Vigor assessment of juvenile rubber tree clones in Northwestern São Paulo State, Brazil[1]

Elaine Cristine Piffer Gonçalves[2*], *Lígia Regina Lima Gouvêa*[3], *Antonio Lúcio Mello Martins*[4], *Roberto Botelho Ferraz Branco*[5], *Paulo de Souza Gonçalves*[6]

10.1590/0034-737X202168060008

ABSTRACT

Besides rubber production, one of the main goals of the genetic improvement of rubber tree [*Hevea brasiliensis* (Willd. ex Adr. de Juss.) Muell. Arg.] is to develop vigorous clones. The objective of the present study was to evaluate the vigor of 34 elite juvenile rubber clones. To this end, three experiments were conducted in the municipality of Pontes Gestal, in the northwest region of the São Paulo State. Each experiment consisted of 10 treatments, and 2 controls in common to the 3 experiments. The experiments were arranged in the randomized block design, with three replications and ten plants per plot, in the 8 m x 2.5 m spacing. Individual and joint analyses of variance were performed. The means were compared using the Dunnett test at 5%. Significant effect of treatments was found in the three experiments and in the joint analysis. The most vigorous clones were not different from the controls in the comparison of means by the individual and joint analyses. The less vigorous clones were statistically different from the others and from the controls, reflecting this difference in the genetic variability observed. The breeding program must consider the lack of difference between the most vigorous clones and the controls when recombining superior clones, since genetic gain depends on variability.

Keywords: joint analysis; Dunnet test; rubber tree girth; genetic variability.

INTRODUCTION

One of the objectives of the genetic improvement program of rubber tree [*Hevea brasiliensis* (Willd. ex Adr. de Juss.) Muell. Arg.] is to seek vigorous clones. The girth is considered a measure of vigor, which determines the age at which a rubber clone can be economically grown and defines the unproductive period of the rubber tree plantation (Gonçalves *et al*., 1999). Gonçalves & Marques (2014) point out that early tapping and good rubber production are possible only in clones that grow vigorously in the juvenile phase. Vigorous plants have a larger tapping area which is reflected in the production (Obouayeba *et al*., 2002). In addition, more vigorous clones are more resistant to wind damage (Gonçalves *et al*., 2006). Another beneficial aspect of vigor is the alternative use as wood when latex production is no longer advantageous (Kronka, 2014).

The importance of assessing the vigor of rubber tree clones has been highlighted in several studies (Gonçalves *et al*., 2011; Gouvêa *et al*., 2012; Silva *et al*., 2014; Alem, *et al*., 2015). The genetic improvement program of the Agronomic Institute of Campinas (IAC) has evaluated elite clones of different clone series in distinct regions of São Paulo State. The IAC 500 series was evaluated in the Northwest region of the state of São Paulo (Gonçalves *et al*., 2011), the IAC 400 series in the Midwest region (Gonçalves *et al*., 2007), and the IAC 300 series in the Center-North (Gonçalves *et al*., 2002) and Northwest (Gonçalves *et al*., 2001a) regions. Thus, the objective of the present study was to evaluate the vigor of 34 elite juvenile rubber clones.

Submitted on May 13th, 2020 and accepted on February 18th, 2021.
[1] This work was Funded by São Paulo State Secretariat of Agriculture and Supply – SAA/SP.
[2] APTA Alta Mogiana, Colina, São Paulo, Brazil. elainegoncalves@apta.sp.gov.br
[3] Instituto Agronômico, Programa Seringueira, Campinas, São Paulo, Brazil. lgouvea@iac.sp.gov.br
[4] APTA Centro Norte, Pindorama, São Paulo, Brazil. lmartins@apta.sp.gov.br
[5] APTA/IAC, Ribeirão Preto, São Paulo, Brazil. branco@apta.sp.gov.br
[6] Instituto Agronômico, Programa Seringueira, Campinas, São Paulo, Brazil. paulogiac@gmail.com
*Corresponding author: elainegoncalves@apta.sp.gov.br

MATERIAL AND METHODS

The experimental evaluation was conducted at the Córrego do Ouro farm, municipality of Pontes Gestal, in the Northwest region of the State of São Paulo, on the geographic coordinates 20º 12' 03'' S; 49º 39' 03'' W. The soil of the area is classified as Red-Yellow Argisol. The clones evaluated belong the collection of the Genetic Improvement Program of the Agronomic Institute of Campinas (IAC) (Table 1). Three experiments were arranged in a randomized block design, with three replications and ten plants per plot spaced 8.0 m between rows and 2.5 m between trees. Each experiment consisted of 10 treatments, using 2 controls (the Malaysian clone RRIM 600 and the Indonesian clone GT1) in common to the 3 experiments. Vigor was assessed by the girth measured at 1.30 m above ground, in three year-old trees.

