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Repeatability of yield and girth growth traits in rubber tree clones of series IAC 300

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ABSTRACT – *This study aimed to estimate the repeatability coefficients, to compare the efficiency of methodologies used in the estimation process, and further to determine the minimal number of evaluations in the selection of rubber tree [*Hevea brasiliensis *(Willd. ex Adr. de Juss.) Muell. - Arg.] clones. The following methodologies were used: analysis of variance; principal component analysis based on the correlation matrix together with the phenotypic variances and covariance matrix; and the structural analysis. The r values for girth growth varied from 0.77 to 0.79 and rubber yield from 0.39 to 0.52. It was therefore admitted that the principal component method based on the correlation matrix as well as for the phenotypic variances and covariance matrix are the most efficient to estimate the coefficient of repeatability. At an accuracy of 90% and 80%, two measurements of girth growth and four to six measurements of rubber yield would be necessary for the selection of rubber tree clones, respectively.*

Key words: *Hevea brasiliensis,* plant breeding, clone selection, rubber yield.

INTRODUCTION

The rubber tree [*Hevea brasiliensis* (Willd. ex Adr. de Juss.) Muell. - Arg.] is a valuable market species owing to the multiple use of rubber in the industry. *Hevea* is widely distributed in the countries of South America. *Hevea* species are indigenous to Bolivia, Colombia, French Guiana, Guayana, Peru, Surinam, and Venezuela. With exception of *H. microphylla* they are all found in Brazil, the center of origin (Webster and Paardekooper 1989).

In the beginning of the century Brazil was the world's main rubber producer and exporter. By 2006, Brazil produced 94 thousand tons of dry rubber, which is only 1.2% of the world production, while the domestic consumption amounted to 286 thousand tons (Rossman et al. 2006).

The increase of rubber-producing area requires the use of clones with high yield potential and excellent girth growth. The highest possible number of progenies must be evaluated to increase the chances of capturing desirable allele associations in the new clones.

Usually, three selection stages are involved and 25 to 30 years are required until the clones for large-scale planting can finally be chosen. This protracted breeding process has led to reinforced investment in studies of genetic parameters to maximize the selection progress. The genetic variance, heritability, repeatability, and gains obtained by different selection methods are of particular interest for breeders.

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The repeatability coefficient of agronomical traits represents an effective tool to estimate how many years genotypes must be evaluated to warrant a high precision.

The concept of repeatability can be expressed as the correlation between measures of a given trait in an individual, repeated in time or space. This coefficient expresses the proportion of total variation that is explained by variations owing to the genotype and environment (Cruz and Regazzi 1997). According to Falconer (1987), this coefficient defines the upper limit of heritability and can optimize the efficiency and reduce the costs of the selection process.

Nowadays the repeatability coefficients are estimated by the analyses of variance and principal components, also denominated multivariable methods.

Repeatability estimates have been used in several studies with perennial crops, as reported for cacao (Dias and Kageyama 1998), coffee (Costa et al. 2001), mango (Costa 2003), coconut (Farias Neto et al. 2003), peach-palm (Oliveira et al. 2004), and peach (Albuquerque et al. 2004). However, the number of measurements for rubber yield and girth growth traits in the selection of rubber tree clones is still undefined.

The study objectives were the estimation of the repeatability coefficient, a comparison of the efficiency of methodologies used for this purpose as well as the determination of the minimum number of evaluations needed to warrant a precise selection of the rubber tree clones.

MATERIAL AND METHODS

Originally the plant material consisted of 41 *Hevea* clones of the series IAC 300 obtained by controlled pollination between 1984 and 1988. One and a half-year-old rootstock seedlings raised in nurseries were used to bud-graft rubber clones. The seedlings were grafted in December 1991. The successful bud grafts were uprooted and planted in polyethylene bags. After the appearance of the first flush leaves in January 1992, the experiment was transferred to the field.

Rows were spaced 7 m and the trees 3 m apart. The experimental plots were fertilized with a NPK mixture applied according to recommendations of the Instituto Agronômico. Dead plants were replaced with spares during the first year after planting to maintain the planting density, but were not scored. A randomized complete block design was used with four replicates and six plants per plot.

The experiment was conducted at the Experimental Station of Votuporanga, São Paulo State, Brazil (lat 20º 25' S, long 49º 59´ W and alt 450 m asl) on a podzolized sandy soil. The climate is tropical continental with a wet summer and dry winter with lower temperatures. The average annual temperature and rainfall are 22.3 ºC and 1,420 mm, respectively.

