Indian Journal of Natural Rubber Research, **16** (1 & 2) : 35-40, 2003

GROWTH ANALYSIS OF *HEVEA BRASILIENSIS* CLONES IN COASTAL KARNATAKA REGION

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Vinod, K.K., Suryakumar, M., Nazeer, M.A., Sulochanamma, S., Thomas, K.U., Vijayakumar, K.R. and Saraswathyamma, C.K. (2003). Growth analysis of *Hevea brasiliensis* clones in Coastal Karnataka region. *Indian Journal of Natural Rubber Research*, **16** (1 & 2) : 35-40.

Two clone evaluation trials with five clones each were planted during 1987 and 1988 to study the adaptability of *Hevea brasiliensis* clones in the Coastal Karnataka region. Growth of the clones was monitored by measuring girth initially at annual intervals and later at quarterly intervals. The growth was compared by means of absolute girth and girth increment values. Clones PB 235 and RRII 118 were found to be the more vigorous. A quadratic trend was fitted for annual average girth as a function of age. Clones showed non-significant variation for girth increment. The growth in terms of girth increment (GI) was fitted as a power function of age (X). Since all the clones irrespective of the trials showed similar growth trend, a general equation, $GI = 616.012\ X^{-1.8982}$ was fitted. Comparison of quarterly and half-yearly girth increment has shown that, growth was maximum during the rainy season (April-October). There was no definite pattern of contribution so far as individual quarters were concerned.

Key words: Coastal Karnataka, Growth analysis, *Hevea brasiliensis* clones.

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INTRODUCTION

Growth, expressed in terms of increment in morphological traits is an important parameter in assessing genotypes for their adaptability in growth environments. Trunk girth measurements and calculated annual girth increment are widely used in *Hevea* cultivation as parameters of growth, particularly during the period of immaturity. These parameters are also commonly used in assessing growth performance of new planting materials (Shorrocks *et al.*, 1965). Clones that are more adaptable show vigorous growth, thus reducing the initial phase before attaining tappability.

Agroclimate of coastal Karnataka region (Region VI) nearly resembles that of the traditional rubber growing areas in India. The rainfall pattern in this region shows, four wet months from June to September, two semi-wet months from October to November and six dry humid months from December to May (UAS, 1989). Rubber cultivation has been extended to this region between latitudes 12.06°N to15.16°N ranging from an elevation of 27 m to 1182 m above MSL. Initially, unselected seedling populations and later primary clones recommended for the traditional region occupied the entire rubber area in South Karnataka (Nazeer, 1990). Few biotic and abiotic constraints in this region like, diseases, severe scorching summer, heavy monsoon and poor soil fertility are unfavourable to rubber cultivation. However, no comprehensive information on the adaptability of *Hevea brasiliensis* clones in this region is available so far.

With this in background, clone evaluation trials were laid out in the Hevea Breeding Sub-Station at Nettana since 1987 to study the adaptability and performance of clones in terms of growth, yield and crop management practices. The present study being a part of that, is aimed at studying the initial growth pattern of ten clones.

MATERIALS AND METHODS

Two clone evaluation trials, with five clones each were planted during 1987 and 1988 in randomised complete blocks with three replications at Hevea Breeding Sub-Station at Nettana, Dakshina Kannada District, Karnataka (12° 43'N; 75° 32'E; 1100 m MSL). The experiment laid out during 1987 (referred to as 1987 trial throughout this paper) comprised of clones RRII 105, RRII 300, PB 235, PB 260 and PB 311. The experiment laid out during 1988 (referred to as 1988 trial throughout this paper) consisted of clones RRII 118, PR 255, PR 261, RRIC 36 and RRIC 45. The growth of the plants were monitored by measuring girth at 150 cm height from the bud union, commencing from the third year after planting in both the trials. The recording of data on girth at quarterly intervals i.e., during April, July, October and January, began from April 1994 onwards. The girth data was collected from all the plants in the individual plots.

The data up to April 1997 from the 1987 trial and up to April 1998 from the 1988 trial were used in the present study. The growth of the clones was compared in terms of average absolute girth values on yearly basis as well as using calculated annual, half-yearly and quarterly girth increments expressed in percentages. Analysis of variance was performed using all data sets. The trend of growth as girth (G) was fitted as a function of age (X) i.e., years after planting for all the clones. Also, trend of girth increment (GI) of the clones was fitted as a function of age (X) and comparison of fitted regression equations was made. The quarterly and half-yearly girth increment and contribution of each quarter to annual growth was also worked out and compared. The correlation of girth increment to antecedent weather parameters like maximum temperature (T_{max}), minimum temperature (T_{min}), relative humidity (RH%), total rainfall and sunshine hours (SH) also were worked out.

