Yield repeatability and evaluation period in hybrid cocoa assessment

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ABSTRACT

Repeatability estimates were obtained from an experiment carried out in Rondônia state to define the evaluation period necessary to discriminate between cocoa hybrid yields. Data collection involved these traits: total number of fruits harvested (TNFC), total number of healthy fruits (TNHF), total weight of fresh seeds (TWFS), mean weight of fresh seeds per fruit (MNFSF), percentage of wasted fruits (SPWF) and percentage of wasted fruits due to witches' broom disease (PWFWB). Repeatability estimates were high for the two last traits (values above 0.8) but were relatively low (lower than 0.65) for the others when the ANOVA estimation was performed on data collected at maturity. These estimates indicated that three evaluations are necessary from the 8th year after planting for efficient selection (accuracy > 70%) for all the assessed traits. When the average of the assessments carried out in two pre-climax years was considered, it was possible to obtain a correlation greater than 0.70 between the real hybrid value and the traits total number of fruits collected and percentage of wasted fruits.

KEY WORDS: Yield components, breeding, *Theobroma cacao*.

INTRODUCTION

Repeatability traditionally refers to the correlation between measurements repeated in time taken from a single individual (Lush, 1945). In assays with experimental designs, however, the genotype value under selection is often inferred from the average of the experimental plots bearing this genotype and not from the mean of a single individual. Thus, when assessments on each individual of each experimental plot are repeated in time, the repeatability may be defined as correlation among the averages of the experimental plots taken at the successive assessments (successive means) of a single genotype (Cruz and Regazzi, 1994; Dias and Kageyama, 1998 and Carvalho, 1999). Based on these estimates, the number of measurements the breeder should take to select with specific precision can be determined for each genotype.

The use of successive assessments of a genotype over several years of cultivation has been a normal practice in cocoa (*Theobroma cacao* L.) yield evaluation. However, little is known about the number of years that is necessary to discriminate between cocoa genotype yields. Such information would reduce costs and selection and labor time. Dias and Kageyama (1998) is one of a few reports available on the estimate of repeatability, and consequently, on the determination of this number. Other studies (Soria and Esquivel, 1967, Atanda, 1972; Dias et al. 1996) have obtained correlation coefficients between yields in each annual period and the accumulated yield of the whole period. Use of this coefficient allows the calculation of the minimum number of measurements necessary to assess genotypes with acceptable precision.

Fructification beings in cocoa 18 months after planting (Soria and Esquivel, 1970), but it is only after the 8th or 10th year (climax period) that the trees express their maximum yield potential (Dias and Kageyama, 1998). The yield level of the trees may continue after the climax, or may decline gradually (post-climax period). The economic production of a plantation varies from 25 to 50 years (Toxopeus, 1972). Trees with the largest yields at the beginning of fructification may not be the highest yielding in later phases. Atanda (1972) and Dias et al. (1996) reported that the selection for yield should be based on the period when the trees are at maturity (climax and post-climax periods). On the other hand, the possibility of selecting genotypes at the initial fructification was indicated by Soria and Esquivel (1970).

The main aim of cacao plant breeding is to increase the dry cacao bean yield while maintaining an adequate bean quality. Since dry cacao bean yield is a difficult trait to evaluate, selection can be practiced on more easily measured correlated traits. Several traits, when taken isolated or in combination, have been mentioned as important and considered sufficient to discriminate cacao tree genotypes for yield. Pereira et al. (1987) and Dias et al. (1998) used the number of healthy fruits per plant and the weight of fresh beans per plant and per fruit, together and successfully, to select promising hybrids in Linhares, ES. The increase in the first two yield components provided the increase in yield and the addition of the third yield component is associated with improvement in the bean size.

The present paper has the following objectives: a) to estimate the yield component repeatability of cocoa hybrids assessed in a assay with experimental design carried out in Rondônia; b) to determine the number of measurements that should be carried out on each hybrid to obtain a selection accuracy for yield between 70% to 90%; and c) to verify whether the assessments made at the initial fructification stage are satisfactory for hybrid selection.