The individual variance analyses were performed in the design with additional control blocks, joint analysis of variance, and the Dunnett Test at 5%, using the Genes Program (Cruz, 2013). The joint analysis of variance followed the mathematical model Cruz (2006):

$Z_{ijk=}\mu + Te_i + B_{j(k)} + E_k + TeE_{ik} + \varepsilon_{ijk}$, where:

Z_{ijk} = observation of the *i*th treatment in common, in the *j*th repetition of experiment *k*;

Table 1: Rubber tree clones used in experiments in the municipality of Pontes Gestal, São Paulo State, with their respective genealogies

Clone	Genealogy
Experiment 1	
PB 312	RRIM 600 (Tjir 1 x PB 86) x PB 235 [PB 5/51 (PB 56 x PB24) x PB S/78 (PB 49 x PB 25)])
IRCA 111	PB 5/51 (PB 86 x PB 5/78) x RRIM 600 ((Tjir 1 x PB 86)
PB 314	RRIM 600 (Tjir 1 x PB 86) x PB 235 [PB 5/51 (PB 56 x PB24) x PB S/78 (PB 49 x PB 25)])
RRIM 710	RRIM 605 (Tjir 1 x PB 49) x RRIM 71
RRIM 938	PB 5/51(PB 56 x PB24) x RRIM 703 [RRIM 600 (Tjir 1 x PB 49) x RRIM 500 (Pil B84 x PilA 44)]]
RRIM 711	RRIM 605 (Tjir 1 x PB 49) x RRIM 71
RRIM 937	PB 5/51(PB 56 x PB24) x RRIM 703 [RRIM 600(Tjir 1 x PB 86) x RRIM 500 (Pil B84 x PilA 44)]
PB 350	RRIM 600 (Tjir 1 x PB 86) x PB 235[PB 5/51 (PB 56 x PB24) x PB S/78 (PB 49 x PB 25)])
RRIM 600	Tjir 1 x PB 69
GT 1	Primary clone
Experiment 2	
RRIM 713	RRIM 605 (Tjir 1 x PB 49) x RRIM 71
RRIM 714	RRIM 605 (Tjir 1 x PB 49) x PB 49
IAC 35	Fx 25 [(F35L x AVROS 49) x RRIM 600 (Tjir 1 x PB 86)] x RRIM 600 (Tjir 1 x PB 86)
IAC 40	RRIM 608 (Tjir 33 x Tjir 1) x AVROS 1279 (AVROS 256 x AVROS 374)
IAC 300	RRIM 605 (Tjir 1 x PB 49) x AVROS 353(AVROS 164 x AVROS 160)
IAC 301	RRIM 501 (Pil A 44 x Lun N) x AVROS 1518 (AVROS 214 x AVROS 317)
PC 96	PB 5/51(PB 56 x PB24) x RRIM 600 (Tjir 1 x PB 86)
PC 140	PB 5/51(PB 56 x PB24) x RRIM 703 (RRIM 600(Tjir 1 x PB 86) x RRIM 500 (Pil B84 x PilA 44)]
RRIM 600	Tjir 1 x PB 69
GT 1	Primary clone
Experiment 3	
PM 10	-
PR 255	Tjir 1 x PR 107
PB 291	-
IAC 400	GT 711 x RRIM 600 (Tjir 1 x PB 86).
IAC 402	GT 711 ill.(2)
IAC 403	GT 711 ill. (2)
IAC 404	PB 5/63 (PB 56 x PB 24) x AVROS 363
IAC 405	Tjir 1 x RRIM 623 (PB 49 x Pil B 84).
RRIM 600	Tjir 1 x PB 69
GT 1	Primary clone

ill. , = illegitimate (clone obtained from an open pollination donor plant)

Amazonian clone (Fx = Ford crossing); Brazilian clones (IAC = Campinas Agronomic Institute, PM = Michelin Plantations), Indonesian clones (AVROS = Algemene Vereniging Rubberplanters Oostkust Sumatra, GT = Godang Tapen, Tjir = Tjirandji, PR= Poefstation voor Rubber); Malaysian clones (Lun = Lunderston, PB = Prang Besar, Pil = Pilmoor, PC = Promotional clones, Gl = Glenshiield, RRIM = Rubber Research Institute of Malaysia); Indian Clone (RRII = Rubber Research Institute of Ceilon).

