and for average fruit weight, indicating a very favorable condition for selection for these traits. Total yield shows a moderate positive correlation ($r = 0.517$) with early yield (Table II). Selection for greater early yield would also increase total yields. Genotypic correlations between early and total yield, on one hand, and average fruit weight, brix and percent pulp, on the other, were generally low, indicating that genetic gains in yield can be achieved without major changes in the other traits.

Average fruit weight proved to be a highly heritable trait, with broad-sense heritability estimates higher than 0.90. Direct selection for this trait should result in rapid genetic progress. This would be an important selection criterion if improvement is sought for fresh market consumption purposes. For processing purposes, the trait has only limited importance.

Table I - Variance components, broad-sense heritabilities and genetic coefficients of variation of economic traits in passion fruit.

Trait	Variance components[a]		Broad sense heritabilities[b]		Genetic coefficient of variation (%)
	V_G	V_E	H^2	H^2_m	
Early yield (kg/ha)	448169 (±77410)	233402 (±31189)	0.658 (±0.114)	0.793 (±0.137)	98.2
Total yield (ton/ha)	21.433 (±4.052)	15.507 (±2.072)	0.580 (±0.110)	0.734 (±0.139)	25.9
AVG. fruit weight (grams/fruit)	374.46 (±52.46)	32.09 (±4.29)	0.921 (±0.129)	0.959 (±0.134)	22.1
BRIX1[c] (%)	1.5454 (±0.3235)	1.4348 (±0.1953)	0.519 (±0.109)	0.675 (±0.141)	9.0
BRIX2[c,d] (%)	1.4565 (±0.3791)	1.6744 (±0.2615)	0.465 (±0.121)	0.586 (±0.152)	7.9
% PULP1[c]	59.539 (±19.349)	130.050 (±17.697)	0.314 (±0.102)	0.469 (±0.152)	14.0
% PULP2[c,d]	41.411 (±18.543)	112.337 (±17.438)	0.269 (±0.121)	0.376 (±0.169)	12.4

(a) V_G = genotypic variance; V_E = environmental variance.
(b) H^2 = broad sense heritability on a single plot (= single plant) basis; H^2_m = broad sense heritability on a treatment mean basis.
(c) BRIX1, BRIX2 = percent soluble solids in the 24th. and 31st. weekly harvest, respectively; %PULP1, %PULP2 = percent pulp in the 24th. and 31st. weekly harvest, respectively.
(d) Estimates based on data of 104 clones.
(e) Numbers within parenthesis are standard errors of the estimates.

The lower values of broad sense heritabilities and genetic coefficients of variation for BRIX1, BRIX2, %PULP1 and %PULP2 (Table II) indicate that genetic gains for these traits tend to be slower than for yield (early and total) and for fruit size. Genotypic correlation (r = 0.414) between BRIX1 and BRIX2 is low (Table II),

Table II - Genotypic correlations between economic traits in passion fruit.

	Total yield	Early yield	AVG. fruit weight	BRIX1	BRIX2	%PULP1
Early yield	+0.517					
AVG. fruit weight	+0.183	-0.255				
BRIX1[(a)]	-0.124	-0.365	+0.473			
BRIX2[(a)]	-0.124	-0.326	+0.349	+0.414		
%PULP1[(a)]	-0.159	+0.218	-0.258	+0.160	+0.249	
%PULP2[(a)]	-0.354	-0.001	-0.244	+0.737	-0.007	-0.674

[(a)] BRIX1, BRIX2 = percent soluble solids in the 24th. and 31st. weekly harvest, respectively; %PULP1, %PULP2 = percent pulp in the 24th. and 31st. weekly harvest, respectively.

indicating that soluble solids readings in passion fruit are subject to considerable genotype x sampling date interaction. Therefore, soluble solids on a whole season basis, which is ultimately the economically important trait for processors, were not adequately sampled by only a few sampling dates along the season. The genotypic correlation ($r = 0.674$) between readings of different sampling dates was slightly higher for percent pulp (Table II), but indicates that this trait is also subject to considerable genotype x sampling date interaction.

Considering the high genetic gains that can be achieved by mass selection of single plants based on yield, and the low gains expected from selection based on soluble solids and percent pulp under the same conditions, it seems appropriate that the initial phase of a breeding program for passion fruit should place emphasis on selection for higher yields. Selection for higher solids or percent pulp would require a considerable number of sampling dates along the season, and this may prove expensive or impractical in the initial steps of the program.

Table III indicates the expected genetic gains obtained by direct selection of the 24 highest yielding clones, and the indirect genetic gains obtained for early yield, average fruit weight, soluble solids (BRIX1 and BRIX2), and percent pulp (%PULP1 and %PULP2). Since broad-sense heritabilities were used in the calculations, the estimates reflect genetic gains that would be realized by direct utilization of the subset of 24 clones selected, and not those realized from growing plants from the recombinant population from these clones. As expected, a sizeable genetic gain of +29.1% is estimated for total yield. The only other trait indirectly affected was early yield (+89.2%). Average fruit weight, soluble solids, and percent solids remained essentially

Table III - Genetic gain for total yield obtained by selection of the 24 highest yielding passion fruit clones and correlated responses for other traits.