The girth (circumference in cm) of each tree was measured annually for six years after the trees had reached a girth of 45 cm or more. The tapping system was 1/2 S d/4 6d/7. ET 2.5% La 8/y (a half-spiral cut around the stem tapped every four days, six days of tapping followed by one day of rest, stimulated with 2.5% ethephon, with lace application, eight times a year). Yields were recorded on days when normal tapping was possible, which starts at about 7:00 am, also during six years (1998 to 2003). The dripping latex was collected in plastic cups. Once the latex flow came to a stop, the rubber was coagulated in the same cup by adding two percent of acetic acid solution and stirring it well. The coagulated rubber in every cup was made into "biscuit". The dried rubber biscuits were strung on a wire tied to each tree for about 30 days. Then they were weighed and the dry rubber content for each tree was recorded.

The methodologies used to estimate the coefficient of repeatability were: analysis of variance in which the temporary effect is removed from the error (ANOVA) Cruz and Regazzi (1997); analysis of the principal components obtained from both the correlation matrix (PCCOR) and the phenotypic variances and covariance matrix (PCCOV) (Abeywardena 1972, Rutledge 1974); and structural analysis based on the theoretic eigenvalue of the correlation matrix or mean correlation (EVCOR) (Mansour et al. 1981).

The software Genes (Cruz 2001) was used for the genetic-statistic analysis. The statistical model used for the variance analysis $Y_{ij} = u + g_i + a_j + \varepsilon_{ij}$ where, Y_{ij}: is the observation of the i^{th} genotype (clone) in the j^{th} year; u: is the general mean; g_i: is the effects of the i^{th} clone under influence of the permanent environment (i=1,2,...p); a_j: is the fixed effect of the year in the j^{th} measurement (j= 1,2,...η); ε_{ij}: is the experimental error

Table 1. Summary of the variance analysis of girth growth (GG) and rubber yield (RY) traits of six years of experiments with 41 rubber tree clones series IAC 300

Sources of variation	df	Mean square	
		GG (cm)	**RY** (g tapping^{-1})
Years	5	2363.19**	858.22**
Clones	40	141.31**	569.01**
Error	200	6.47	116.58
Mean		57.30	37.21
CV (%)		4.43	21.02

** P < 0.01

established by the temporary effects of the year in the jth measurement of the ith genotype.

Once the repeatability was estimated (r), the number of measurements required to predict the real genotype value (η_0) with the desired value of the genotypic determination coefficient (R^2) was obtained by the expression: $\eta_0 = R^2 (1-r)/(1-R^2) r$, with genotypic determination values (R^2) of 0.80, 0.90 and 0.99.

The determination coefficient (R^2), which represents a confirmation of the real value prediction for the selected individuals based on (n) years was obtained by the expression: $R^2 = nr/1+ r (n-1)$.

RESULTS AND DISCUSSION

The mean square values, resulting from the analysis of variance, using a model with two variation factors (years and clones), are listed in Table 1. It is possible to observe significant differences in the clones for the evaluated traits. This evidences the occurrence of genetic variability in the clones which is a basic requirement for the selection of superior genotypes. The same variation was observed in relation to the year effect. A similar situation was observed over a few years by Gonçalves et al. (1990), who studied the rubber yield of a population of 211 individuals derived from clone Fx 25 by open pollination in Pariquera-açu, state of São Paulo.

Experimental coefficients of variation (CV) indicated a good precision (between 4.43% and 21.02%), respectively, for girth growth and rubber yield. It must be emphasized that in this case the use of a standard clone as rootstock, as for example clone GT 1, would decrease the variations among the different clones for the traits under study. However, the higher magnitude of variation coefficients for the trait rubber yield reinforces the need for a control of the experimental procedures such as an increased plot size and number of replications, aiming at more reliable results.

The repeatability estimates and determination coefficients for girth growth and rubber yield traits are shown in Table 2. The magnitudes of the coefficients of repeatability and determination for girth growth were high (r ranging from 0.77 for ANOVA to 0.79 for PCCOR) and R^2 over 95%, reflecting the accuracy of the evaluation of the phenotypic values, the clone stability and the strong genetic control for the evaluated trait. In another study, Gonçalves et al. (1998) reported values ranging from 0.52 to 0.75 for girth growth in six years of evaluation.

The rubber yield values obtained by the different methods differed most, with estimates of the repeatability coefficient ranging from 0.39 (ANOVA) to 0.52 (PCCOV) and of the determination coefficient from 79.51% to 87.05%. According to Lopes et al. (2001), when the estimates of the repeatability coefficient are lower, the differences among the results obtained by different methods increase. This observation was confirmed in our study. It was further observed that rubber yield was more influenced by environmental effects than girth growth. Vasconcellos et al. (1985) argues that the seasonal factor can not be isolated from the experimental error by variance analysis, resulting in lower estimates of the repeatability coefficient.

In selection studies, traits with estimates of repeatability and determination coefficients of over 0.75 and 98%, respectively, should be prioritized since they contribute to the identification of the superior genotypes.

