Estimates of repeatability and path coefficients on grapes

Patrícia Coelho de Souza Leão[1] and João Gomes da Costa*

[1]Embrapa Semi-Árido, BR 428, Km 152, Zona Rural, Petrolina, PE, Brazil, Caixa Postal 23, CEP 56300-970, E-mail: patricia@cpatsa.embrapa.br. (* Corresponding Author. E-mail: jgomes@cpatsa.embrapa.br)

ABSTRACT

The objective of this study was to estimate the repeatability coefficient, the minimum number of evaluations to which a trait should be subjected and the effect of the inter-relationships of five characters on grapevine (*Vitis spp.*) yield, aiming at getting useful information for breeding strategies of this fruit crop. Repeatability coefficients were estimated for the following characters: total soluble solids (TSS); total titrable acidity (TTA); TSS/TTA ratio; berry length, diameter and weight; bunch length, width and weight, and number and yield of bunches per plant on eleven seedless grape varieties in five yield cycles (1997 and 1998) in Petrolina-PE. The repeatability estimates were obtained by the main components method from the correlation matrix. The simple correlation coefficients were calculated and they were partitioned into direct and indirect effects by the path analysis. The estimated repeatability coefficients ranged from 0.4750 to 0.8372 associated to the coefficients of determination from 81.9% to 96.26%. The traits TSS, TTA and bunch length presented low repeatability coefficients, meaning a low regularity of performance from one measurement to another. The other characters showed regularity on the repetition of the behavior of the genotypes. The results of the path analysis showed that the studied variables satisfactorily explain the character yield per plant.

KEY WORDS: Table grapes, plant breeding, repeatability, correlation, *vitis vinifera*.

INTRODUCTION

Grapes (*Vitis spp.*) are one of the most important fruit crops in the agribusiness of the São Francisco River Valley. The cultivated area of 5,300 hectares positions the region as the major exporter of table grapes in Brazil (Agrianual, 2002). The economic and social importance of this crop is the greatest reason for carrying out research studies on grape breeding programs for the Brazilian semi-arid region.

In any breeding program the selection for superior genotypes must be accomplished in the most efficient way possible and for this it is necessary to know the phenotypic and genetic parameters such as heritabilities, repeatabilities, and path analyses of the characters. Cruz (2001) pointed out the importance of biometric procedures as auxiliary tools for decision making at the different stages of the breeding program.

In a breeding program aiming at parent crossing and cultivar release, it is important to select genotypes with good agronomic potential and that their superior performance be maintained across evaluations. Thus, when choosing a genotype, it is expected that its initial performance be permanently maintained (Cruz and Regazzi, 1994). This expectation can be confirmed by the repeatability coefficient of the evaluated character. The repeatability concept can be defined as the correlation among the parameters of a certain character in a same individual where evaluations were physically repeated. It expresses the total variation proportion which is explained by the variations provided by the genotype and by the permanent alterations attributed to common environment (Cruz and Regazzi, 1994).

Based on that, repeatability studies are very important tools for helping breeders achieve precise results, and also for saving time and labor in trait evaluations. High values of the repeatability coefficient indicate that it is possible to predict the real value of the individuals using a relatively small number of measurements (Cornacchia et al., 1995), suggesting that there will be little gain in precision with increase of the number of repeated measurements (Falconer, 1987). When the repeatability is low, a large number of repetitions will be necessary in order to get a satisfactory determination value.

Repeatability studies are essential for perennial crops breeders, since they represent the maximum value that the heritability of a character in a wide sense can reach (Falconer, 1987; Cruz and Regazzi, 1994). They are also used to determine the number of phenotypic observations to be made in each individual so that the discrimination or phenotypic selection among genotypes is efficiently carried with reduced costs. In this context, repeatability coefficients have been estimated in fruit crops like coconut (Siqueira, 1982), "cupuaçu" (Fonseca et al., 1990; Costa et al., 1997), cashew tree (Cavalcanti et al., 1999) and barbados cherry (Gonzaga Neto et al., 1999; Paiva et al., 2001; Lopes et al., 2001).

