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Interaction between flowering pattern and latex yield in *Hevea brasiliensis* Muell. Arg.

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ABSTRACT *- The interaction between flowering and latex yield was evaluated in 10 clones of* Hevea brasiliensis *to determine clonal stability across tapping seasons. The clones, consisting of seven clones developed in Nigeria and three imported clones, were evaluated for latex yield in three seasons according to the flowering pattern of* Hevea *trees. Latex yield data collected in five years were evaluated for clonal variation and stability using analysis of variance and five stability parameters. There was significant variation of latex yield across seasons, clones, and interaction of clone x season. Three Nigerian clones (NIG 800, NIG 803, and NIG 804) surpassed the imported clones in latex yield. Three clones (NIG 802, NIG 805 and RRIC 45) were stable across the three seasons and could serve as donor parents for stability genes.*

Key words: *Hevea*, latex, stability.

INTRODUCTION

Natural rubber tree (*Hevea brasiliensis* Muell. Arg.) is valued mainly for the latex. Since the 1970s, rubber seed has gained economic importance through the utilization of rubber seed oil and meal (Vijayagopalan and Gopalakrishnam 1971, Nwokolo and Akpapunam 1986, Aigbodion and Okiemien 1996). However, the latex production maintains its primary importance as natural rubber has significant advantages over synthetic rubber in the production of heat-resistant plastic products such as tires, tube, bearings etc. (Zenghua 1984, Joseph and Tharian 1994).

Production of latex obeys an annual regime of peak and lean periods. Such fluctuation affects the farm gate price of raw latex, the farmers' income, and the availability of latex to processing factories. Stable clones will ensure steady prices, income, and raw latex supply. Two factors are closely associated with the seasonal fluctuation of latex production: weather and flowering/seed development patterns. Priyadarshan et al. (1998) and Mondal et al. (1999) reported the influence of weather pattern on latex yield. This study was conducted to evaluate the influence of the pattern of flowering and seed development on clonal latex yield.

MATERIAL AND METHODS

Study site

Experimental site was the Outstation of the Rubber Research Institute of Nigeria in Igbotako, Ondo state, Nigeria. Ten clones of *Hevea brasiliensis* were evaluated in three distinct seasons for five years. The seasons were consistent with the pattern of flowering and seed development in Nigeria (January to May, June to September and October to December in each year).

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Experimental clones and design

The ten test clones included seven clones developed in Nigeria. These were NIG 800 to NIG 805, and C 159. The other test clones were RRIM 600 and RRIC 45 from Malaysia and Sri Lanka (respectively), and IAN 710, which is a selected clone from Brazil. The experimental design was the randomized complete block of the ten clones. There were four replications and ten-tree plots. Tree spacing was 3.4m x 6.7m with a total of 450 trees per hectare (Omokhafe 2000).

Clonal evaluation

The test clones were planted in 1983 and at tapping maturity, the trees were opened for tapping in 1993. Each clone was exploited for latex as described by Omokhafe (2001). Clonal latex yield was recorded in gram per tree per tapping (g t^{-1} t^{-1}) as described by Aniamaka and Olapade (1990), and Omokhafe and Alika (2003). An evaluation of clonal latex yield was carried out for five years from 1993 to 1997. In each year, the clonal latex yield was recorded in each of the three seasons.

Data analysis

Data were analyzed as a three-factor experiment using analysis of variance (ANOVA). The factors were the clones, tapping seasons, and years of evaluation. The ANOVA for stability test was conducted as described by Singh and Chaudhary (1977). The average error was calculated as recommended by Eberhart and Russell (1966). Five stability parameters were applied to test clonal stability across the three tapping seasons. The stability parameters were environmental variance, Shukla's (1972) stability variance, regression of clonal latex yield on environmental index and the Eberhart and Russell's (1966) variance due to regression and deviation from regression. These stability parameters were calculated as follows:

1. Environmental variance as described by Lin et al. (1986)

$$S_i^2 = \Sigma\left(Y_{ij} - \overline{Y}_{i.}\right)^2 / (q-1)$$

2. Shukla's stability variance as described by Shukla (1972) and Lin et al. (1986)

$$\sigma_i^2 = A(C) - B$$

where

$$A = p/(p-2)(q-1)$$

$$B = SS(C1xEnv)/(p-1)(p-2)(q-1)$$

$$C = \sum\left(Y_{ij} - \overline{Y}_{.j} - \overline{Y}_{i.} + \overline{Y}_{..}\right)^2$$

