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Estimates of genetic parameters for the rubber yield and secondary traits in rubber tree

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ABSTRACT

The objective of this study was to estimate genetic parameters of rubber yield and morphological traits of the plant and structural system laticiferous in open pollinated progeny of rubber tree [*Hevea brasiliensis* (Wild. ex Adr. Juss.) Muell. Arg.; Euphorbiaceae] for indirect selection effect. The progeny was obtained from 22 clones from Asia and Africa by phenotypic selection aiming at yield and vigor of a population of rubber tree established at Central Experimental Center in Campinas, Agronomy Institute. Progeny trials were installed in experimental stations from Jaú, Pindorama and Votuporanga, in a randomized block design, five replications and 10 plants per plot, spaced 2.0 × 2.0 m. Fourteen traits have been evaluated such as rubber yield, girth, morphological and laticiferous system traits at three years old. The genetic parameters were estimated using the software Selegen-Reml/Blup. The progeny has showed genetic variability for most traits, desirable situation in breeding programs. Progeny means heritability lead to high accuracies for most traits, which infers greater estimates reliability. Girth has a high relative variation coefficient indicating fair chances of better results with the selection of vigor for that trait.

1. Introduction

The evaluation of the rubber tree genotypes from the traits parameter estimates is essential for superior clone selections and planning promising program crossings (Silva et al., 2013). Several studies are developed aiming at the genetic breeding of rubber tree, however, more researches are needed to yield parameters estimates, involving morphological and structural laticiferous system traits. This is due the fact most studies involved few traits (Gonçalves et al., 1998b; Silva et al., 2013), are more specific on rubber yield, vigor and some of plant morphology traits.

Due to unbalancing experiments with perennial species, the usage of the procedure Reml (restricted maximum likelihood) is important for estimating variance components in disequilibrium conditions (Farias Neto and Resende, 2001; Furlani et al., 2005). The use of Reml/Blup (restricted maximum likelihood/best linear unbiased prediction) methodology is used in various species, such as rubber tree (Bombonato et al., 2015), eucalyptus (Costa et al., 2015), coffee (Pereira et al., 2013), common bean (Bertoldo et al., 2009), cowpea (Barros et al., 2011), rice (Borges et al., 2010) and wheat (Pimentel et al., 2014). The information generated in this study will allow better understanding of the genetic parameters and the application of the species genetic breeding programs.

Thus, the objective was to estimate, among other parameters, heritability and variation coefficients for rubber yield, plants morphological traits and structural laticiferous system traits in rubber tree open pollinated progeny for indirect selection effect using the methodology Reml/Blup.

2. Material and methods

2.1. Material

It was used in the study open-pollinated progeny obtained from selected 22 Asian and African clone seeds phenotypically aiming at yield and vigor of a population-based rubber tree clones established at Central Experimental Center (CEC), in Campinas, Agronomy Institute (IAC).

The seeds corresponding to each progeny were germinated, transplanted to polyethylene bags, and after six months development, transplanted to the definitive site. Progeny trials were

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Table 1
Geographical and climate characteristics of the sites in which the progeny trial rubber tree was conducted: Jaú, Pindorama and Votuporanga, State of Sao Paulo.

Characteristics	Jaú	Pindorama	Votuporanga
Latitude (S)	22°10′	21°06′	20°15′
Longitude (W)	48°19′	48°32′	49°34′
Altitude (m)	523	534	525
Climate classification Köppen	Aw	Aw	Aw
Average annual temperature (°C)	22.7	23.3	24.3
Average annual rainfall (mm)	1254.2	1425.7	1448.7
Soil type	Lixisol	Acrisol	Acrisol

Source: Cepagri, 2015. Aw: Tropical rainy climate with dry winter.

installed in experimental stations from Jaú, Pindorama and Votuporanga, which represent the state of São Paulo productive areas, in Brazil.

The experimental design, in three sites, was a randomized block design with five replications. The plots were linear, consisting of 10 plants, spaced 2.0 × 2.0 m. Table 1 shows edaphoclimatic characteristics and geographical coordinates.

2.2. Methods

2.2.1. Traits analyzed

In the study of progeny trials were evaluated the yield, vigor, morphological and structural laticiferous system traits. For structural laticiferous system traits were collected three samples of bark per plant, 15 cm from the ground, with the aid of an extractor in the third year of planting. The morphological and botanical traits were represented by the average of three samples per useful plant, at three years of age.

Rubber yield and girth

(a) *Rubber yield*: obtained by Hamaker Morris-Mann test (HMMm), modified for three-year-old plants. The opening of the panels were opened at 15 cm above the soil, using the S/2 d/3 system (half spirals cut and the interval tapping, in this case, one tapping every three days), discarding the first five tapping samples that corresponded to the adaptation of the panel. Three tests were carried out of 10 descending tappings on the individuals of each progeny. The results were expressed in grams of dry rubber yield per tapping per tree (g.t^{-1}.t^{-1}). Yield was estimated by the average of the three tests.
(b) *Girth*: obtained when the plants were three years, given to 50 cm from the ground with the aid of tape measure, and expressed in centimeters (cm).

