Industrial Crops & Products 118 (2018) 118–124

Contents lists available at ScienceDirect

Industrial Crops & Products

journal homepage: www.elsevier.com/locate/indcrop

Selection strategies for growth characters and rubber yield in two populations of rubber trees in Brazil

Cecília Luzia Dourado[a,*], Marcela Aparecida de Moraes[b], Patrícia Ferreira Alves[c], Thaisa Yuriko Kuboyama Kubota[c], Janaína Rodrigues da Silva[c], Juliana Prado Moreira[c], Alonso Ângelo da Silva[c], José Cambuim[c], Paulo de Souza Gonçalves[d], Mario Luiz Teixeira de Moraes[c]

[a] Universidade do Estado de Mato Grasso/UNEMAT, CP 08, Rua Prof. Dr. Renato Figueiro Varella, Nova Xavantina, Mato Grosso State, 78690-000, Brazil
[b] Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto/USP, Ribeirão Preto, SP, 14040-901, Brazil
[c] Faculdade de Engenharia de Ilha Solteira/UNESP, Ilha Solteira, SP, CP 31, 15385-000, Brazil
[d] Instituto Agronômico de Campinas/IAC, Campinas, SP, CP 28, 13012-970, Brazil

ARTICLE INFO

Keywords:
Hevea brasiliensis
Estimation of genetic parameters
Rubber yield
Multi-effect index
Selection gains

ABSTRACT

The objective of this work was to evaluate the genetic parameters and estimate genetic gains in two populations of *Hevea brasiliensis*. The first population of the study is originated from the primary forest of Rio Branco – Acre (wild population – PS), and the other population is originated from clonal matrices (improved population – PM). Thirty-seven progenies were evaluated at 23 years for PS. For PM, 31 progenies at eight years of age were evaluated for growth traits and dry rubber yield. Estimates of the genetic parameters were made using the univariate linear mixed-model additive model REML/BLUP and gains in selection by the Multi-Effects Index (MEI) method. The selection strategies of 50%, 40% and 22% of individuals for the character of dry rubber yield (PBS) and stem perimeter (PAP) using the multi-effects index revealed high and low selection gains in both populations. For MP, the strategy of selection between and within progenies was more appropriate and for PS, the individual selection. The gains obtained in the selection were 54% for the PBS character in the improved population of 0.46% for the PAP character for the wild population.

1. Introduction

The effectiveness of the rubber tree breeding program [*Hevea brasiliensis* (Willd. Ex Adr. de Juss.) Muell. – Arg.] depends on the availability of diversity in the germplasm collection. This diversity allows the obtainment of clones with high production potential, which are resistant to diseases, with products of better quality and adapted to adverse environmental conditions, among other attributes. The Amazon forest is the genetic diversity center of the rubber tree and it is being threatened by deforestation, which compromises the expansion of germplasm collections, mainly in terms of new attributes valued in rubber tree crop (Ambrósio et al., 2013).

In this context, in 1991 Engineering College at Ilha Solteira/UNESP, SP, acquired seeds from open pollinating rubber trees originating from the primary forest of Rio Branco-Acre to settle a germplasm bank, which objective was to conserve the genotypes and, in the future, select them to establish an improvement program at the institution. Subsequently, in 2006, clonal test seeds were obtained from the Center of Rubber Tree and Agroforestry Systems, IAC (Agronomic Institute), with a certain degree of improvement, which would support the continuation of the breeding program.

The State of São Paulo has an improvement program, aimed at increasing production, associated with other desirable secondary characteristics, such as vigor, bark thickness and others (Aguiar et al., 2012). The vigor, measured by the stem perimeter, is the most important character to determine the clone precocity, allowing the rubber producer to have a faster financial return on their investment. The idea of the present study was to establish selection strategies aiming not only the production of latex, but also the quality of wood, guaranteeing to the producer the increment of income at the end of the crop cycle. Today, much of the wood of the rubber tree is destined for energy, adding low value to the product; the present study aimed to value the use of wood.

For the purpose of conducting an improvement program, knowledge of the genetic characteristics of study populations is essential to make selection more effective. Qualitative data are useful for estimating

* Corresponding author.
E-mail address: douradocl.cl@gmail.com (C.L. Dourado).

https://doi.org/10.1016/j.indcrop.2018.03.005
Received 26 September 2017; Received in revised form 28 February 2018; Accepted 2 March 2018

genetic variation and based on heritability data and genetic correlations between economically important variables, genetic gains can be estimated after successive selection cycles. The quantitative data determine the most appropriate selection strategies to overcome the difficulties in the selection of superior genotypes and to increase knowledge about the genetic structure in populations of rubber trees (Silva et al., 2012).