3. Regression of clonal latex yield on environmental index as described by Finlay and Wilkinson (1963), Singh and Chaudhary (1977)

$$b_i = \sum I_q Y_{ij} / \sum I_q^2$$

where

$$I_q = \left(\overline{Y}_{.j} - \overline{Y}_{..}\right)$$

4. Variance due to regression as described by Eberhart and Russell (1966), Singh and Chaudhary (1977)

$$S_i^2 = \Sigma\left(Y_{ij} - \overline{Y}_{i.}\right)^2 / (q-1)$$

where

$$\delta_{ij}^2 = n\sigma_i^2 - b_i \sum I_q Y_{ij}$$

$$n\sigma_i^2 = \Sigma\left(Y_{ij} - \overline{Y}_{i.}\right)^2$$

5. Variance due to deviation from regression as described by Eberhart and Russell (1966), Singh and Chaudhary (1977)

$$S_{di}^2 = \left[\sum \delta_{ij}^2 / (q-2)\right] - S_e^2/r$$

where

$$\delta_{ij}^2 = n\sigma_i^2 - b_i \sum I_q Y_{ij}$$

$$n\sigma_i^2 = \Sigma\left(Y_{ij} - \overline{Y}_{i.}\right)^2$$

S_e^2/r = average error

In these equations, p = number of clones, q = number of environments and r = number of replications.

RESULTS AND DISCUSSION

The period from January to May is characterized by severe defoliation of the rubber trees in February, refoliation in March, and onset of flowering from February to March. Flowers are in full bloom in March and early April while fruit set begins in April to early May. The second season (June to September) covers the period of fruit development from June leading to physiological maturity in July (Olapade and Omokhafe 1990). Fruit dehiscence through an explosive mechanism takes place in August. The period of October to December is when the rubber tree is free from the burden of flowering and fruit development.

Clonal variation of latex yield

There was significant variation of the clone latex yield and also across the tapping seasons (Tables 1 and 3). Three Nigerian clones viz NIG 800, NIG 803 and NIG 804 had superior latex yields of 30.43, 40.67, and 46.73 g t^{-1} t^{-1} respectively (Table 4). The significant clonal variation of latex yield suggests the prospect of clonal selection for latex yield among the test clones. The superior performance of three Nigerian clones (NIG 800, NIG 803, and NIG 804) over the Asian clones (RRIM 600 and RRIC 45) is noteworthy. The superior clones could serve as parents in crosses for the further genetic improvement of latex yield in *H. brasiliensis*.

Table 1. Mean squares of analysis of variance of latex yield in *Hevea brasiliensis*

Sources of variation	df	Mean squares
Replication	3	330.44 **
Year	4	6704.91**
Season	2	3633.04**
Clone	9	4866.65**
Clone x Season	18	92.47*
Clone x Year	36	103.17**
Season x Year	8	762.34**
Clone x Season x Year	72	57.99
Error	447	51.67

*, **: Significant at $P \leq 0.05$, $P \leq 0.01$, respectively (F-test)

Seasonal variation of latex yield

In the case of the tapping seasons, the highest mean latex yield was obtained from October to December (32.29g t^{-1} t^{-1}), followed by the period from June to September (28.37 g t^{-1} t^{-1}), and lastly January to May at 23.78 g t^{-1} t^{-1} (Table 2). The significant seasonal variation shows the importance of the pattern of flowering and seed development for the latex yield. For example, the season, which is relatively free of the burden of flowering and seed development had the highest output of latex yield. The lowest latex yield was obtained in the period of defoliation, refoliation, initiation of flower buds, anthesis, shedding of pollen, pollination, and fruit set. The stress on the trees leading to reduction in latex yield could be minimized through application of fertilizers. However, a stable and inexpensive approach is the cultivation of stable clones. Such clones will be consistent for high latex yield while going through the various stages of flowering and seed development.

Table 2. Mean latex yield of *Hevea brasiliensis* in three tapping seasons

Tapping season	Latex yield g t^{-1} t^{-1}
January to May	23.78
June to September	28.37
October to December	32.29

g t^{-1} t^{-1}: gram per tree per tapping

Effect of interaction

The clone x season interaction was significant with a significant non-linear component (Tables 1 and 3). The significant interaction between clone and latex yield was an indication of significant variation in the response of the test clones to the seasons. The application of the five stability parameters minimized the bias often associated with single parameter evaluation (Lin et al. 1986).

