

## SELECTION OF *Hevea* MOTHER TREES ADAPTED TO UNPREDICTABLE ANNUAL CLIMATIC VARIABILITY

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### ABSTRACT

Phenotypic stability of yield was estimated from nineteen pre-selected fifteen year old serial Pind mother rubber trees (*Hevea brasiliensis* Muell. Arg.). Several environments were represented by annual average yielding. The linear Genotype x Year interaction component for yield was significant and predictable. This indicated that the performance of genotypes over years for this trait could be predicted. The nonlinear component of Genotype x Year was significant. Three genotypes (Pind 039, Pind 103 and Pind 274) were found to be stable, though only Pind 103 gave above average yields. This genotype could be utilized in a breeding programme to incorporate stability into commercial genotypes.

### INTRODUCTION

*Hevea* spp. are indigenous to the tropical rain forest in the Amazon Basin, Brazil. They require a warm, humid and stable climate and fertile soils for optimal growth. According to Pushparajah (1983), the important rubber growing areas are confined to tropical regions lying between 10°S and 15°N of the equator. However in Brazil the São Paulo rubber growing region an area well recognized as hospitable for the crop, lies between 21°S and 25°S far beyond the normal limits.

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According to Ortolani (1985), commercial rubber cultivation in areas with different climates, requires the development and adaptation of rubber clones to each environment type.

In the presence of genotype x environment interaction, the relative performance of clones varies with the environment. Results of clone evaluation trials can be used to select and recommend a clone adapted to a particular agro-climatic condition if the agro-climatic differences can be defined according to factors such as rainfall, light, temperature, humidity and soil. Unfortunately agro-climatic conditions are complex and the contributing factors are unpredictable and cannot be controlled. Therefore the only possibility open is to use clones stable within a wide range of agro-climatic variability.

In the rubber tree breeding programme of the Instituto Agrônomico de Campinas (IAC), described previously by Gonçalves *et al.* (1989), several populations have been submitted to selection for rubber production. The main objective is to supplement the existing breeding programme by providing a wider range of good clones in a short time, because the perennial nature of the crop imposes long cycles in conventional breeding.

No extensive studies have been performed on the phenotypic stability of yielding. In general a large amount of variation in yielding is observed. According to Pushparajah (1980), various agro-climatic elements such as dryness, temperature and rainfall, that affect several components of the yield cycle of *Hevea*, contribute to the large amount variability.

A number of statistical methods are available to evaluate the phenotypic stability of a genotype in a series of yield trials (for review see Lin *et al.*, 1986; Wescott, 1986). But though yield stability is one of the most important breeding objectives, a statistical measure of this trait is very seldom considered in a breeding program of perennial crops like *Hevea*.

The most widely used method to analyse phenotypic stability is to calculate a regression of the yield of a given genotype in different environments on the mean of all tested genotypes. The coefficient of regression ( $b_i$ ) can be used to describe the general response to environmental conditions (Stringfield and Salter, 1934) and the mean squares deviations ( $\bar{S}_d^2$ ) from linear regression actually measure the yield stability (Yates and Cochran, 1938; Eberhart and Russell, 1966).

Kalil Filho (1982) was the first one to employ the methodology of Eberhart and Russell (1966) to study temporal yielding. The phenotypic stability of 55 *Hevea* clones was estimated from eight years of yield data. Where the environments were represented by different months and years at one site.

Jayasekera *et al.* (1977) demonstrated a significant genotype x environment component for survival rate and first height measurement in ten *Hevea* clones in Sri-Lanka. Later, Jayasekera (1983) carried out a joint regression based on the significance for both these characters, showing that the genotype x environmental interaction among the ten *Hevea* clones was mainly non-linear.

The present work is an attempt to estimate the phenotypic yield stability of nineteen mother tree selections during five years.