Laticiferous system traits

(c) *Bark thickness*: Measuring, three barks samples were collected from each plant, using a gouge, measured with a digital caliper and the mean expressed in millimeters. The measurements were made in the third year.
(d) *Number of latex vessel rings*: bark samples that were blocked in histological paraffin. It was used the radial longitudinal type of histological cut. To obtain this cut the cambium rings were placed in parallel position in relation to the workbench at the time of inclusion in paraffin. The samples were sectioned in a microtome 125 micras thick, dehydrated in 90% ethylic alcohol and stained with Sudam III. The number of latex vessel rings was counted under an optical microscope with 10 x amplitude.
(e) *Average distance between consecutive latex vessel rings*: was determined based on the distance between the first and last ring, in micra (μ), after prepared into microscopic slides for histological laboratory.

Morphological traits

(f) *Leaf storey*: obtained in the 2nd year (unit) with two years of age.
(g) *Petiole length*: distance between the insertion of leaflets and leaf stem, expressed in centimeters (cm).
(h) *Petiole diameter*: diameter of the stem of a mature leaf, with digital caliper and expressed in centimeters (cm).
(i) *Petiole index*: obtained by expression $PI = \frac{PD}{PL}x100$, as a percentage, where: PD = diameter of the petiole and PL = petiole length.
(j) *Leaflet length*: obtained by average between the lengths of the leaflets, expressed in centimeters (cm).
(k) *Leaflet width*: determined from the average of the diameters of all leaflets of the leaves with digital caliper and expressed in centimeters (cm).
(l) *Leaf width*: distance between the banks in the central region of the leaflets expressed in centimeters (cm).
(m) *Leaf index*: the ratio of the average leaflet width (LWt) (measured in half the length) and the length of leaves (LL), represented by the equation: $LI = \frac{LD}{LL}x100$, expressed as a percentage (%).
(n) *Leaf area*: determined by the formula of Lim and Narayanan (1972): $LA = LLxLWxR^2$, where LL = leaflet length; LW = width of the central part of the leaflet and R^2 = linear regression coefficient (R^2 = 0.56). The unit is expressed in square centimeters (cm^2).

2.2.2. Statistical analysis

Genetic and phenotypic parameters were estimated by software Selegen-Reml/Blup (Resende, 2007b).

2.2.3. Individual analysis

Individual genotypic and phenotypic parameters estimates were obtained, according to Resende (2007a), using the method of linear mixed modeled by Reml/Blup (restricted maximum likelihood/best linear unbiased prediction) that evaluates individuals in open pollinated progeny in out crossing plants, with multiple observations per plot, evaluation at a site and a harvest, completed blocks (model 93). The statistical model is the following:

$$\mathbf{y} = \mathbf{Xr} + \mathbf{Za} + \mathbf{Wp} + \mathbf{e} \tag{1}$$

Where, **y**: data vector; **r**: vector replication effects (assumed to be fixed) added to the general average; **a**: vector of individual genetic additive effects (assumed to be random); **p**: vector of the effects of plots (random); **e**: error vector (random). The capital letters represent the incidence matrices for these effects.

The parameter estimates obtained by the individual model were $\hat{h}^2_a$: individual plant in the narrow sense heritability, i.e., the additive effects; $\hat{c}^2_{plot}$: coefficient determining the effects plot; $\hat{h}^2_{mp}$: progeny mean heritability, assuming complete survival; $\hat{r}^2_{\hat{a}a}$: accuracy of progeny selection, assuming complete survival; $\hat{h}^2_{ad}$: additive heritability within plot; CV_g (%): genotypic coefficient of variation; CV_e (%): experimental coefficient of variation; CVr: relative coefficient of variation.

The formulas are displayed below:

$$\hat{h}^2_a = \frac{\hat{\sigma}^2_a}{\hat{\sigma}^2_p} = \frac{\hat{\sigma}^2_a}{\sigma^2_a + \sigma^2_{plot} + \sigma^2_e} \tag{2}$$

$$\hat{h}^2_{ad} = \frac{0.75\hat{\sigma}^2_a}{0.75\hat{\sigma}^2_a + \hat{\sigma}^2_e} \tag{3}$$

$$\hat{h}^2_{mp} = \frac{0.25\hat{\sigma}^2_a}{0.25\hat{\sigma}^2_a + \frac{\hat{\sigma}^2_{plot}}{r} + \frac{0,75\hat{\sigma}^2_a + \hat{\sigma}^2_e}{nr}} \tag{4}$$