Simple and canonic correlation between agronomical and fruit quality traits in yellow passion fruit (*Passiflora edulis f. flavicarpa*) populations

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ABTRACTS

These research objectives were to estimate the simple correlations (phenotypic, genotypic and environmental) and canonic correlations; in order to do that, it was evaluated five characteristic related to the fructification and three characteristics related to the quality of the fruit in two yellow passion populations grown in two environment (Macae and Campos dos Goytacazes). To the Macae environment in 32% of the simple associations, the genotypic correlations were the higher than the environmental correlations, indicating that the environment component is more influent than the genotypic component. To the Campos dos Goytacazes environment, in 50% of the simple associations, the genotypic correlations were higher than the environmental correlations, verifying, as it was observed in Macae environment, that the environment component is more influent than the genotypic component; it was observed high genotypic correlation between weight and fruit length. To the canonic correlations in the Macae environment, it was demonstrated that the individuals with high content of acidity and brix would have the tendency to present reduction in the fruit number, fruit length and peel tickness. In Campos environment reduction in the peel thickness and fruit length can increase the juice content and brix content.

KEY WORDS: Breeding, variability, passion fruit.

INTRODUCTION

Fruit cultivation, especially passion fruit cultivation, has increased in importance in Brazil recently and it has become a significant source of income. The international market, characterized by the commercialization of concentrated passion fruit juice, increased about 80% (25% per year) between 1987 and 1992 and has the perspective of maintaining such rates for the next ten years (Firjan, 1998).

The exotic flavor of the passion fruit makes it very attractive and it is consumed mainly in candy compositions and blends with other tropical flavors. The commercialized volume of concentrates in 1994 was 12,000 tons (of which Brazil participated with 1,800 tons) and there is the perspective of reaching 30,700 t/year in the next ten years (Agrianual, 2000).

Studies on the breeding of this species are rare but very important given the economic potential for the producing countries. Germplasm collection and assessment in the field is one of the stages for a good start to the program, along with identification of superior genetic materials.

Analysis of the simple correlation among traits is important for breeding because it enables indirect selection of the required trait, especially when the traits involved have complex heredity and are correlated to another easily identifiable trait (Robinson et al., 1951). According to Falconer (1987) knowledge of the association among traits and the consequences caused by the simultaneous change in any two traits can result in greater efficiency in selection of the traits to be improved as well as savings in time and work, compared to isolated selection for a determined trait.

The Canonic Correlations technique was described by Hotelling (1936) and was also analyzed by Rao (1952), Mardia et al. (1979), Arnold (1981), Dunteman (1984), Manly (1986) Jhonson and Winckern (1988), Liberato (1985), Amaral Junior et al. (1997) and Cruz and Regazzi (2001). According to these authors, the general and usual application consists of identifying and quantifying the association between two groups of variables. The possibility of the use of this methodology is mentioned in plant breeding in cases where it is interesting to assess the relationships between, for example, traits from the canopy ‘versus´ the root system, agronomic traits ‘versus´ physiological traits, primary components ‘versus´ secondary yield components etc. (Cruz and Regazzi, 2001).

Amaral Junior et al. (1997) studied the Canonic Correlation in tomato plants and divided the traits studied into two groups, group I: mean fruit weight, mean pericarp thickness and mean number of fruit locules, and group II: soluble solid content, lycopene percentage, betacarotene content and vitamin C content. The first correlation was chosen by data analysis because of its high significance. It was concluded that fruit with greater mean weight and pericarp thickness tended to present greater soluble solid, vitamin C and betacarotene contents. In contrast, fruit with greater mean weights and pericarp thickness would tend to contain less lycopene. They also observed that the decrease in the number of locules was conditioned by the decrease in lycopene content and raising of the magnitudes of soluble solids, betacarotene and vitamin C contents.

Carvalho et al. (1998) studied the Canonic Correlation between primary components (mean weight and total number of fruit) and secondary components (peduncle and stem diameter, plant height and first forking, length, width, length/width ratio, and thickness of fruit pulp) of sweet pepper fruit yield and ascertained that the most expressive association of sweet pepper fruit was established between these components and fruit traits. For these traits, the fruit length and width should be considered simultaneously for gain in total number and principally mean fruit weight. The peduncle diameter was more important among the morphological and agronomic traits and could enable correlated response to be obtained with mean fruit weight.