MATERIAL AND METHODS

An experiment with 20 cocoa hybrids was carried out by the Comissão Executiva do Plano da Lavoura Cacaueira (CEPLAC) at the Ouro Preto Experimental Station in the county of Ouro Preto do Oeste, Rondônia, from 1978-1991. The county is located at 10º42´30” latitude south and 62º13´30” longitude west. The soil in the region is classified as Xibiu unit: mineral soils, medium depth, well-drained, medium natural fertility with well-differentiated horizons. The climate is Am type by the Köppen classification. The mean annual temperature is 25.6°C, mean annual air relative humidity is 89% and total annual rainfall is over 2200mm (Barbosa and Neves, 1983).

All hybrids were obtained from crosses among clones of the Upper and Lower Amazon genetic types, except for SCA 6 x ICS 1 (Upper Amazon x Trinitario). These crosses aimed to obtain trees combining the vigor of the Upper Amazon type with the yield and bean quality of the Lower Amazon and Trinitario types. The High Amazon, Low Amazon and Trinitário clones consist of selections made in Peru and Ecuador, Brazil and Trinidad, respectively (Table 1).

A randomized complete block design with seven replications was used. Each plot consisted of 12 plants distributed in three rows and four columns with a 3.0 x 3.0 m plant spacing. Two rows of cocoa trees were planted around the experiment area as a border. Temporary shading was provided by 3.0 x 3.0 m spaced banana trees and by cassava plants, using four cassava plants per cocoa tree. Permanent shading was also provided by planting 24.0 x 24.0 m spaced *Erythrina glauca*.

Fertilization and other crop management practices (weeding, hoeing, pruning, shoot removal, plant tutoring and phytosanitary control) were carried out to maintain the plants under optimum growth and development conditions.

The assessed traits were: a) total number of fruits harvested (TNFC); b) total number of healthy fruits (TNHF); c) total weight of fresh seeds (TWFS) in kilograms; d) mean weight of fresh seeds per fruit (MWFSF) in grams; e) percentage of wasted fruit (SPWF) due to presence of witches' broom (*Crinipellis perniciosa*) or other disease symptoms, damage by wild animals or germinated seeds; f) percentage of wasted fruits due only to the occurrence of *C. perniciosa* (PWFWB). These yield components were measured from the 4th to the 13th years after planting (1982 to 1991), except TWFS and MWFSF assessed only from 1982 to 1989, and PWFWB that was measured only from 1986 to 1991. Fruits were harvested monthly, but the accumulated yield of each year was considered in the analyses.

An analysis of variance of the yield components was carried out according to a model using the means of the genotype experimental units in each year (Cruz and Regazzi, 1994; Dias and Kageyama, 1998 and Carvalho, 1999). The following model was used:

$$y_{ij} = \mu + g_i + a_j + E_{ij}$$

where y_{ij} = the mean of kth blocks (k=1,...,r) of the ith hybrid (i=1,...,h) in the jth year (j=1,...,n); μ = constant, inherent in all means for each hybrid in each year; g_i = effect of the ith hybrid under the permanent environment effect; a_j = effect of the jth year and E_{ij} = residue including $ga_{ij} + \bar{\varepsilon}_{ij.}$

Two distinct assessment periods were considered for these analyses. The first, from 1982 to 1985 (4th and 7th years after planting), refers to the pre-climax period of the hybrid cocoa experiment and the second, from 1986 to 1991 (8th and 13th years after planting), refers to maturity. The climax and post-climax periods are included in the latter period. A pre-climax period

Table 1. Cacao tree hybrids and geographic origin of the clones used as their parents.