The knowledge of the association among characters is another tool of great importance for breeding works, mainly if the selection for one of them is difficult due to low heritability and/or if there are problems measuring the traits. However, although being of great use toward quantifying the magnitude and direction of the influence of factors on determination of complex characters, this association does not give the relative importance of the effects of these factors. The path analysis (Wright, 1921, 1923) consists of studies concerned with direct and indirect effects of characters on a basic variable whose estimations are obtained through regression equations where the variable is previously standardized. Among the fruit crop species this technique has been utilized on guarana (Nascimento Filho et al., 1993), cocoa (Almeida et al., 1994), umbu tree (Santos and Nascimento, 1998) and "açaí" tree (cabbage-palm) (Oliveira et al., 2000).

In spite of the importance and the non-requirement that the data be originated from experimental designs, the two techniques have not been used by grape breeders.

This study had the objective of estimating the repeatability coefficient and the minimum number of evaluations to be taken for a precise prediction of the real value of individuals and quantifying the direct and indirect effects among agronomically important characters on grapevine crop.

MATERIAL AND METHODS

The experiment was carried out at Bebedouro Experimental Station, from Embrapa Semi-Arid, Petrolina, Pernambuco State, Brazil, latitude 9°09'S, longitude 40°22'W and altitude of 350.5m.

According to Köeppen classification, the climate of the area is classified as Bswh type, which corresponds to a very hot semi-arid region. The mean annual rainfall is 571.5mm. The mean annual temperature is 26.4°C, with minimum of 20.6°C and maximum of 31.7°C.

The vineyard where the experiment was run was a seedless grape variety collection established on September 1994, using the cultivar IAC 572 'Campinas" as rootstock. The study period was in the years 1997 and 1998, the evaluations being made during five yield cycles.

Repeatability coefficients (r) and number of years necessary to measure the following characteristics were estimated: number of bunches (NB); yield of bunches per plant (YBP); bunch length (BL), bunch width (BW), medium bunch weight (MBW), berry diameter (BD), berry length (BeL), medium berry weight (MbeW), total soluble solids (TSS), total titrable acidity (TTA) and TSS/TTA ratio.

Due to the cyclical behavior of the yield in many grapevine cultivars, the estimate of the repeatability coefficient was accomplished by the analysis of the main components proposed by Abeywardena, (1972) and modified by Rutledge (1974). Accordingly, the estimates of repeatability coefficients are obtained by the method of the main components (CP), based on the correlations coefficient among each pair of measured traits, from which normalized eigenvalues and eigenvectors are determined. The eigenvector, whose elements present same sign and close value, is the one that expresses the tendency of the genotypes in maintaining its relative positions in several intervals of time, acordding Cruz and Regazzi (1994). The proportion of the eigenvalue, associated to the eigenvector, is the estimator of the repeatability coefficient, given by:

$$r = \frac{\hat{\lambda}_1 - 1}{n-1}, \text{ being } \hat{\lambda}_1 = 1 + (n-1)P$$

where,

$\hat{\lambda}_1$ = eigenvalue associated to the eigenvector whose elements have same sign and closed values;

P= number of genotypes; and

n= number of periods.

The minimum number of measurements to predict the individuals' real value, with base in a preset determination coefficient (R2), was calculated by:

$$n_0 = \frac{R^2(1-r)}{(1-R^2)r}$$

where:

n_0 = number of mensurations for prediction of the real value; and

r = estimated repeatability coefficient.

The coefficient of genotipic determination (R^2), which represents the percentage of certainty of the prediction of the individuals' real value selected with base in n measurements, was obtained by:

$$R^2 = \frac{nr}{1+r(n-1)}, \text{ where:}$$

n = mensurements number;

r = estimated repeatability coefficient.

For a better interpretation of the correlations obtained among the characteres, they were submited to the path analysis, in order to separate a correlation value into direct and indirect effects. A cause-effect diagram, was established aiming to present the relationships among the main variable and the explanatory variables, as well as its interrelations (Figure 1). The parameter yield per plant was considered the basic variable and berry length and diameter, bunch length and number, as the explanatory variables. The variable e represents the residual effects.

After the establishment of the basic equations of the path analysis, the resolution in the matricial form was given by the system of normal equations X'Xb = X'Y, where X'X is a non-singular correlations matrix among the explanatory variables; b is a vector-column of path coefficients; and X'Y is a vector-column of the correlations among the main and explanatory variables.

The determination coefficient for the analysis of the explanatory variables on the main variable is given by: $R^2_{0.123} = \hat{\rho}_{01} r_{01} + \hat{\rho}_{02} r_{02} + \hat{\rho}_{03} r_{03} + \ldots + \hat{\rho}_{0n} r_{0n}$.