Vidigal et al. (1997) studied the simple and canonic correlations among morphoagronomic traits and root quality in cassava cultivars and observed the presence of positive correlations, both genotypic and phenotypic, between mean plant height and dry matter content and starch. This denoted that genetic materials with greater starch and dry matter contents culd be selected based on plant height that facilitated the selection process. For the Canonic Correlations, it was ascertained that larger plants, with greater internode length and greater first branch height, and with more stems and roots, but with smaller roots, will tend to present roots with greater dry matter and starch contents. The objective of this study was to establish Simple and Canonic Correlations to orient the future passion fruit breeding programs in the north of Rio de Janeiro state.

MATERIAL AND METHODS

Genetic materials

Passiflora edulis f. flavicarps plants were sampled in three large populations located in the counties of São Francsico de Itabapoana, Itaperuna and Campos dos Goytacazes, in the north and northeast of Rio de Janeiro state. They were collected based on the producer´s technological level in these locations. Five individuals were collected randomly in each population and the county of São Francisco was divided into three collection locations (producers).

The plants were propagated to obtain genetically equal individuals for the field assessments because it was intended to study the genetic diversity of the agronomic traits at the level of the collected individuals. Twenty-centimeter stem cuttings were prepared with a pair of half leaves, without treatment with any growth regulator and planted in a coarse sand rooting bed. Planting began in March and April 2000 and rooting continued until July. The cuttings were irrigated twice a day during the rooting period. At the end of July, the cuttings, already rooted, were transferred to 7 x 15 cm polyethylene bags filled with Plantemax® substrate. Acclimatization was completed 40 days after planting when the cuttings were transplanted to the definitive field.

Experiment

The plants derived from the plant multiplication were cultivated in a wire system, sustained by a single nº 12 wire at 1.80 m from the soil. A randomized complete block design with three replications was used. Experiments were set up in two locations, one in Campos dos Goytacazes, in the Antônio Sarlo Agricultural School and the other in Macae, in the PESAGRO-RIO Experimental Fruit Cultivation Station. The rooting resulted in a different number of plants per individual so the experiments were implanted with a different number of plants per plot, which ranged from two to four.

Traits assessed

The genetic materials were sampled three times during three months (January, February and March) to assess the genetic diversity based on the morphoagronomic traits. The number of fruits obtained for the genetic materials varied in each sampling because only ripe fruit were collected. The following traits were assessed:

a) Number of fruit per plant

The number of unripe fruit per plot was counted in the first flowering in January. The values were divided by the number of plants to obtain the mean number of fruit per plant.

b) Fruit weight (g)

Obtained by weighing the ripe fruit on an electric OHADUS scales, model TP 4000D with 4.0 kg capacity and 0.01 gram precision.

c) Fruit length (cm)

Obtained from measuring the longitudinal length of the fruit using a pachymeter.

d) Fruit width (cm)

Obtained by measuring the transversal length of the fruit using a pachymeter.

e) Peel thickness (mm)

Determined by measuring the external peel in the mid portion of transversally cut fruit at the greatest diameter using a pachymeter.

f) Brix degree content

Obtained by refratometry, using a portable ARTAGO N1 refratometer with reading in the 0 to 32º degrees brix range using juice and pulp samples extracted by manual pressure and filtered through a nylon sieve.

g) Titer of the acid contents

Ten ml of juice were added to a backer to determine the titer of the acid contents. Three drops of 1% phenolphthalein indicator were added and the titer was performed under agitation, with NaOH at 0.1 N solution, previously standardized with potassium biftalato. The results were expressed in g equivalent of citric acid (100g pulp)-1.

h) Juice percentage

Expressed in percent, obtained by the difference between the fruit weight and the weight of the juice extracted by squeezing 2 to 4 fruit.

Simple Correlation Estimators

The simple correlation coefficients were estimated according to Kempthorme (1973). The covariance between the X and Y traits was calculated based on the random model analysis of variance (Vencovsky and Barriga, 1992; Cruz and Regazzi, 2001) shown below:

Model where

$$Y_{ijk} = \mu + G_i + A_j + GA_{ij} + B / A_{jk} + \varepsilon_{ijk}$$

m - general mean

Gi - effect of the I-eth genotype (i= 1,2,…, g);

GAij = effect of the interaction of the I-eth genotype with the j-eth environment.