Hybrid	Geographic origin
IMC 67 x SIC 813	Iquitos-Peru x Bahia-Brasiil
SCA 6 x ICS 1	Equador x River State-Trinidad
IMC 67 x CA 4	Iquitos-Peru x Amazonas-Brasil
IMC 67 x BE 8	Iquitos-Peru x Pará-Brasil
IMC 67 x BE 9	Iquitos-Peru x Pará-Brasil
IC 67 x SIAL 169	Iquitos-Peru x Bahia-Brasiil
POUND 7 x BE 10	Iquitos-Peru x Pará-Brasil
POUND 7 x MA 12	Iquitos-Peru x Manaus-Brasil
POUND 7 x SIC 864	Iquitos-Peru x Bahia-Brasiil
POUND 7 x MA 15	Iquitos-Peru x Manaus-Brasil
POUND 12 x SIC 329	Iquitos-Peru x Bahia-Brasiil
POUND 12 x MA 14	Iquitos-Peru x Manaus-Brasil
POUND 12 x SIAL 505	Iquitos-Peru x Bahia-Brasiil
POUND 12 x SIC 831	Iquitos-Peru x Bahia-Brasiil
PA 150 x SIC 328	Parinari-Peru x Bahia-Brasil
PA 150 x SIAL 325	Parinari-Peru x Bahia-Brasil
PA 150 x MA 11	Parinari-Peru x Manaus-Brasil
PA 150 x SIC 864	Parinari-Peru x Bahia-Brasil
SCA 6 x BE 9	Equador x Pará-Brasil
SCA 6 x BE 10	Equador x Pará-Brasil

analysis of variance of PWFWB was not carried out because this trait was only assessed at maturity. The maturity period analyses of variance of TWFS and MWFSF were performed using data from only four assessment years.

Repeatability estimates such as correlation among successive measurements (plot means taken at the successive assessments) of a hybrid were calculated for the two periods using ANOVA $(\hat{\rho}_{AV})$ (Lush, 1945), principal component $(\hat{\rho}_{CP})$ (Rutledge, 1974), structural analysis $(\hat{\rho}_{E})$ (Mansour et al., 1981) estimators and principal component estimator with previously classified hybrids $(\hat{\rho}_{CPC})$. The $\hat{\rho}_{CPC}$ values were obtained from a previous classification of the hybrids from 1 to h (Santhirasegaram et al., 1966) and using the expression described by Rutledge (1974).

Based on the $\hat{\rho}_{AV}$ value obtained from the assessments made at maturity, the number of measurements (n^*) which should be taken on each hybrid was calculated to allow selection of the assessed traits with 70% $(R^2 = 0{,}7)$, 80% $(R^2 = 0{,}8)$ and 90% $(R^2 = 0{,}9)$ coefficient of determination. The hybrid selection accuracy (R^{2*}) was also obtained from the n_c measurements carried out in this period for each assessed trait. The expression of n^* and R^{2*} are described in Lush (1945) and Cruz and Regazzi (1994).

For those traits with R^{2*} values greater than 0.9, the correlation coefficients between the yield mean of measurements carried out at maturity with the yield mean measurements of one, two, three and four successive assessment years in the pre-climax period were obtained. These correlations were analyzed to check if the assessments in the initial fructification phase were satisfactory for hybrid selection purposes. When the correlation coefficient was greater than 0.70 for a given pre-climax period (one, two three or four successive measurements) the use of this period measurement mean was considered satisfactory for hybrid discrimination.

All the statistical analyses of the experiment were done using the GENES computer program (Cruz, 1997).

RESULTS AND DISCUSSION

Necessary period for yield assessment

Except for SPWF and PWFWB, the ANOVA $(\hat{\rho}_{AV})$ repeatability estimates of the yield components assessed at maturity in the hybrid cocoa experiment showed values relatively low (0.466 to 0.645) (Table 2). This indicates a lack of consistency of hybrid performance for these traits from one measurement to another at maturity. Based on these repeatability estimates, the number of TNFC, SPWF and PWFWB assessments already carried out at maturity discriminated the hybrids with accuracy greater than 90%, while a other five, seven and four measurements should be taken for TNHF, TWFS and MWFSF, respectively, for similar precision. The selection efficiency for these latter traits was less than 90% but greater than 75% ($R^{2*} > 0.75$). In spite of the relatively low $\hat{\rho}_{AV}$ values, three measurements suffice to discriminate the hybrids with above 70% accuracy for all the assessed traits.