Trait	Population mean	Mean of the 24 highest yielding clones	Selection differential	Genetic gain	% Genetic gain
Total yield (ton/ha)	17.9	25.0	+ 7.1	+ 5.2	+ 29.1
Early yield (kg/ha)	682	1449	+ 767	+ 608	+ 89.2
AVG. fruit weight (grams/fruit)	87.7	85.6	- 2.1	- 2.0	- 2.3
BRIX1 [a]	13.8	13.2	- 0.6	- 0.4	- 2.9
BRIX2 [a]	15.3 [b]	15.1	- 0.2	- 0.1	- 0.8
% PULP1 [a]	55.1	55.7	+ 0.6	+ 0.3	+ 0.5
$ PULP2 [a]	51.9 [b]	50.4	- 1.5	- 0.6	- 1.0

[a] BRIX1, BRIX2 = percent soluble solids in the 24th. and 31st. weekly harvest, respectively; %PULP1, %PULP2 = percent pulp in the 24th. and 31st. weekly harvest, respectively.
[b] Estimates based on data of 104 clones.

unchanged. Therefore, while direct selection for higher total yield will favorably increase early yields and will not bring about improvement in the other traits, it will not however promote any indirect negative response for these traits. The strategy of emphasizing selection for yield in the initial steps of the program and of postponing selection for brix and percent pulp until a later phase appears to be reinforced.

Higher genetic gains could be realized with a higher intensity of selection. In this program, we selected 24 clones out of a total of 110. We chose this number of 24 as a safeguard against the phenomenon of cross-incompatibility among genotypes, which is a common occurrence in passion fruit populations (Ruggiero, 1973; Toma-Braghini, personal observation). Furthermore, we want to keep an effective population size of at least this magnitude, in order to avoid random genetic drift (Falconer, 1981).

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RESUMO

Cento e dez plantas foram selecionadas a partir de pomares comerciais de maracujá na região do Triângulo Mineiro, estado de Minas Gerais, no ano de 1986. Estas plantas foram clonadas por estaquia, e seus clones plantados em delineamento inteiramente casualizado num pomar comercial do município de Araguari-MG. Caracteres hortícolas foram avaliados em 1988. Estimativas de herdabilidade no sentido amplo (H^2) foram obtidas para produção total e precoce, peso médio do fruto, sólidos solúveis e percentagem de polpa. Houve considerável variação genética entre os diferentes clones para produção total e precoce, bem como para peso médio dos frutos, conforme indicado pelos altos valores de H^2 obtidos para estes caracteres. Estimativas de herdabilidade para sólidos solúveis foram moderadamente altas, mas sujeitas a considerável interação genótipo x data de amostragem, conforme indicado pela baixa correlação entre as leituras das diferentes datas. Estimativas de herdabilidade para percentagem de polpa foram menores do que para sólidos solúveis, porém menos sujeitas a interações com datas de amostragem. Considerando-se as magnitudes das estimativas de herdabilidade e dos coeficientes de variação genéticos, esperam-se maiores ganhos por seleção direta para maior produtividade total e precoce e para peso médio de frutos do que para sólidos solúveis e percentagem de polpa. Com a seleção dos 24 clones mais produtivos, foram obtidos ganhos genéticos de +29,1% para produção total e +89,2% para produção precoce, com variações insignificantes para peso médio de fruto, sólidos solúveis e percentagem de polpa.

REFERENCES

Becker, W. (1984). *Manual of Quantitative Genetics* - 4th. edition. Academic Press, Pullman, Washington, 190 p.

Falconer, D.S. (1981). *Introduction to Quantitative Genetics* - 2nd. edition. Longman, London, 340 p.

Hallauer, A.R. and Miranda Filho, J.B. (1981). *Quantitative Genetics in Maize Breeding.* Iowa State University Press, Ames. 468 p.

Knight, Jr., R.L. and Winters, H.F. (1963). Effects of selfing and crossing in the yellow passion fruit. *Proceedings of the Florida State Horticultural Society 76*: 345-347.

Landgraf, J.H. (1978). Perspectiva da cultura do maracujá no Brasil. *2º Simpósio sobre a cultura do maracujazeiro.* Jaboticabal, FCAV. p. 2-8.

Nakasone, H.Y., Hirano, R. and Ho, P. (1967). Preliminary observation on the inheritance of several factors in the passion fruit (*Passiflora edulis* L. forma *flavicarpa*). *Tech. Prog. Rep. Hawaii Agric. Exp. Sta. 151.* 11 p.

Oliveira, J.C. (1980). Melhoramento genético de *Passiflora edulis* Sims f. *favicarpa* Deg. visando aumento de produtividade. "Livre Docência" Thesis. FMVA, Jaboticabal.

Oliveira, J.C. (1987). Melhoramento genético. In: *Maracujá* (Ruggiero, C., ed.). UNESP/Ed. Legis Summa, Ribeirão Preto. pp. 218-246.

Ruggiero, C. (1973). Estudos sobre floração e polinização do maracujá amarelo (*P. edulis f. flavicarpa*). Doctoral Thesis, FMVA, Jaboticabal, SP.

Suzuki, O.Y. and Lins, W.B.A. (1987). Considerações econômicas brasileiras. In: *Maracujá* (Ruggiero, C., ed.). UNESP/Ed. Legis Summa, Ribeirão Preto. pp. 8-19.

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