μ: experiment overall mean;

Te: effect of the *i*th control (treatment in common)

$B_{j(k)}$ = effect of the *j*th block within the *k*th experiment;

E_k; effect of the *k*th experiment:

TeE_{ik}: effect of the interaction between the treatment in common and the experiment (environment);

εijk; random error

The genetic parameters estimated by this model were Coefficient of Variation (CV%); Genotypic variability ($\hat{\theta}_g^2$); Coefficient of genotypic determination ($\hat{H}_g^2$) ; Coefficient of genetic variation (CV_g %).

RESULTS AND DISCUSSION

The treatment effect was significant for girth in the individual analyses of variances of the three experiments (Table 2). This significance indicates presence of genetic variability for vigor among these clones. In these experiments, in the unfolding of the treatments (clones) in genotypes and controls, it was observed that this variability is among genotypes, the two controls were not significantly different in any of the experiments. The control means were higher than the genotype means. However, the significant effect observed between genotypes and control indicates that the group of genotypes differed significantly from the group of controls only in experiments 2 and 3. The coefficients of variation (CV%) varied from 7.06 to 10.81%. These values were low in experiments 2 and 3 and intermediate in experiment 1, according to Pimentel-Gomes (2000), who considers coefficients of variation below 10% as low and between 10 and 20% as intermediate. Therefore, the observed values indicate good experimental precision. The CV% values in the three experiments were similar to those observed for clones (Alem *et al*., 2015) and progenies (Verardi *et al*., 2012) of rubber trees of the same age.

No significant effect of experiment was found in the joint analysis (Table 3), indicating no significant difference between experiments. The significance of the adjusted treatment, on the other hand, indicates genetic variability among the 26 clones evaluated. Regarding the estimation of parameters, in this analysis the coefficient of experimental variation 1ty is of genetic nature. The coefficient of variation (CVg = 11.13%) was higher than that estimated by Verardi *et al*., (2012) for progenies with the same age (CVg = 5.81%) and is in agreement with Gouvea *et al*. (2010), who evaluated the vigor of 23 rubber clones at the pre-tapping stage (CVg = 10.41%). This parameter expres-

Table 2: Analysis of individual variances, coefficients of variation, and mean girth (cm) of three-year-old rubber clones of three experiments conducted in the municipality of Pontes Gestal, São Paulo State

Source of Variation	D.F.	Mean Squares		
		Experiment 1	Experiment 2	Experiment 3
Blocks	2	8.94	0.30	0.79
Treatments	9	14.66**	11.86**	17.20**
Genotypes (G)	7	17.50**	7.95**	17.02**
Control (T)	1	0.28	0.54	8.40
G. *vs* T	1	9.19	50.57**	27.26*
Residue	18	3.84	1.83	3.38
C.V.(%)		10.80	7.06	9.70
Overall Mean		18.14	19.19	18.94

*, ** significant at 1 and 5% by the F test, respectively.

Table 3: Analysis of joint variance and genetic parameters of the girth (cm) of three-year-old rubber tree clones of three experiments conducted in the municipality of Pontes Gestal, São Paulo State

Source of Variation	D.F.	M.S.	F
Blocks	6	3.25	2.96
Experiment	2	8.98 ns	5.10
Ajusted treatment	25	15.47**	
Residue	56	3.03	
Overall Mean		18.76	
Coefficient of Variation (CV %)		9.28	
Genotipic variability ($\hat{\theta}_g^2$)		4.15	
Coefficient of genotypic determination ($\hat{H}_g^2$)		80.39	
Coefficient of genetic variation (CV_g %)		11.13	

*, ** significant at 1 and 5% by the F Test, respectively.

ses the existing genetic variation as a percentage of the overall mean.

(Table 3-Analysis of joint variance and genetic parameters of the girth (cm) of three-year-old rubber tree clones of three experiments conducted in the municipality of Pontes Gestal, São Paulo State**)**

The mean comparisons by the Dunnett's test, at 5% probability, in the individual analyses are presented in Table 4. The means not accompanied by letters correspond to the clones that differed significantly from both controls. In experiment 1, the controls were not significantly different from the 7 best clones. The only significant difference was found for clone RRIM 710, which had with lower performance than the two controls. In experiments 2, the clones RRIM 713, IAC 40, and IAC 300 differed from the two controls, with lower performance. In experiment 3, the clone PM 10 was significantly different from the two controls, with lower performance, whereas the other clones did not differ from the controls.