GAij = effect of the k-eth block within the j-eth environment (k = 1,2, ….r);

eijk = random error

where we have:

$$V(x+y) = V(x) + V(y) + 2Cov(x,y)$$

$$Cov(x,y) = \frac{V(x+y) - V(x) - V(y)}{2}$$

by analogy with the mean squares, we have X where Y is the PM(x,y) mean product between the x and y traits.

$$PM(x,y) = \frac{QM(x+y) - QM(x) - QM(y)}{2}$$

where we have:

a) Phenotypic covariance

$$C\hat{o}Vf(x,y) = \frac{PMG(x,y)}{r}$$

b) Genotypic covariance

$$C\hat{o}Vg(x,y) = \frac{PMG(x,y) - PMR(x,y)}{r}$$

c) Environmental covariance

$$C\hat{o}Va(x,y) = PMR(x,y)$$

d) Phenotypic correlation

$$r_F = \frac{PMGxy}{\sqrt{QMGxQMRy}}$$

e) Genotypic correlation

$$r_G = \frac{(PMGxy - PMRxy)/r}{\sqrt{\hat{\sigma}_g^2(x)\hat{\sigma}_g^2(y)}} = \frac{\hat{\sigma}_g^2(x,y)}{\sqrt{\hat{\sigma}_g^2(x)\hat{\sigma}_g^2(y)}}$$

f) Environmental correlation

$$r_A = \frac{PMRxy}{\sqrt{QMRxQMRy}}$$

Canonic Correlation Estimators

The canonic correlation technique was used to estimate the maximum correlation among linear combinations of the traits distributed in groups I and II. The weights of the traits in each linear combination were also estimated. Let X and Y be one of the combinations, then: Xi = a1X1 + a2X2 + ... + apXp e Yi= b1Y1 + b2Y2 + ...+ bpYp.

According to Cruz and Regazzi (2001) the canonic correlation maximizes the Xi and Yi relationship and is estimated from the correlation matrixes:

R_{11}: p x q matrix of correlation between the traits in group I;

R_{22}: p x q matrix of correlations between the traits in group II and

R_{12}: p x q matrix of correlation between traits in groups I and II

The first canonic correlation is given by the square root of the largest eigenvalue of the $R^{-1}_{11} R_{12} R^{-1}_{22} R_{21}$. matrix. The first canonic pair (Xi = a'X Yi= b'Y) is obtained considering that **a** is the first eigenvalue of $R^{-1}_{11} R_{12} R^{-1}_{22} R_{21}$ or equivalent to $R^{-1}_{11} R_{12} R^{-1}_{22} R_{21}$. We have also that **b** is the first eigenvalue of $R^{-1}_{11} R_{12} R^{-1}_{22} R_{21}$ or similarly b= $R^{-1}_{11} R_{12} R^{-1}_{22} R_{21}$ (Cruz and Regazzi, 2001). The other correlations in equal or lesser number between **p** and **q** are estimated using the eigenvalues, of corresponding order to the estimated correlation. The Genes programs was used (Cruz, 2001) for the analyzes.

RESULTS AND DISCUSSION

Estimates of phenotypic, genotypic and environmental correlations

Table 1 presents the estimates of the phenotypic, environmental and genotypic correlations among the eight traits studied for the Macae location. The genotypic correlations were less than the environmental correlations in 68% of the trait pairs, indicating that the environmental component was much more influential than the genetic component. It was further ascertained that there were differences in sign in 32% of the associations between the genotypic and environment correlation. According to Falconer (1981), this behavior indicated that the causes of genetic and environmental variation influence the traits by different physiological pathways.

The high genotypic correlation (0.9084) between the fruit weight and fruit width can be taken as an example, showing that heavier fruit tended to be wider. A high genotypic correlation (0.76445) was also shown between fruit width and length that was verified by the fact that the bigger fruits also had proportionally increased dimensions. Most of the traits (weight, width, peel thickness, length, brix content and acidity content) correlated negatively with juice percentage, showing that, for these traits, selection to increase juice yield tended to be inefficient.

A low correlation between the fruit weight and number of fruit traits (0.3603) was obtained. This implied that plants with more fruit did not necessarily have the heaviest fruit.

The same was shown with peel thickness that presented low correlation with number of fruits and fruit weight, 0.2810 and 0.3485, respectively.

The negative sign of the environmental correlation for fruit weight and number (-0.0924) characterized that the location although it favored the increase in the number of fruits, did not favor increase in their weight.

Table 2 shows the estimate of the phenotypic, environmental and genotypic correlations for the Campos dos Goytacazes location. In the case of this location the genotypic correlations were greater than the environmental correlations in 50% of the trait pairs indicating that, as observed in the Macae location, there were considerable environmental effects in the expression of the traits. Furthermore, the signs of the genotypic and environmental correlations were different for 28.75% of the associations. Changes were detected in some pairs of correlations for the traits considered.

There was high correlation in the case of fruit width and length (0.7022), as ascertained previously. Fruit weight and fruit length also presented high correlation (0.9714); it was noted that these traits, because they were highly correlated, would be important in future breeding program monitoring as there are researchers who consider that ideal genetic materials have small but heavy fruit.