Among the stability parameters, the regression index and environmental variance were weak stability parameters as both of them presented all test clones as stable (Table 4). Shukla's stability variance, variance due to regression, and deviation from regression had components of stable and unstable clones. Using these three discriminatory stability parameters, three clones (NIG 802, NIG 805 and RRIC 45) were stable for two out of the three stability parameters. Four clones (NIG 800, NIG 801, C 159, and IAN 710) were stable for one discriminatory stability parameter, while NIG 803, NIG 804, and RRIM 600 were unstable across the three discriminatory parameters (Table 4). The unstable clones viz NIG 803, NIG 804, and RRIM 600 were the major determinants of the significant non-linear component of clone x season interaction (Tables 3 and 4).

Table 3. Analysis of variance of stability of *Hevea* latex yield across seasons

Sources of variation	df	Mean squares
Total	29	na
Season	2	na
Clone	9	97333.08**
Clone x Season	18	1850.93**
Season + (Clone x Season)	20	na
Season	1	na
Clone x Season (linear)	9	2036.51
Clone x Season (non linear)	10	1498.82**
Pooled error	90	115.35

na: not applicable
**: Significant at $P \leq 0.01$, respectively (F-test)

According to Singh and Gupta (1988), clonal stability has genetic influence. The clonal stability of NIG 802, NIG 805, and RRIC 45 could be exploited via the use of these clones in crosses to develop a progeny with combined attributes of consistent and high latex yield throughout the year.

In conclusion, three clones (NIG 802, NIG 805, and RRIC 45) have stability genes for consistent latex yield despite the annual pattern of flowering and seed development. There are prospects for the use of the test population for genetic improvement of high and stable latex yield of *H. brasiliensis*. In this regard, NIG 800, NIG 803, and NIG 804 were outstanding for high latex yield, while NIG 802, NIG 805, and RRIC 45 could serve as donor parents of stability genes.

Table 4. Stability parameters of clone x season interaction in *Hevea brasiliensis*

Clone	Parentage	Latex yield	Stability parameters				
		— g t^{-1} t^{-1+}—	EV	SH	FW	ER (A)	ER (B)
NIG 800	RRIM 501 x Har 1	30.43 (3)	8.86	-160.45**	0.92	11.33	-104.02**
NIG 801	RRIM 600 x PR 107	20.51 (8)	12.65	6868.97**	1.88	7.69	-107.65**
NIG 802	RRIM 501 x RRIM 628	25.27 (6)	9.72	-34.54	1.11	41.87	-73.48**
NIG 803	RRIM 600 x PR 107	40.67 (2)	7.77	5677.68**	0.43	4603.31**	4487.76**
NIG 804	RRIM 600 x Tjir 1	46.73 (1)	10.58	1100.28**	1.29	871.24**	755.89**
NIG 805	RRIM 628 x RRIM 501	20.19 (9)	7.92	473.51**	0.73	99.60	-15.74
C 159	RRIM 501 x RRIM 628	26.97 (5)	6.11	2664.49**	0.44	-12.07	127.41**
RRIM 600	Tjir 1 x PB 86	24.12 (7)	11.05	1686.16**	1.42	9155.24**	9039.89**
IAN 710	Fx 516 x PB 86	19.56 (10)	7.85	495.12*	0.72	55.47	-57.87**
RRIC 45	RRIC 8 x Tjir 1	27.00 (4)	9.57	-77.54	1.07	154.51	39.17**

+: Figures in parenthesis represent rank, g t^{-1} t^{-1}: gram per tree per tapping
*,** : Significant at $P \leq 0.05$ and $P \leq 0.01$ respectively (t - test for EV and ER (B), F - test for ER (A) and SH)
EV: Environmental variance, SH: Shukla's stability variance, FW: Finlay and Wilkinson's regression index
ER (A): Eberhart and Russell's variance due deviation from regression (non-linear component),
ER (B): Eberhart and Russell's deviation from regression

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Interação entre padrão de florescimento e produção de látex em *Hevea brasiliensis* Muell. Arg.

RESUMO - *A interação entre florescimento e produção de látex foi avaliada em 10 clones de* Hevea brasiliensis *para se determinar a estabilidade clonal entre épocas de sangria. Os clones, sete desenvolvidos na Nigéria e três importados, foram avaliados para produção de látex em três épocas, segundo o padrão de florescimento das seringueiras. Dados de produção de látex coletados por cinco anos foram avaliados para variação clonal (análise de variância) e estabilidade (cinco parâmetros). Houve variação significante para produção de látex entre épocas, clones e para a interação clones x épocas. Três clones nigerianos (NIG 800, NIG 803 e NIG 804) superaram os importados em produção de látex. Três outros clones (NIG 802, NIG 805 e RRIC 45) foram estáveis e poderão servir como parentais doadores de genes para estabilidade.*

Palavras-chave: *Hevea*, latex, estabilidade

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