With regard to the four different methods used to determine the estimates, it was observed that the principal components methods employing the correlation matrix (for girth growth) and also for the phenotypic variances and covariance matrix (for rubber

Table 2. Coefficients of repeatability (r) and determination (R^2) by different methods for the traits girth growth (GG) and rubber yield (RY), in six years of experiments with 41 rubber tree clones series IAC 300

Methods[1]	GG		RY	
	r	R^2 (%)	r	R^2 (%)
ANOVA	0.77	95.42	0.39	79.51
PCCOV	0.78	95.65	0.52	87.05
PCCOR	0.79	95.85	0.42	81.66
EVCOR	0.78	95.67	0.45	83.34

[1]ANOVA: analysis of variance; PCCOV: analysis of the principal components/phenotypic variances and covariance matrix; PCCOR: analysis of the principal components/correlation matrix; EVCOR: structural analysis

Table 3. Estimates of the number of measurements (η_0) required to predict the real genotype value for the traits girth growth (GG) and rubber yield (RY) considering different methods and coefficients of determination of 80%, 90% and 99% in six years of experiments with 41 rubber tree clones series IAC 300

Estimator[1]	GG			RY		
	80 %	90 %	99 %	80 %	90 %	99 %
ANOVA	1	3	28	6	13	123
PCCOV	1	2	27	4	7	78
PCCOR	1	2	25	5	11	113
EVCOR	1	2	25	6	14	134

[1] ANOVA: analysis of variance; PCCOV: analysis of the principal components/phenotypic variances and covariance matrix; PCCOR: analysis of the principal components/correlation matrix; EVCOR: structural analysis

yield) are more appropriate to estimate the coefficient of repeatability in different rubber tree clones. This efficiency of the principal components method can be explained by the suitability for situations when the evaluated clones present cyclical performance of the studied traits. The results obtained here can be considered good since they are in agreement with Vasconcellos et al. (1985), Farias Neto et al. (2003) and Oliveira et al. (2004) who investigated the repeatability coefficient in different traits for rubber tree, coconut and peach palm, respectively.

The estimates of the minimum number of measurements needed to predict genotypic values at 80, 90 and 99% reliability by the different methods were very similar for girth growth. On the other hand, these values differed for the trait rubber yield, especially by the principal component analysis with phenotypic variances and covariance matrix (PCCOV) (Table 3).

For the trait girth growth, at least one or two measurements were needed to predict genotypic values of 80 and 90% reliability by the different methods, with exception of the analyses of variance (ANOVA). In practice, the best plants can be identified by a double girth measurement in evaluation trials, since these same plants continue to be superior until the end of the evaluation period.

A larger number of measurements is required for the trait rubber yield. At least four and seven annual measurements were necessary to obtain a determination coefficient of 80 and 90%, respectively, through the use of the principal component analysis with phenotypic variances and covariance matrix (PCCOV) (Table 3). These results, together with the presence of significant years and clones (Table 1), support the hypothesis that many years are necessary for a precise estimate of the performance of the study clone for the phenotyped (rubber yield) trait.

In both cases (girth growth and rubber yield), a higher accuracy (99%) would entail increased costs and require at least 25 and 78 years of evaluation, respectively.

In general, at least two measurements (for girth growth) and four (for rubber yield) are needed for an effective selection of rubber tree clones from the 7th year after planting onwards. The determination of this period is in line with results obtained by Gonçalves at al (1990), where the authors obtained coefficients of repeatability from 0.67 to 0.89 for rubber yield in the 2nd and 6th year of evaluation. For rubber trees, a period of four years must not be considered long, once the juvenile period is protracted.

CONCLUSIONS

Our results show that the principal component methods based on the correlation matrix and also for the phenotypic variances and covariance matrix are most appropriate to estimate the coefficient of repeatability in different rubber tree clones. It was further observed that the estimates can increase the precision in evaluations to obtain new rubber tree clones. For the variables under study, two and four to six measurements from the 7th year after planting onwards allow for the selection of genotypes with at least 90 and 80% precision for girth and rubber yield, respectively.

Repetibilidade de caracteres de produção e vigor em clones de seringueira da série IAC 300

RESUMO – *Os objetivos desta pesquisa foram estimar coeficientes de repetibilidade, comparar a eficiência das metodologias utilizadas no processo de estimação, e determinar o número de avaliações necessárias à seleção de clones de seringueira. As metodologias utilizadas constaram da análise de variância; dos componentes principais obtidos da matriz de correlações e da matriz de variâncias e covariâncias fenotípicas e da análise estrutural. Verificou-se que em relação ao caráter perímetro os valores de r variaram de 0,77 a 0,79 e quanto à produção, os valores foram de 0,39 a 0,52. Constatou-se também que o método de componentes principais utilizando-se tanto a matriz de correlações quanto a de variâncias e covariâncias fenotípicas são mais efetivos para estimar os coeficientes de repetibilidade. Observou-se que são suficientes duas medições de perímetro e no mínimo de quatro a seis anos de produção para seleção de clones, com precisão de 90 e 80%, respectivamente.*

Palavras-chave: *Hevea brasiliensis*, melhoramento genético, seleção clonal, produção de borracha.

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