Dias and Kageyama (1998) found repeatability estimates greater than 0.84 when assessing number of fruits collected per plant, number of healthy fruits per plant and weight of fresh seeds per plant. The lower $\hat{\rho}_{AV}$ values obtained for TNFC, TNHF, TWFS and MWFSF in this work compared to those obtained by the referred authors may be explained by significance of the genotypes x years interaction (in the Table 1, the significance of genotypes x years interaction can not be observed because it is included in residue) and by a larger experimental coefficient of variation. They obtained a repeatability estimate of only 0.41 for percentage of diseased fruits per plant, which differs greatly from the values obtained for SPWF and PWFWB, which were the traits with the greatest repeatability values in this study. This is due to the lower variation coefficient value found in this experiment.

Comparison of repeatability estimates

There was good agreement among the repeatability values obtained by the all estimation methods (Tables 2 and 3). Therefore, also because the analysis of variance is traditionally used to estimate repeatability, only $\hat{\rho}_{AV}$ was used to determine R^{2*} and n^*, described in the previous section.

The ANOVA estimator is affected by any regular (e.g. biennial effects) or irregular changes (e.g. fluctuations in the weather) during the assessment period. These periodic changes increase the variability between repeated observations of a hybrid and are considered random disturbances that cause underestimation of the coefficient (Abeywardena, 1972). However, the removal of the year effect from the residue in the statistical model, as in this study (Table 1), reduces the influence of the irregular changes in the repeatability estimation. Furthermore, even when the variance equality $(V(y_{ij}) = V(y_{ij'}))$ assumption necessary for repeatability calculation did not seem plausible, as for TNHF $(\hat{V}(y_{i4}) > 8\hat{V}(y_{i2}))$, $\hat{\rho}_{AV}$ values were similar to those of $\hat{\rho}_{CPC}$ and $\hat{\rho}_E$, which are more satisfactory estimators in these situations. The structural analysis, for example, corresponds to standardizing the experimental data at year level prior to the use of the analysis of variance. This allows a reduction in the influence of the irregular changes on the $\hat{\rho}$ calculation. The robustness of the ANOVA estimator obtained in this experiment is in line with the theoretical studies carried out by Mansour et al. (1981).

It can be further mentioned that the eigenvector elements associated with the first eigenvalue of the correlation matrices of pairwise measurements in each hybrid for the yield components assessed (except TWFS) had the same signs and similar magnitudes. According to Abeywardena (1972), the eigenvector whose elements show same signs and similar magnitudes reflects the tendency of the genotypes to

Table 2. Mean squares of ANOVA for the yield components[1/] assessed at maturity in a cocoa hybrid experiment. Estimates of the mean, experimental coefficient of variation (C.V.), repeatability coefficient[2/], determination coefficient (R^{2*}) and number of measurements associated with 70% (n^{*a}), 80% (n^{*b}) and 90% (n^{*c}) coefficients of determination.

Sources	Df [3/]	Mean squares					
		TNFC	TNHF	TWFS	MWFSF	SPWF	PWFWB
Hybrids	19(19)	23084.193 [4/]	97442.086 [4/]	11.519 [4/]	184.552 [4/]	367.453 [4/]	376.371 [4/]
Years	5(3)	210341.156 [4/]	4047.085 [4/]	24.557 [4/]	131.884 [4/]	7440.202 [4/]	7312.626 [4/]
Residue	95(57)	1938.458	650.261	2.559	3.028	14.627	14.786
Mean		311.332	117.277	6.650	91.542	58.546	58.313
C.V. (%)		14.142	21.743	24.054	6.058	6.523	6.594
$\hat{\rho}_{AV}$		0.645	0.465	0.466	0.555	0.801	0.803
R^{2*}		0.916	0.839	0.777	0.830	0.960	0.960
n^{*a}		2	3	3	2	1	1
n^{*b}		3	5	5	4	1	1
n^{*c}		5	11	11	8	3	3