There was a 0.8958 correlation in the trait pairs acid content and fruit width, indicating that fruits with higher acid content tended to be larger. Furthermore, as acid content and fruit weight presented a correlation of 0.7117, heavier fruit may be more acid. There was high correlation between juice percentage and number of fruits (0.7014) and high genotypic correlation (0.8251) between juice percent and acid content. This led to the conclusion that direct selection could be made on plants with greater prolificacy and an indirect gain could obtained in juice yield, which is a very important trait for the processing industry.

The presence of negative sign (-0.1102) characterized that the location, by favoring increases in peel thickness, did not favor increase in fruit weight. The same happened with juice percent and length, width, peel thickness and brix degree content, that presented location correlations of -0.1286, -0.1412, -0.0171 and -0.0313, respectively.

The positive correlations between number of fruit, fruit weight, length, width and peel thickness showed that all these traits could be acted on simultaneously in future breeding generations.

However, it should be pointed out that the genotypic correlations are unique to each trait and population and their extrapolation is not recommended because the genetic set with pleiotropic action, similar to the genetic blocks, is varied and leads to alterations in the association in the derived populations (Cruz and Regazzi, 2001).

The economic value of a product is influenced by a reasonable number of traits. Therefore, in plant breeding programs, changes in traits due to correlated response may be equally important as those occurring in traits submitted to selection. The size and direction of the correlated responses depend on the genetic correlation or on the genetic covariance that exists between pairs of traits (Silva, 1980).

Table 1. Estimates of the phenotypic (r_f), environmental (r_a) and genotypic correlation (r_g), among twenty genetic materials of yellow passion fruit in Macae.

Caracteristics		NF	CF	LF	Ecasca	PF	Brix content	Acid content	PS
NF	r_f		0.285	-0.012	0.231	0.275	-0.291	-0.334	-0.065
CF				0.694[1/]	0.344	0.779[1/]	-0.516	0.255	0.333
LF					0.257	0.667[1/]	-0.367	0.597	0.269
Ecasca						0.581[1/]	-0.122	-0.097	-0.427
PF							-0357	0.144	0.080
Brix content								0.044	-0.129
Acid content									0.100
PS									
NF	r_a		0.018	0.004	-0.295	-0.092	0.049	0.260	-0.083
CF				0.570[1/]	0.387	0.271	0.156	0.095	-0.180
LF					0.106	0.052	0.115	0.177	-0.064
Ecasca						0.364	0.172	-0.062	-0.149
PF							-0.108	0.206	-0.251
Brix content								0.343	0.142
Acid content									0.162
PS									
NF	r_g		0.368	-0.014	0.281	0.360	-0.382	-0.587	-0.191
CF				0.764[1/]	0.348	------	-0.926[1/]	0.411[1/]	-----
LF					0.292	0.908[1/]	-0.568	0.927[1/]	-----
Ecasca						0.666[1/]	-0.222	-0.130	-----
PF							-0.494	0.099	-----
Brix content								-0.220	-----
Acid content									-0.110
PS									

[1/] Significant at 10% t Test.

The genetic correlation between two traits is defined as that due to the additive effects of the genes that affect both the traits. It cannot be confused with the correlation between genetic effects that affect the same trait (Silva, 1980).

The location becomes the cause of correlation when two traits are influenced by the same differences in environment conditions. Negative factors in this correlation indicate that the location favors one trait in detriment to another, and positive values indicate

Table 2. Estimates of the phenotypic (rf), environmental (ra) and genotypic correlation (rg), among twenty genetic materials of yellow passion fruit in Campos dos Goytacazes.

Caracteristics		NF	CF	LF	Ecasca	PF	Brix content	Acid content	PS
NF	r_f		0.061	0.344	0.175	0.542	-0.049	0.028	0.369
CF				0.685[1/]	0.159	0.666[1/]	-0.360	0.228	-0.405
LF					0.066	0.901[1/]	-0.124	0.489	-0.175
Ecasca						0.226	-0.147	-0.223	0.002
PF							-0.105	0.404	0.001
Brix content								-0.231	-0.125
Acid content									0.206
PS									
NF	r_a		0.150	-0.017	-0.013	0.168	-0.010	-0.145	0.119
CF				0.697[1/]	0.337	0.081	0.101	0.091	-0.128
LF					0.312	0.309	0.119	0.164	-0.141
Ecasca						-0.110	-0.175	-0.227	-0.017
PF							0.116	0.154	0.309
Brix content								0.345	-0.113
Acid content									-0.031
PS									
NF	r_g		0.060	0.407	0.206	0.599[1/]	-0.075	0.091	0.701[1/]
CF				0.702[1/]	0.072	0.971[1/]	-0.874[1/]	0.440	-0.879[1/]
LF					-0.015	1.00[1/]	-0.310	0.895[1/]	-0.259
Ecasca						0.321	-0.145	-0.272	0.021
PF							-0.252	0.711[1/]	-0.254
Brix content								-----	-0.154
Acid content									0.825[1/]
PS									

[1/] Significant at 10% t Test.