## MATERIAL AND METHODS

Data used in this study were collected from nineteen *Hevea* mother trees (genotypes) selected on the basis of similarities in girth performance from a population with 640 trees. Established in 1975 at the Pindorama Experimental Station - São Paulo State, the group of trees was opened for tapping in 1984 on a half spiral, third daily system with a tapping intensity of 67% (S/2 d/3 67%) at a height of 1,00 metre from the ground. On each day, tapping was started around 6:30 in the morning. Latex was collected in plastic cups and coagulated naturally in the cups. The lumps were air dried for a two-month period until they gave a constant weight. Yield was recorded over the first one to five years of tapping and expressed in grams per tree tapping. The experimental design for each year considered was a randomized complete block design assuming 19 treatments (genotypes), 12 replications (months) and 100 tappings/genotype. For all years combined the statistical model used was:

$$Y_{ijk} = \mu + g_i + a_k + (ga)_{ik} + m_{jk} + \bar{e}_{ijk}$$

In the model,  $Y_{ijk}$  is the observation on the  $i$ th genotype, in the  $j$ th month in  $k$ th year;  $\mu$  is the overall mean;  $g_i$  is the fixed effect of  $i$ th genotype;  $a_k$  is the effects of the  $k$ th year;  $(ga)_{ik}$  is the interaction of the  $i$ th genotype with  $k$ th year;  $m_{jk}$  is the effects of the  $i$ th month in the  $k$ th year and  $\bar{e}_{ijk}$  is the experimental error associated with the  $ijk$ th observation.

For the stability study, the several environments were represented by years through an environmental index, in terms of a mean performance of all the selections in each year.

The monthly average of yield and the annual total yield per tapping per genotype were also utilized. The linear regression coefficient ( $b_i$ ) and the variance of the deviations ( $\bar{S}_{d_i}^2$ ) from linear regressions for each genotype were considered as parameters.

The technique of Eberhart and Russell (1966) was used in this study to characterize genotype stability in different years. The model used was:

$$Y_{ij} = \mu + \beta_i I_j + \delta_{ij}$$

Where:  $Y_{ij}$  is the mean of  $i$ th genotype in the  $j$ th environment (year);  $\mu$  is the mean of all the genotypes over all the environments;  $\beta_i$  is the regression coefficient of the  $i$ th variety on the environmental index which measures the response of this genotype

to varying environments;  $I_j$  is the environmental index which is defined as the deviation of the mean of all the genotypes at a given year from the overall mean and  $\delta_{ij}$  is the deviation from regression of the  $i$ th genotype in the  $j$ th environment.

With this methodology two parameters of stability were estimated: a) The regression coefficient which is the regression of the performance of each genotype under different years on the annual mean over all the genotypes and b) The variance of the deviation ( $\overline{S_{d_i}^2}$ ) from the regression line.

## RESULTS AND DISCUSSION

All effects, including genotypes x years interaction, were highly statistically significant ( $p \leq 0.01$ ) in the overall analysis of variance (Table I), indicating that genotypes perform differently between years.

Great differences among genotypes were observed (Table II). Overall genotype means ranged from 10.89 grams for genotype Pind 096 to 27.58 grams of dry rubber per tree tapping for genotype Pind 130. Genotype Pind 130 was particularly outstanding, ranking first during four of five years. The fifth year was the most productive with a mean yield of 18.40 grams of rubber, nearly six grams higher than the first year. Differences between the increased annual yields, might be related to the variable number of latex ring vessels contained in the bark of the trees. According to Dijkman (1951), in seedlings, the number of the latex vessels as well as the bark thickness, increases towards the base of the stem. A tapping cut of, say 10 cm in length will give, therefore, less latex at a height of one meter on the stem than the same length cut at 30 cm above ground.

The combined analysis of variance for yield according to Eberhart and Russell's model is also presented in Table I. The analysis revealed that 1) the genotypes differ significantly, 2) significant variation was present among the years (linear), and 3) genotypes exhibited significant interaction with annual variations. The genotype x year interaction components were further partitioned into linear (year and genotype x year) and non-linear (pooled deviations) components. Mean squares for both these components were tested against pooled error mean squares. Both linear and non-linear components were significant, indicating that both predictable and unpredictable components shared genotype x year interaction. Preponderance of linear genotype interaction is of great practical importance. This implies that there are differences among the linear regression coefficients for each genotype.

The stability parameters for all genotypes are given in Table III. Estimates of regression coefficients ( $b_i$ ) and variance of the deviation ( $\overline{S_{d_i}^2}$ ) from the regression line showed a wide range of values. Regression coefficients were significant for 11 genotypes, indicating the responsiveness of these genotypes to annual variations. However, for eight genotypes regression coefficients did not differ significantly from unity, demonstrating

a low response of these genotypes to annual variations. Genotypes Pind (008, 016, 039, 062, 130, 220 and 283) had significantly higher values than 1.0, whereas Pind (096, 103, 274 and 304) had significantly lower estimates of regression coefficients. According to Tripathi *et al.* (1987) the regression coefficient measures responses to an improving environment. Breeze (1969) and Gama and Hallauer (1980) emphasizes that genotypes with coefficients greater than one would be adapted to less favourable conditions.