[1/] TNFC: total number of fruits harvested; TNHF: total number of healthy fruits; TWFS: total weight of fresh seeds; MWFSF: mean weight of fresh seeds per fruit; SPWF: percentage of wasted fruit due to presence of witches' broom or other disease symptoms, damage by wild animals or germinated seeds and PWFWB: percentage of wasted fruits due only to the occurrence of witches' broom; [2/] ANOVA $(\hat{\rho}_{AV})$ estimator was used; [3/] numbers within brackets correspond to the ANOVA degrees of freedom for TWFS and MWFSF; [4/] P<0.01.

maintain their relative positions during the assessment period. Their association with the first eigenvalue, as occurred in this study, is an indication of no biennium effect in the sample data. This explains obtaining similar $\hat{\rho}_{AV}$ and $\hat{\rho}_{CP}$ values (Tables 2 and 3). However, in the presence of biennium effect the estimation of R^{2*} and n^* should be based on the principal components analysis. The principal components with previously classified data may be considered a good estimation method, as it considers the occurrence of biennium effect and tends to reduce the influence of irregular changes.

There are reports in the literature that cocoa trees can express a tendency to biennial behavior in alternate years (Atanda and Jacob, 1975). But this tendency was not observed either in the experiment carried out by Dias and Kageyama (1998) or, as shown, in this essay. When genotype measurements are considered as means of the experimental units, the detection of biennial behavior in the sample data may be hindered, as the biennial effects may cancel when the mean of these units is calculated.

The occurrence of an abnormal year (the 4th year in the maturity period) for TWFS caused dissimilarities among the magnitudes of eigenvector elements associated with the first eigenvalue of correlation matrix. The correlations between this 4th year and the other years were discrepant compared to the correlations involving just the three other years. As the other elements of this eigenvector had the same signs and similar magnitudes, it may be said that biennium effect did not occur for this trait either. This abnormal year (1989) effect was the consequence of a drastic pruning at the end of 1988 to control witches' broom disease. The disease is endemic in the region where the experiment was carried out.

Selection in the yield pre-climax period

The possibility of selecting genotypes at the initial fructification phase and, consequently, increasing the selection gain per year, can be verified by calculating the correlation between the mean yield values obtained from the measurements taken in the pre-climax period with the real genotypic value. In practice, this value is not known. However, as shown, inference can be made on the selection accuracy (R^{2*}) based on the mean of n_c measurements taken at maturity for a determined yield component. The mean of these n_c measurements are good estimators of the real genotype value when R^{2*} is large. In this context, the correlation analysis between the mean yield of measurements taken at maturity and at the pre-climax phase for a trait, whenever R^{2*} has a value >0.9, may be a good strategy to check the possibility of practicing selection at the initial fructification phase. Other R^{2*} values can be used, but as R^{2*} gets smaller the maturity period mean will not denote the true hybrid value, and if it is very low, the study of the correlation in the selection process will not be very effective. The accuracy of hybrid selection based on the means of measurements taken at maturity in the present experiment was superior to 90% for TNFC (R^{2*}=0.916), SPWF (R^{2*}=0.960) and PWFWB (R^{2*}=0.960), as previously reported (Table 1).

The correlation coefficients calculated between the mean yield of the TNFC measurements taken at maturity and the mean yield of one, two, three and four successive years of measurements taken in the pre-climax period varied from 0.63 to 0.76 (Table 4). When the correlation coefficient was greater than 0.70 for a determined pre-climax period (one, two, three or four successive measurements) the use of the mean of the measurements of the referred period was considered satisfactory for hybrid selection. Thus, with the mean of two measurements it was possible to predict satisfactorily the real hybrid value for this trait. Similarly to R^{2*}, correlation values less than 0.70 can be considered satisfactory by the breeder to be able to use the mean of the measurements obtained in the respective pre-climax period in the cocoa genotype selection process. However, the lower this value, the less reliable the process will be. The successful possibility of using yield measurements taken at the initial fructification phase, when assessing the number of fruits per plant, was also described by

Table 3. Repeatability[1/] estimates for the yield components[2/] assessed at maturity in a cocoa hybrid experiments with statistical design.