Table 3. Estimates of correlations and canonic pair between two characteristcs of fruit quality (group I) and four characteristics on prodution (group II), evaluated among twenty genetic materials of yellow passion fruit in Macae.

Canonic Pairs		
	Variable[1] Coeficients of Group I	
	1ª V.C.	2ª V.C.
Brix content	0.1652	1.0118
Acid content	1.0233	0.0619
	Variable[2] Coeficients of Group II	
	1ª V.C.	2ª V.C.
NF	-0.3870	0.0424
CF	-0.4923	-1.3032
LF	1.3055	0.4569
Ecasca	-0.2713	0.0760
r	1.1350[1/]	0.9595ns

[1/] Significant at 5% Qui-quadrado test.

that the two traits are benefited or harmed by the same cause of environmental variation (Falconer, 1981).

Canonic correlations between yield traits and fruit quality

The traits were divided into two groups for the study of the Canonic Correlations and according to the analysis in each study location, the following groups were selected: for the Macae location it was established that group I consisted of the brix degree content and acid content traits and group II was formed by the number of fruits, fruit width and length and peel thickness traits. The first correlation (Table 3) was used because of its significance and it could be established that there was important correlation for the traits involved in the study. Individuals that presented high acid content and brix degree content (than the sugar contents reference) tended to present reduction in the number of fruit, fruit length and peel thickness and wider fruit had higher levels of acidity and brix degree contents.

The following traits were chosen for the Campos de Goytacazes location: number of fruit, fruit length and width, peel thickness, brix content and juice percent. Group I was formed by the traits brix degree content and juice percent, and group II consisted of the number of fruit, fruit length and width and peel thickness. The first correlation was chosen (Table 4) because of its high significance, from which it could be established that individuals with greater prolificacy tended to produce fruit with greater brix degree content and juice percent, wider fruit have higher acid content and brix content and that the reduction in peel thickness and fruit length increased the juice percent and brix degree content.

Table 4. Estimates of correlations and canonic pair between two characteristcs of fruit quality (group I) and four characteristics on prodution (group II), evaluated among twenty genetic materials of yellow passion fruit in local Campos dos Goytacazes.

Canonic Pairs		
Variable[1] Coeficients of Group I		
	1ª V.C.	2ª V.C.
Brix content	0.7118	0.7195
PS	0.8208	-0.5921
Variable[2] Coeficients of Group II		
	1ª V.C.	2ª V.C.
NF	0.3242	-0.6554
CF	-1.9054	-0.4165
LF	0.7717	0.4924
Ecasca	-0.0024	0.0556
r	1.5476[1/]	0.5584ns

Significant at 5% Qui-quadrado test.

RESUMO

Correlações simples e canônicas entre caracteres agrônomicos e de qualidade de frutos em populações de maracujazeiro amarelo (*Passilfora edulis* f. *flavicarpa*)

Esta pesquisa teve o objetivo de estimar as correlações simples (fenotípica, genotípica e de ambiente) entre pares de características, bem como as correlações canônicas entre grupos de características. Para tal foram avaliados cinco caracteres morfológicos relacionados à produção dos frutos e três relacionados à qualidade dos frutos em populações de maracujazeiro amarelo em dois ambientes (Macae e Campos dos Goytacazes). Para o ambiente Macae, em 32% das associações simples, as correlações genotípicas foram maiores que as ambientais, indicando que o componente ambiental tem grande influência em relação ao genético. Foram observadas altas correlações genotípicas entre peso e largura de fruto. Para o ambiente Campos dos Goytacazes, em 50% das associações simples, as correlações genotípicas foram maiores que as de ambiente, verificando, conforme o ambiente Macae, o efeito de ambiente teve maior influência que os genéticos, observou-se uma alta correlação genotípica entre peso e comprimento de fruto. Para as correlações canônicas no ambiente Macae, demonstrou-se que indivíduos com elevados teores de acidez e graus brix, teriam a tendência de apresentar reduções nos números de frutos, comprimento de fruto e espessura de casca. No ambiente Campos dos Goytacazes, redução na espessura de casca e comprimento de frutos levam a aumentos da percentagem de suco e aumento dos teores de graus brix.

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