Table I - Analysis of variance for dry rubber yields in five different years (environments).

Source	d.f.	Mean square
Genotypes	18	87.0248**
Years	4	112.3562**
Genotypes x Years	72	6.9414**
Years + (gen. x years)	76	12.4895**
Years (linear)	1	450.0008**
Genotypes x ears (linear)	18	22.6878**
Pooled deviation	57	1.5933
Pind 008	3	1.0547
Pind 016	3	1.0508
Pind 031	3	2.8087*
Pind 039	3	1.1889
Pind 041	3	3.8935**
Pind 058	3	0.9443
Pind 0.62	3	1.4200
Pind 096	3	1.9917
Pind 103	3	0.9088
Pind 127	3	1.5059
Pind 130	3	2.1301
Pind 132	3	2.1867
Pind 218	3	2.0929
Pind 220	3	1.2992
Pind 225	3	0.7616
Pind 274	3	0.2907
Pind 283	3	0.1712
Pind 295	3	4.3231**
Pind 304	3	0.0131
Pooled error	990	0.8630

\* :  $P \leq 0.05$ .

\*\* :  $P \leq 0.01$ .

Table II - Annual and overall means of dry rubber per tree tapping of nineteen adult mother trees (genotypes) in five temporal environments (years).

Genotypes	1 <sup>st</sup> year		2 <sup>nd</sup> year		3 <sup>rd</sup> year		4 <sup>th</sup> year		5 <sup>th</sup> year		Overall	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
Pind 130	23.10	1	22.53	1	23.88	1	30.72	1	27.65	2	27.58	1
Pind 062	12.22	10	16.31	4	19.27	2	26.43	2	34.70	1	21.78	2
Pind 283	13.85	6	14.03	6	16.59	4	20.74	3	25.43	3	18.13	3
Pind 132	20.91	2	19.13	2	16.55	5	16.09	8	16.08	10	17.75	4
Pind 225	15.14	4	15.78	5	17.50	3	17.59	5	17.33	9	16.58	5
Pind 103	15.26	3	13.42	7	15.67	6	18.36	4	18.88	6	16.32	6
Pind 008	12.64	9	13.39	8	13.32	7	17.56	7	21.95	4	15.77	7
Pind 220	12.05	11	12.90	9	12.62	9	17.72	5	17.55	8	14.57	8
Pind 295	14.29	5	12.32	11	12.56	10	13.28	14	18.85	7	14.26	9
Pind 016	10.60	13	11.11	13	12.31	17	14.79	11	19.99	5	13.56	10
Pind 058	13.21	8	17.79	3	11.35	19	11.44	19	12.80	17	13.32	11
Pind 218	9.99	15	12.79	10	13.12	8	15.19	9	14.19	13	13.04	12
Pind 304	11.86	12	12.21	12	12.16	13	12.98	15	13.52	15	12.55	13
Pind 274	10.05	14	10.61	14	12.45	11	14.20	13	15.20	11	12.50	14
Pind 031	13.66	7	9.66	18	11.76	18	12.11	18	13.53	14	12.26	15
Pind 039	8.94	17	10.57	15	11.82	17	15.05	10	14.75	12	12.23	16
Pind 041	8.96	16	9.85	16	11.83	16	14.55	12	11.26	19	11.23	17
Pind 127	8.55	18	9.85	17	12.12	14	12.68	17	12.53	18	11.14	18
Pind 096	7.29	19	9.08	19	11.86	15	12.82	16	13.41	16	10.89	19
Overall genot. means	12.77 ± 5.50		13.33 ± 5.59		14.14 ± 4.91		16.57 ± 6.75		18.40 ± 8.05		15.04 ± 5.14	

Table III - Mean yield of dry rubber per tree tapping and stability parameters ( $b_i$  and  $\bar{S}_{d_i}^2$ ) of nineteen adult *Hevea* mother trees in five temporal environments (years).