The residual effect was expressed by:

$$\rho\varepsilon = \sqrt{1 - R_{0.123 \ldots n}}$$

All estimations for repeatability, determination coefficient, minimum number of evaluations, phenotypic correlation coefficients and path analysis were carried using the GENES computer program (Cruz, 2001).

RESULTS AND DISCUSSION

The estimates of the repeatability coefficient and the respective determination coefficients can be found in Table 1. It can be observed that the variables bunch length, berry diameter and medium weight and bunch weight, width and number presented repeatability coefficients higher than 0.69 and determination coefficients higher than 90%, suggesting a high regularity in the repetition of the character from one evaluation to another, making possible the prediction of the individuals' real value with few evaluations and a significant precision level. Berry diameter needs only two and four evaluations for a reliability level of 90 and 95%, respectively.

For prediction of real values of bunch yield per plant, six measurements will be necessary for a coefficient of determination of 90%, while for bunch width and mean weight, a mean number of four measurements should be performed for a certainty level of 90% (Table 2). Generally, yield is subjected to a great degree of environmental influence . In evaluations where the factor periodicity occurs, the measurements are affected by regular, irregular or systematic changes of physiologic order, which naturally occur in the organisms.

The character bunch length showed the lowest values of the estimates of repeatability coefficient, being, among the studied characters, the most influenced by environmental conditions. On the average, ten measurements are necessary to reach a coefficient of determination of 90%.

Total soluble solids (TSS), total titrable acidity (TTA) and TSS/TTA ratio also showed low values for estimation of the repeatability coefficient, making

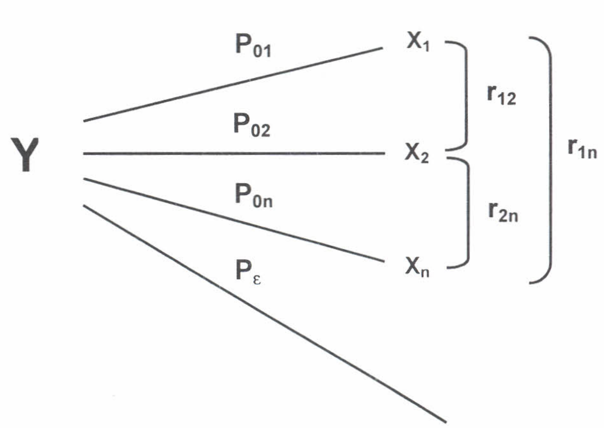

Figure 1. Causal Diagram of the inter-relationship among yield of bunches per plant (YBP) and the primary explanatory variables berry lenght (BeL), berry diameter (BD), medium bunch weight (MBW), bunch lenght (BL), and number of bunches per plant (NB).

Table 1. Estimates of repeatability coefficients (r) and respective determination coefficients (R^2) in characters of grapevine

Characters	r	R^2 (%)
Total soluble solids (TSS)	0.52	84.59
Total titrable acidity (TTA)	0.50	83.38
TSS/TTA ratio	0.60	88.11
Berry length	0.78	94.65
Berry diameter	0.84	96.26
Berry weight	0.81	95.56
Bunch weight	0.69	91.93
Bunch length	0.47	81.90
Bunch width	0.73	93.05
Yield of bunches per plant	0.60	88.42
Number of bunches per plant	0.70	92.23

Table 2. Number of measurements at 90 and 95% determination coefficients for some grapevine characters.

Characters	90 %	95%
Total soluble solids (TSS)	8	17
Total titrable acidity (TTA)	9	19
TSS/TTA ratio	6	13
Berry length	3	5
Berry diameter	2	4
Berry weight	2	4
Bunch weight	4	8
Bunch length	10	21
Bunch width	3	7
Yield of bunches per plant	6	12
Number of bunches per plant	4	8

evident the influence of the environment on such characters. Considering a coefficient of determination of 90%, eight and nine measurements are necessary, respectively, for prediction of the real values of TSS and TTA.

For characters associated with berries (length, diameter and medium weight), the obtained estimates present reasonable regularity on the repetition of the character from one evaluation to another. Two measurements, on the average, were sufficient to obtain coefficients of determination of 90% in these characters.