One of the tools used in plant breeding programs are the mixed models, such as the Restricted Maximum Likelihood (REML), which is a generalization of Variance Analysis (ANOVA) for more complex situations and which allows the estimation of variance components and genetic parameters for the situation of unbalanced data and heterogeneity of variances. Another interesting procedure for the prediction of genetic values is the BLUP (Best Linear Unbiased Prediction), being more appropriate when considering the genotypic effects as random, aiming to obtain the BLUPs of said effects (Resende, 2004). The REML/BLUP methodology is used in several species, such as in *Hevea* (Souza et al., 2017), *Eucalyptus* (Costa et al., 2015); *Pinus* (Santos et al., 2016), *Acacia* (black wattle) (Dunlop et al., 2005). Resende (2016) suggests the use of the Selegen-REML/BLUP software for the application of analysis of mixed models in the estimation of variance components and estimation of genetic parameters to optimize the conduction of plant breeding programs.

For Resende (1995), the adoption of efficient forest improvement strategies depends on the use of accurate selection methods. To do so, the Multi-Effects Index (IME) method can be used, which explores fractions of the additive genetic variance that are not considered in the selection between and within progenies and suggests that a more effective selection could be made by weighing individual values and values of their respective families. In this method, selection is based on genetic measures (net genetic value) and non-phenotypic measures of the candidates for selection (Resende and Higa, 1994). Several studies have been carried out using the MEI method, due to the more expressive gains in selection (Costa et al., 2000a, 2000b; Santos et al., 2016; Arantes et al., 2010; Tung et al., 2010; Silva et al., 2011; Verardi et al., 2013, 2014; Kubota et al., 2015).

Thus, the objective of the present study was to estimate the genetic parameters and gain prediction in selection for growth traits and rubber yield in two progenies of *H. brasiliensis*. With this information, it was possible to verify the value of the genetic variation and the selection of the best selection strategy for the continuation of the breeding program of the species.

2. Material and methods

2.1. Material

The first population described by Paiva et al. (1994) is native to the primary forest of Rio Branco-Acre, generated by open pollination, characterized by not being submitted to any breeding program (PS, wild population) (Table 1). The second one is a population generated by open pollination of selected clonal matrices: 1-12-56-77, 64B 850, Fx (2261 and 3864), GT1, IAC (15, 35, 40, 41, 44, 301, 307 and 311), IAN 873, IRCA 111, MT 45, PB (28/59, 217, 235, 252, 260 and 330), Pind 595/89, PR (255 and 261), RO-I (35 and 110), RRIM (600, 606, 701 and 725), coming from the Center of Rubber Tree and Agroforestry Systems, IAC (Agronomic Institute). Therefore, it is part of an advanced stage improvement program (MP, improved population) (Table 2). The PS progeny test was installed on December 6, 1991, at a spacing of 5 × 3 m, with a randomized block design with 37 progenies distributed in three replications, unbalanced with a maximum of 10 plants per progeny. PM was installed as a progeny test on September 5, 2006, with a randomized complete block design, consisting of 31 treatments (progenies), four replications and linear plots of 10 plants, spaced 3 × 3 m.

The populations are installed as progeny tests at Teaching, Research and Extension Farm (FEPE)/Engineering College at Ilha Solteira/UNESP, located in Selvíria, MS. The approximate geographical location of the experiment area is at latitude 20° 22 '01' S, longitude 51° 25 '08' W and 357 m altitude. The relief is characterized as moderately flat and wavy. The climate of the site is Aw type, by Köppen classification, with an annual mean temperature of 24.5 °C, annual mean humidity of 64.8%, average annual rainfall of 1232.2 mm and average sunshine of 7.3 h/day (Hernandez et al., 1995). The soil was classified as a Distroferric Red Latosol, clay texture (Embrapa, 2013).

Table 1
Wild population (PS) constituted by 37 progenies of open pollination situated in Selvíria, MS.

Progenies	Size of the progenies
1	12
2	13
3	19
4	19
5	16
6	25
7	19
8	13
9	7
10	11
11	17
12	14
13	13
14	12
15	11
16	21
17	19
18	14
19	14
20	3
21	10
22	9
23	3
24	6
25	12
26	9
27	9
28	12
29	7
30	10
31	6
32	8
33	5
34	3
35	7
36	6
37	5
–	–

2.2. Methods

2.2.1. Evaluated characters

The silvicultural characters were evaluated during 2 years (2014 and 2015), being them: a) Commercial height (AC) and total height (ALT) (m); b) stem perimeter at 50 cm above ground level (P50) (cm); c) Stem perimeter at 1,30 m above ground level (PAP) (cm); d) Stem form (FOR), being this one obtained based on the arithmetic average between the two measures obtained by scale of marks from 1 to 5 (Kageyama et al., 1979), in which 1 mark (Trunk with very serious defect; very tortuous trunk), 2 marks (Trunk with severe defect; torso with tortuosity above average), 3 marks [Trunk with defect quite visible; torso with average tortuosity (up to 3,5 m in height)], 4 marks [Trunk with defect barely visible; trunk with tortuosity below average (up to 4,5 m in height)] and 5 marks attributed to the trunk with no blemish or trunk tending to righteousness (> 4,5 m in height). Obtained by the following expression: FOR = (BI + TO)/2, in which BI is the Bifurcation of the stem, with 1 mark (Bifurcation below 1,30 with diameter equal to the main stem), 2 marks (Bifurcation above 1,30 with