Genotype	Parameters for dry rubber yield			
	$X_i$	$b_i$	SE <sub>b</sub>	$\bar{S}_{d_i}^2$
Pind 008	15.77	1.5894**	0.1921	0.1918
Pind 016	13.76	1.5361	0.2103	0.1879
Pind 031	12.26	0.3160	0.3611	1.9458*
Pind 039	12.33	0.9983*	0.2296	0.5628
Pind 041	9.50	0.5346	0.4190	3.0306**
Pind 058	12.12	0.0054	0.5830	0.0814
Pind 062	21.78	3.6328**	0.2434	0.5571
Pind 096	10.91	0.9423*	0.3004	1.1288*
Pind 103	16.32	0.8704*	0.2263	0.0459
Pind 127	11.15	0.6218	0.2618	0.6430
Pind 130	27.57	2.6355**	0.3117	1.2672*
Pind 132	17.75	-0.7210	0.3128	1.3238*
Pind 218	13.04	0.6216	0.2974	1.2300*
Pind 220	14.57	1.0856*	0.2317	0.4363
Pind 225	16.67	0.3467	0.1873	-0.1013
Pind 274	12.50	0.8930**	0.1251	-0.5722*
Pind 283	18.13	2.0263**	0.1236	-0.6917*
Pind 295	14.25	0.8194	0.4412	3.4602**
Pind 304	12.55	0.2766	0.0239	-0.8498**
Average	14.89	1.0000		

\*, \*\* : Significant against standard error of regression coefficient SE<sub>b</sub>, 0.05 and 0.01 levels, respectively.

The regression coefficient measures the "relative" performance of the genotype. Clair and Kleinschmit (1986) emphasizes that in forest tree breeding this information is useful to distinguish genotypes for specific environments, but if all environments tested are in one planting zone, and each represents the same proportion of area to be planted, then this information is irrelevant. Selection on the overall mean is all that is necessary to assure the largest overall gain.

Eleven genotypes had a significant variance of the deviations ( $\bar{S}_{d_i}^2$ ) from regression, indicating that unpredictable components also shared in genotype x year

interaction. Out of these 11 genotypes, regression coefficients for five were also significant against their own remainder variance of the deviations, indicating predominance of predictable components.

More importante to *Hevea* breeding is the predictability of yield of a genotype in various environments. According to Breeze (1969) and Becker (1981) this concept of stability may be measure by the variance of the deviations ( $\overline{S}_{d_i}^2$ ) from the regression line, whereas the deviation around the regression line is considered as a measure of stability, the least deviating genotypes being the most stable. Figures 1 and 2 show the performance and responsiveness of all the 19 genotypes.

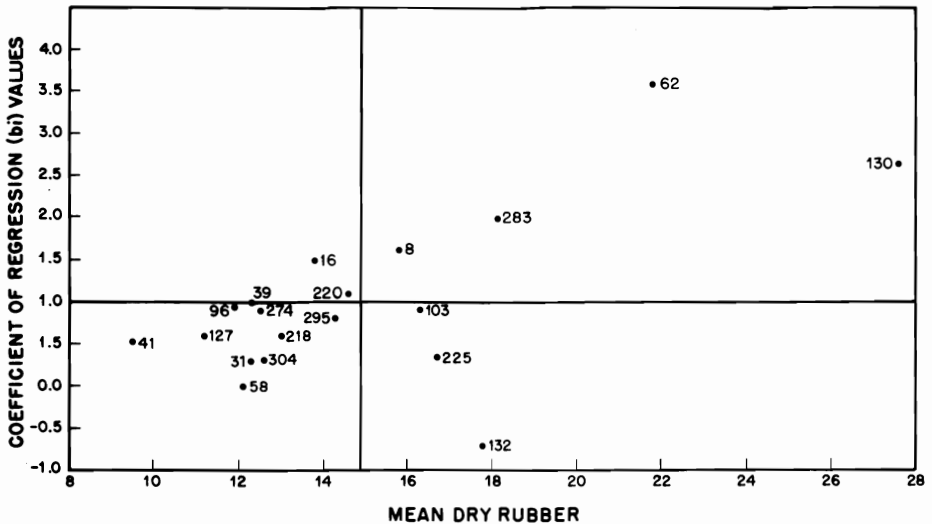


Figure 1 - Mean dry rubber (g/tree/tapping) and regression coefficients in a stability study of nineteen Pind *Hevea* genotypes.