Estimator	TNFC	TNHF	TWFS	MWFSF	SPWF	PWFWB
$\hat{\rho}_{CP}$	0.694	0.555	0.579	0.552	0.833	0.834
$\hat{\rho}_{CPC}$	0.706	0.542	0.529	0.583	0.833	0.833
$\hat{\rho}_{E}$	0.687	0.528	0.466	0.545	0.830	0.832

[1/] Using the estimators from the principal components ($\hat{\rho}_{CP}$), from the principal components ($\hat{\rho}_{CPC}$) with previously classified genotypes and from the structural analysis ($\hat{\rho}_{E}$); [2/] TNFC: total number of fruits harvested; TNHF: total number of healthy fruits; TWFS: total weight of fresh seeds; MWFSF: mean weight of fresh seeds per fruit; SPWF: percentage of wasted fruit due to presence of witches' broom or other disease symptoms, damage by wild animals or germinated seeds and PWFWB: percentage of wasted fruits due only to the occurrence of witches' broom.

Table 4. Correlation coefficients (r) between mean yield measurements taken at maturity and mean yield measurements of one, two, three and four successive years of the pre-climax period in a cocoa hybrid experiment.

Pre-climax period	Correlation coefficient (r)	
	TNFC[1/]	SPWF[2/]
1982	0.63	0.86
1983	0.69	0.83
1984	0.69	0.94
1985	0.75	0.87
1982 – 1983	0.71	0.86
1983 – 1984	0.74	0.90
1984 – 1985	0.77	0.92
1982 – 1983 – 1984	0.72	0.91
1983 – 1984 – 1985	0.76	0.90
1982 – 1983 – 1984 – 1985	0.75	0.90

[1/] TNFC: total number of fruits harvested; [2/] SPWF: percentage of wasted fruit due to presence of witches' broom or other disease symptoms, damage by wild animals or germinated seeds.

Soria and Esquivel (1967) and Atanda (1972).

A single SPWF measurement taken between 1982 and 1985 was sufficient to satisfactorily predict the real hybrid value (Table 4). As PWFWB measurements were not taken in the pre-climax period, the possibility of selection based on assessments made in this period could not be observed. Correlation studies were not made for TNHF, TWFS and MWFSF, as the R^{2*} values obtained for these traits were smaller than 0.9 (Table 2).

Bartley (1970) analyzed the frequency distribution of weight of fresh seeds per plant in experiments with cocoa clones and hybrid in Trinidad. The author reported that yield data from trees in the first production years are not satisfactory for assessment of the individual tree performance. According to Bartley, this assessment should be carried out from the 8th year after planting. Dias et al. (1996) reached similar conclusions after assessing an experiment involving five cocoa cultivars, carried out in Espirito Santo state. In the present experiment, as a low TWFS repeatability value ($\hat{\rho}_{AV}$=0.466) was found at maturity (Table 2), this may be an indication that the use of the assessments made only in the pre-climax period, at least for this trait, are not sufficient to discriminate between hybrids. This sufficiency depends, obviously, on the degree of selection accuracy determined by the breeder.

Concerning the discrepant results for determining the period necessary to assess cocoa genotype yield, Almeida (1991) reported that the occurrence of atypical climatic periods, the establishment of experiments in locations which have inappropriate soil and climate conditions for the crop, and/or bad maintenance of these experiments can contribute in masking or delaying the expression of the genotype yield potential. Consequently, genotypes under selection would require a longer assessment period. Furthermore, as observed in this study, the assessment period may also depend on the yield component under investigation.