In general, except for bunch length, TSS and TTA, the prediction of the real value, expressed by the coefficient of determination, was higher than 88%, suggesting that the superiority or inferiority of the behavior of the varieties can be maintained from one cycle to another.

It can also be found that five cycles of evaluations for all studied traits should be necessary in order to reach a confidence level above 81%. Camargo (2000) pointed out that three to five vegetative cycles should be enough to enable selection. However, the number of necessary evaluations will depend on the variable and on the defined precision level. In the present study, the necessary number of measurements for selection regarding to yield varied from 6 to 13 to get precision between 90 and 95% (Table 2).

The breakdown of the phenotypic correlation coefficients between yield per plant and the explanatory variables can be found on Table 3. The influence of the variables berry diameter and bunch number, expressed by the path coefficients (direct effects) of the same sign and extent of those showed by the correlation coefficients, indicated these variables as determinant of the behavior of the basic variable (yield per plant).The coefficient of total determination of 94.97% indicates that the variables used explain satisfactorily the behavior of yield.

According path analysis and repeatability coefficients, it can be concluded that the most favorable situation for grapevine breeding to increase yield per plant was observed with the character berry diameter, that presented high repeatability estimate, and relatively high and positive values on the correlation and on the direct effect of yield. Thus, the indirect selection for yield can be accomplished through berry diameter, with a reduction of 50% of the time that would be necessary for accomplishing direct selection with the variable yield.

CONCLUSIONS

TSS and TTA showed low values for repeatability coefficient, requiring eight and nine evaluation cycles to predict the individuals' real values with certainty level above 90%;

The estimates of the repeatability coefficient for berry diameter, length and mean weight demonstrate reasonable regularity in the repetition of the character from one cycle to another, and that two evaluations are enough to reach a coefficient of determination of 90%;

Berry diameter presented the highest repeatability coefficient and high and positive values on the correlation, indicating indirect selection on the trait to increase yield per plant.

RESUMO

Estimativas de repetibilidade e análise de trilha em videira

Objetivou-se, com este trabalho, estimar o coeficiente de repetibilidade, o número de avaliações aos quais o caráter deve ser submetido e o efeito das inter-relações de cinco caracteres sobre a produtividade, visando obter informações úteis para a escolha de estratégias no melhoramento desta fruteira. Foram estimados os coeficientes de repetibilidade para os caracteres sólidos solúveis totais (SST); acidez total titulável (ATT); relação SST/ATT; comprimento, diâmetro e peso de bagas; comprimento, largura e peso de cachos; produção e número de cachos por planta, para 11 variedades de uvas sem sementes em cinco ciclos de produção (1997 e 1998) em Petrolina – PE. As estimativas de repetibilidade foram realizadas pelo método dos componentes principais a partir da matriz de correlação. Os coeficientes de correlação simples foram calculados e desdobrados, por intermédio da análise de trilha, em efeitos diretos e indiretos. Os coeficientes de repetibilidade estimados variaram de 0,4750 a 0,8372, associados aos coeficientes de determinação de 81,90% a 96,26%. Verifica-se que houve uma baixa regularidade na repetição do desempenho dos genótipos de uma avaliação para outra para os caracteres SST, ATT e comprimento de cachos. Para os demais caracteres, houve regularidade na repetição do comportamento dos genótipos. Os resultados da análise de trilha mostraram que as variáveis utilizadas explicaram satisfatoriamente a produtividade por planta.

Table 3. Direct effects, indirect effects, collinearity tests, coefficient of determination and residual effects of explanatory variables on yield per plant of grapevine

Character[1]	r	Effects on yield per plant: Direct Effects	Indirect Efects: X1	X2	X3	X4	X5
BeL	0.1281	-0.1465	-	0.2950	0.0396	-0.0341	-0.0258
BD	0.5800	0.5253	-0.0822	-	0.0782	-0.0362	0.0950
MBW	0.2465	0.1555	-0.0373	0.2641	-	0.2653	-0.4012
BL	-0.1299	0.3656	0.0137	-0.0520	0.1129	-	-0.5700
NB	0.7133	0.9434	0.0040	0.0529	-0.0661	-0.2209	-
Residual effects							0.2243
Determination coefficients							0.9497
Collinearity test of explanatory variables							weak

[1]BeL: berry lenght; BD: berry diameter; MBW: medium bunch weight; BL: bunch lenght; NB: number of bunches per plant.

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