Eberhart and Russell (1966) emphasized the need of considering both the linear ( $b_1$ ) and non linear ( $\overline{S}_{d_i}^2$ ) components of genotype-environment interactions in judging the stability of a genotype; a stable genotype was defined as one with  $b_1 = 1.0$  and  $\overline{S}_{d_i}^2 = 0$ . According to these criteria were found three stable genotypes for rubber yield in Table III. Of these (Pind 039, 103 and Pind 274) only Pind 103 gave above average yields. Therefore only this genotype could be considered superior in future breeding programmes in order to incorporate stability. According to Singh and Gupta (1988) it is

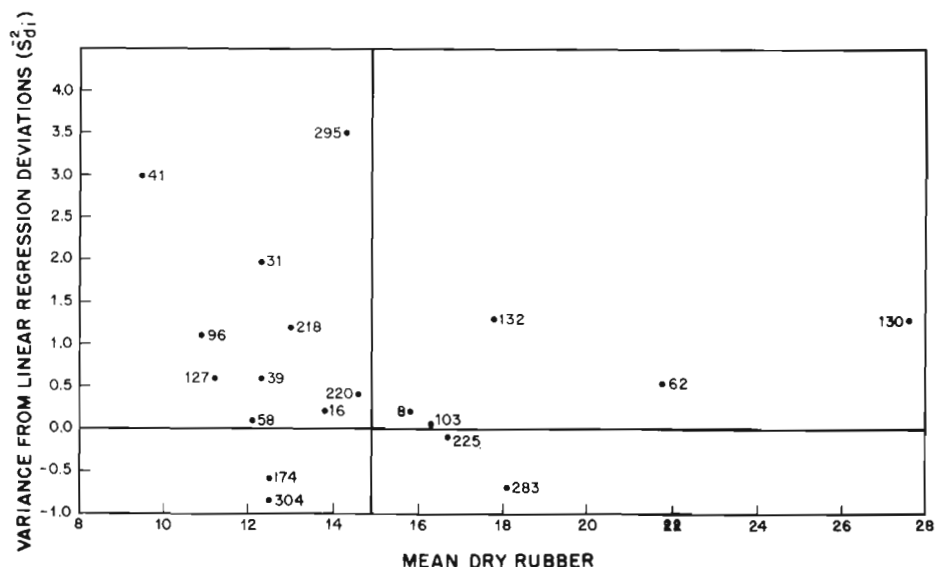


Figure 2 - Mean dry rubber (g/tree/tapping) and variance from regression in a stability study of nineteen Pind *Hevea* genotypes.

possible that stable genotypes carry genes for stability. Stability is useful in a breeding programme, because it facilitates economic production.

There were six other genotypes (Pind 008, 062, 130, 132, 225 and 283), which showed above average yield response. Though these genotypes were unstable according to the model of Eberhart and Russell (Figure 1) it is possible that in the future they could be of economic interest as clone cultivars (see Gonçalves *et al.*, 1989) due to their specific suitability for an annually uniform environment. Among these six genotypes only Pind 130 and Pind 283 had significant values of  $\bar{S}_{d1}^2$  (Table III, Figure 2). For both, regression coefficients were significant against their own remainder variance of the deviations, indicating the predominance of predictable components.

Although the existence of genotype x environment interactions has been clearly demonstrated during the five years, considering each year as a different environment, the amount of variation attributed to annual climatic interaction and the stability of individual genotypes in different years, remain to be investigated over time. If the plastic responses measured by the regressions are heritable, as suggested for other crops (Nayeem and Bapat, 1986; Singh and Gupta, 1988; Chhina and Phul, 1988) then one could hope to breed for genotypes for a specified range of conditions in a more determinate manner.

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## RESUMO

Estabilidade fenotípica da produção foi estimada de dezenove árvores matrizes de 15 anos de idade, (série Pind), pré-selecionadas de uma população de *Hevea* (*Hevea brasiliensis* Muell. Arg.). Para avaliação, os vários ambientes foram representados por média anual de produção. O componente linear da interação Genótipo x Ano para produção foi significativo e previsível. Isso indica que a performance dos genótipos em função dos anos para esse caráter pode ser previsível. O componente não linear da interação Genótipo x Ano foi significativo para o caráter. Três genótipos (Pind 039, Pind 103 e Pind 274) foram considerados estáveis, onde somente o Pind 103 produziu acima da média, podendo ser utilizado em futuros programas de melhoramento, objetivando incorporação desse caráter.

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