RESULTS AND DISCUSSION

The mean values of absolute girth and girth increment for six years are given in Table 1. The analysis of variance given in Table 2 revealed significant variation for year component both for average girth and girth increment. The clones showed significant variation only for the absolute girth. The clonal variation studied was phenotypic and the year variation was attributed to growth of the plants. The clone x year interaction was also found to be significant indicating that clones responded differently for growth during different years in both the trials.

The mean data revealed that when the girth increased steadily over years the girth increment rates decreased in all the clones. In the 1987 trial, the clone PB 260 showed better initial growth up to the fifth year, while PB 235 showed better growth from the fifth year onwards. RRII 300 showed poor girth. In the 1988 trial, clone RRII 118 showed the best growth and clone PB 255 the lowest. Precocity in girthing of RRII 118 and PB 235 during early years was reported earlier in traditional (Sethuraj *et al.*, 1991) and non-traditional (Vinod *et al.*, 1996) rubber growing regions.

Use of dynamic or functional approach, using ordinary least square polynomials in growth analysis was advocated by Radford (1967), in agronomic studies. The partitioning of year component of variation to linear (Y_L), quadratic (Y_Q) and residual (Y_R) elements were done for all the clones individually (Table 3). It was found that both these elements showed significance in all the clones and the Y_R component was non-significant except for clone PR 255. This revealed that the growth could be almost totally described by a quadratic function of age (years after planting). The fitted quadratic equations given in Table 4 have confirmed this. Higher magnitude of the mean squares of the Y_L, indicated that the growth was more linear in early years as described by Margret

Table 1. **Mean girth (cm) and percentage girth increment (in parentheses) of ten clones in two experiments**

Clone	Year after planting					
	4	5	6	7	8	9
1987 Trial						
RRII 105	23.24c	30.79b	36.61b	42.25b	47.18c	51.82c
	(46.06)	(23.24)	(1.41)	(15.46)	(8.40)	(11.18)
RRII 300	21.46d	27.62c	33.72c	39.57c	44.00d	48.23d
	(38.47)	(21.62)	(22.50)	(13.20)	(9.43)	(9.79)
PB 235	24.76b	32.94a	40.76a	47.80a	53.62a	58.91a
	(41.89)	(26.84)	(21.34)	(13.91)	(10.68)	(09.11)
PB 260	25.46a	33.29a	40.06a	46.62a	51.61b	55.72b
	(44.16)	(21.50)	(19.44)	(13.86)	(8.00)	(7.91)
PB 311	24.30bc	30.91b	36.98b	43.14b	48.05	52.81c
	(38.20)	(19.31)	(19.95)	(13.94)	(9.15)	(10.59)
1988 Trial						
RRII 118	23.06a	31.44a	40.36a	47.92a	54.32a	61.32a
	(41.27)	(32.95)	(24.98)	(13.84)	(13.10)	(12.84)
PR 255	18.23b	25.70b	31.72b	36.51c	40.80c	45.77c
	(58.25)	(30.19)	(18.33)	(12.40)	(11.20)	(13.06)
PR 261	19.06b	27.58ab	36.24ab	42.29b	46.90b	52.20b
	(49.48)	(41.90)	(24.07)	(10.81)	(11.10)	(11.60)
RRIC 36	17.52b	24.92b	31.49b	37.09bc	42.68bc	48.56bc
	(58.55)	(32.36)	(21.95)	(14.49)	(15.70)	(12.15)
RRIC 45	17.96b	25.44b	32.91b	38.66b	43.70bc	48.95bc
	(47.65)	(38.21)	(23.08)	(12.89)	(13.17)	(11.01)

Means followed by same letters are not significantly different at P ≤ 0.05 by LSD test.