The measurements taken between 1982 and 1985 were also used to estimate repeatability (Table 5). The $\hat{\rho}_{AV}$ SPWF values obtained for the pre-climax and maturity periods were similar (Tables 2 and 5). Thus the consistency of the relative position of the hybrid during the successive measurements was similar in the two assessment periods. However, this does not necessarily mean that the best or worst hybrid in a period is the best or worst in another period. Due to this fact, inferences using estimates of $\hat{\rho}$ based on the assessments made at the initial fructification phase should be made with caution. The $\hat{\rho}_{AV}$ values obtained for the pre-climax and maturity periods for TNFC, TWFS and, mainly TNHF and MWFSF, were more discrepant than those obtained for SPWF. Consequently, the consistency of the relative position of the hybrid during the successive measurements was less similar in the two assessment periods. This reinforces the idea that only measurements taken at maturity should be used to calculate $\hat{\rho}$ for selection purposes.

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RESUMO

Repetibilidade de rendimento e o período necessário para a avaliação de híbridos de cacau

Estimativas de repetibilidade foram obtidas de um experimento realizado no Estado de Rondônia, com o intuito de definir o período necessário para discriminar híbridos de cacau com relação a rendimento. Os componentes de rendimento avaliados foram número total de frutos coletados (TNFC), número total de frutos sadios (TNHF), peso total de sementes úmidas (TWFS), peso médio de sementes úmidas por fruto (MWFSF), percentagem de frutos não-aproveitáveis

Table 5. Analyses of variance and repeatability estimates[1/] for the yield components[2/] assessed in the pre-climax period of a cocoa hybrid experiment.

Sources	df	Mean squares				
		TNFC	TNHF	TWFS	MWFSF	SPWF
Hybrids	19	29935.578 [3/]	22839.545 [3/]	137.514 [3/]	700.284 [3/]	352.672 [3/]
Years	3	249663.630 [3/]	33595.865 [3/]	416.686 [3/]	195.363 [3/]	4653.762 [3/]
Residue	57	1645.386	1354.267	13.660	15.484	16.009
Mean		350.080	231.425	21.878	96.400	30.778
C.V. (%)		11.587	15.901	16.893	4.082	12.999
$\hat{\rho}_{AV}$		0.811	0.798	0.693	0.911	0.840
$\hat{\rho}_{CP}$		0.836	0.826	0.739	0.929	0.906
$\hat{\rho}_{CPC}$		0.870	0.833	0.735	0.932	0.905
$\hat{\rho}_{E}$		0.835	0.825	0.739	0.929	0.906

[1/] Using the estimators from the ANOVA ($\hat{\rho}_{AV}$), from the principal components ($\hat{\rho}_{CP}$), from the principal components with previously classified genotypes ($\hat{\rho}_{CPC}$) and from the structural analysis ($\hat{\rho}_{E}$); [2/] TNFC: total number of fruits harvested; TNHF: total number of healthy fruits; TWFS: total weight of fresh seeds; MWFSF: mean weight of fresh seeds per fruit and SPWF: percentage of wasted fruit due to presence of witches' broom or other disease symptoms, damage by wild animals or germinated seeds; [3/] $P<0.01$.

(SPWF) e percentagem de frutos não-aproveitáveis devido à ocorrência de vassoura-de-bruxa (PWFWB). Com exceção dos dois últimos caracteres (valores acima de 0,8), as estimativas de repetibilidade obtidas foram relativamente baixas (valores inferiores a 0,65), ao se utilizar o estimador de ANAVA e as avaliações tomadas no período de maturidade. Com base nestas estimativas, concluiu-se que três medições são necessárias, a partir do 8^0 ano de plantio, para realizar o processo seletivo com acurácia acima de 70%, para todos os caracteres avaliados. Levando-se em consideração apenas a média de dois anos de avaliação do período de pré-clímax, foi possível estabelecer, com o valor real dos híbridos, correlação acima de 0,70 para os caracteres número total de frutos coletados e percentagem de frutos não-aproveitáveis.

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