(Table 4. Girth means (cm) in three-year-old rubber tree clones of experiment evaluated in Pontes Gestal, São Paulo State**)**

The Dunnet test at 5% in the joint analysis is shown in Table 5. Of the 24 clones in the mean comparisons, only three were significantly different from the 2 controls, regarding to girth means, but with lower performance. The clones RRIM 710, IAC 300, and PM 10, one from each experiment were statistically different. All other clones performed as same as the controls. Alem *et al*. (2015) observed similar results in the vigor assessment of 14 rubber clones at the pre-tapping stage and found that no clone was statistically superior to the control. The similar performance of clones and the controls may be due to the fact that the clones are the result of crossings between previously selected materials (Table 1), with many of them being tertiary clones. According to Gonçalves *et al*. (2001b), primary clones derive from unknown parents obtained from the vegetative multiplication of donor trees with desirable characters. Secondary clones derive from donor trees obtained through controlled crosses between two primary clones, while tertiary clones derive from crosses in which at least one parent is secondary and so on. Thus, it is found that after consecutive selection

Table 5: Girth means (cm) of three-year-old rubber tree clones of joint analysis of three experiments evaluated in the municipality of Pontes Gestal, São Paulo State

Experiments	Clone	Mean
1	RRIM 937	22.30 ab
1	IRCA 111	22.08 ab
3	IAC 404	21.24 ab
1	RRIM 938	20.71 ab
3	IAC 405	20.08 ab
2	IAC 35	19.69 ab
1	RRIM 711	19.45 ab
3	IAC 400	19.15 ab
3	IAC 403	19.11 ab
2	IAC 301	19.06 ab
1	PB 312	18.56 ab
2	PC 40	18.48 ab
1	PB 314	18.20 ab
3	PR 255	17.89 ab
3	PB 291	17.76 ab
1	PB 350	17.50 ab
3	IAC 402	17.45 ab
2	RRIM 714	17.16 ab
2	PC 96	17.14 ab
2	RRIM 713	16.41 ab
2	IAC 40	16.39 ab
1	RRIM 710	15.16
2	IAC 300	14.71
3	PM 10	13.26
	RRIM 600*	20.99 a
	GT 1*	20.26 b

* Controls common to the three experiments

Means followed by the same letter are not significant different from the control by the Dunnet Test at 5%

Table 4: Girth means (cm) in three-year-old rubber tree clones of experiments evaluated in Pontes Gestal, São Paulo State

Clones Experiment 1	Means	Clones Experiment 2	Means	Clones Experiment 3	Means
RRIM 937	20.92 ab	IAC 35	20.85 ab	IAC 404	21.47 ab
IRCA 111	20.70 ab	IAC 301	20.22 ab	IAC 405	20.30 ab
RRIM 938	19.33 ab	PC 140	19.64 ab	IAC 400	19.37 ab
RRIM 711	18.07 ab	RRIM 714	18.32 a	IAC 403	19.33 ab
PB 312	17.18 ab	PC 96	18.30 a	PR 255	18.12 ab
PB 314	16.82 ab	RRIM713	17.56	PB 291	17.98 ab
PB 350	16.12 ab	IAC 40	17.55	IAC 402	17.67 ab
RRIM 710	13.78	IAC 300	15.87	PM 10	13.47
RRIM 600*	19.46 a	RRIM 600*	21.48 a	RRIM 600*	22.03 a
GT 1*	19.03 b	GT 1*	22.08 b	GT 1*	19.67 b

Means followed by the same letter for each experiment are not significant different from the control by the Dunnet Test at 5%. *Controls.

cycles, the clones evaluated in the present study no longer surpass the controls with respect to vigor.

(Table 5. Girth means (cm) of three-year-old rubber tree clones of joint analysis of three experiments evaluated in the municipality of Pontes Gestal, São Paulo State**)**

Overall, all results must be evaluated because there is evidence of genetic variability, but no significant difference was found between superior genotypes and controls. The observed genetic variability occurred because some clones were less vigorous. The individual and joint analyses showed no statistical difference between the clones with the best performance in vigor and the controls. This points to the need to be aware of the genetic variability regarding vigor in rubber tree breeding program and in germplasm bank. The success of the breeding program is highly dependent on the magnitude of the genetic base available in the germplasm banks for cultivar development (Queiroz & Lopes, 2007).

CONCLUSIONS

The genetic variability observed in the study is due to few clones having inferior performance.

The breeding program must consider the lack of difference between the most vigorous clones and the controls when recombining superior clones, since genetic gain depends on variability.

ACKNOWLEDGEMENTS, FINANCIAL SUPPORT AND FULL DISCLOSURE

Dr. Paulo de Souza Gonçalves, in charge of the Rubber Tree Genetic Improvement Program - IAC / APTA, who has been producing new IAC clones for more than thirty years and is our greatest teacher and supporter (inspiration for life and dedication);

Mr. Antônio César Merenda and family, owners of Córrego do Ouro Farm for have always contributed to research and the rubber sector in general;

To friends and Nursery staff: Carina Ayres and Juliano Ayres - owners of the Citrosol-*Hevea* Nursery for producing and kindly providing the seedlings;

For the entire technical team of the Córrego do Ouro farm and employees who assisted in the experiment;

To Dr. Erivaldo Scaloppi for his collaboration.

REFERENCES

Alem HM, Gouvêa LRL, Silva GAP, Oliveira ALB & Gonçalves PS (2015) Avaliação de clones de seringueira para a região noroeste do Estado de São Paulo**.** Revista Ceres, 62:421–422.

Cruz CD (2006) Programa Genes – Biometria. 1st ed. Viçosa, Editora UFV. 382p.

Cruz CD (2013) Genes: a software package for analysis in experimental statistics and quantitative genetics. Acta Scientiarum Agronomy, 35:271-276.

Gonçalves PS & Marques JRB (2014) Clones de Seringueira: Influência dos Fatores ambientais na Produção e recomendação para o plantio. In: Alvarenga AP (Eds.) Seringueira. Viçosa, Epamig. p.247-325.

Gonçalves PS, Scaloppi-Júnior EJ, Martins MA, Moreno RMB, Branco RBF & Gonçalves ECP (2011) Assessment of growth and yield performance of rubber tree clones of the IAC 500 series. Pesquisa Agropecuária Brasileira, 46:1643-1649.

Gonçalves PS, Silva MA, Aguiar ATE, Martins MA, Scaloppi Junior EJ & Gouvêa LRL (2007) Performance of new *Hevea* clones from IAC 400 séries. Scientia agricola, 64:241-248.

Gonçalves PS, Gouvêa LRL & Aguiar ATE (2006) Expressão fenotípica de clones de seringueira na região noroeste do estado de São Paulo. Bragantia, 65:389-398.

Gonçalves PS, Martins ALM, Furtado EL, Sambugaro R, Ottatti EL, Ortolani AA & Godoy Junior G (2002) Desempenho de clones de seringueira da série IAC 300 na região do Planalto de São Paulo. Pesquisa Agropecuária Brasileira, 37:113-138.

Gonçalves PS, Bortoletto N, Furtado EL, Sambugaro R & Bataglia OC (2001a) Desempenho de clones de seringueira da série IAC 300 selecionados para a região noroeste do Estado de São Paulo. Pesquisa Agropecuária Brasileira, 36:589-599.

Gonçalves PS, Bataglia N, Ortolani AAA & Fonseca FS (2001b) Manual de heveicultura para o Estado de São Paulo. Campinas, Instituto Agronômico. 78p.

Gonçalves PS, Fujihara AK, Ortolani AA, Bataglia OC, Bortoletto N & Segnini JRI (1999). Phenotypic stability and genetic gain in six-year girth growth of *Hevea* clones. Pesquisa Agropecuária Brasileira, 34:1223-1232.

Gouvêa LRL, Silva GAP, Verardi CK, Silva JQ, Scaloppi-Junior EJ & Gonçalves PS (2012) Temporal stability of vigor in rubber tree genotypes in the pre- and post-tapping phases using different methods. Euphytica, 186:625-634.

Gouvêa LRL, Chiorato AF & Gonçalves PS (2010) Divergence and genetic variability among rubber tree genotypes. Pesquisa Agropecuária Brasileira, 45:163-170.

Kronka FJN (2014) Propriedades técnica e utilização da madeira. In: Alvarenga AP (Eds.) Seringueira. Viçosa, Epamig. p. 841-895.

Obouayeba S, Boa D, Ake S & Lacrotte R (2002) Influence of age and girth at opening on growth and productivity of *Hevea*. Indian J Nat Rubber Res, 15:66-71.

Pimentel-Gomes F (2000) Curso de estatística experimental. 14st ed. Piracicaba, Editora da Universidade de São Paulo. 477p.

Queiroz MA & Lopes MA (2007) Importância dos recursos genéticos para o agronegócio. In: Nass LL (Ed.) Recursos genéticos vegetais. Brasília, Embrapa Recursos Genéticos e Biotecnologia. p. 281-305.

Silva GAP, Gouvêa LRL, Verardi CK, Oliveira ALB & Gonçalves PS (2014) Annual growth increment and stability of rubber yield in the tapping phase in rubber tree clones: Implications for early selection. Industrial Crop and Products, 52:801-808.

Verardi CK, Resende MDV, Costa RB & Gonçalves PS (2012) Estimation of genetic parameters in rubber progenies. Crop Breeding Applied Biotechnology, 12:185–190.