Table 2. **Mean squares for the components of variation for mean annual girth and girth increment for six years**

Sources of variation	1987 trial		1988 trial	
	Girth	Girth increment	Girth	Girth increment
Clone	154.33**	5.82	303.91**	7.20
Year (Y)	1865.30**	1067.89**	2139.00**	1599.91**
Clone x Year	3.61**	7.66**	8.17*	19.64**
Error	0.49	2.74	3.78	6.56

Error degrees of freedom = 58 * Significant at P ≤ 0.05 ** Significant at P ≤ 0.01

Table 3. **Mean squares of partitioned year component on annual growth of clones for six years in two experiments**

Elements of variation	1987 trial				
	RRII 105	RRII 300	PB 235	PB 260	PB 311
Year	337.69**	307.61**	496.75**	392.94**	344.75**
Linear	1675.99**	1527.90**	2465.45**	1940.65**	1716.52**
Quadratic	11.68**	9.49**	18.05**	23.69**	6.92**
Residual	0.26	0.22	0.07	0.13	0.11

Elements of variation	1987 trial				
	RRII 118	PR 255	PR 261	RRIC 36	RRIC 45
Year	615.77**	305.47**	460.39**	394.06**	401.17**
Linear	3067.12**	1511.07**	2261.40**	1964.28**	1989.13**
Quadratic	8.24*	13.45**	37.23**	4.76**	15.59**
Residual	0.48	0.95**	1.11	0.42	0.38

* Significant at P ≤ 0.05 ** Significant at P ≤ 0.01

et al. (1988). The analysis revealed that the growth curve was inclined to become non-linear as the age of the trees advanced. The regression coefficients of linear and quadratic terms gave no indications that some clones had significant variation than others. However, significance of residual element observed in PR 255 which was due to significance of the cubic term (mean square -= 2.758) could have resulted due to a minor error in the data.

The trend of growth, expressed as girth increment (GI) is presented in Table 5. The trend of falling GI as age (X) advanced was fitted using best-fit regression method. GI was best explained by a power function of X. Though the slope or regression coefficients (ß) of the equations varied from –1.63 to –1.92 in the 1987 trial, and from -1.64 to –2.17 in the 1988 trial, analysis of homogene-

Table 4. **Growth trend of clones in terms of mean absolute girth during six years in two experiments**

Clone	Regression equation	Mean squares of		Coefficient of
		Regression	Deviation	determination (R^2)
1987 Trial				
RRII 105	G= -14.03 + 11.01 X - 0.41 X2	188.99**	0.09	0.9995
RRII 300	G= -9.18 + 9.28 X - 0.28 X2	185.35**	0.09	0.9995
PB 235	G= -10.77 + 9.19 X – 0.29 X2	169.87**	0.07	0.9995
PB 260	G= -17.18 + 12.06 X - 0.40 X2	274.897**	0.03	0.9999
PB 311	G= -15.46 + 12.05 X - 0.46 X2	217.30**	0.04	0.9998
1988 Trial				
RRII 118	G= -18.54 + 11.59 X - 0.30 X2	340.94**	0.16	0.9995
PR 255	G= -13.81 + 9.36 X - 0.31 X2	498.75**	0.58	0.9965
PR 261	G= -27.96 + 14.06 X - 0.58 X2	254.40**	0.37	0.9986
RRIC 36	G= -14.16 + 8.80 X - 0.21 X2	217.782**	0.14	0.9994
RRIC 45	G= -20.08 + 11.01 X - 0.37 X2	221.75**	0.13	0.9994

** Significant at $P \leq 0.01$

Table 5. **Growth trend of clone in relation to annual girth increment in two experiments**

Clone	Regression equation	Mean squares of		Coefficient of determination (R^2)	Homogeneity of regression coefficient (ß)
		Regression	Deviation		
1987 Trial					
RRII 105	GI = 510.040 X-1.8542	1.572**	0.052	0.882	a
RRII 300	GI = 425.497 X-1.7600	1.417**	0.026	0.933	a
PB 235	GI = 608.151 X-1.9224	1.690**	0.003	0.992	a
PB 260	GI = 783.136 X-2.1236	2.062**	0.023	0.996	a
PB 311	GI = 325.533 X-1.6265	1.210**	0.032	0.904	a
Mean	GI = 507.861 X-1.8550	1.574**	0.017	0.958	a
1988 Trial					
RRII 118	GI = 423.201 X-1.6440	1.236**	0.023	0.932	a
PR 255	GI = 710.637 X-1.9555	1.749**	0.093	0.824	a
PR 261	GI = 1079.792 X-2.1663	2.146**	0.069	0.886	a
RRIC 36	GI = 723.009 X-1.9019	1.654**	0.023	0.957	a
RRIC 45	GI = 793.783 X-1.9364	1.807**	0.026	0.946	a
Mean	GI = 726.399 X-1.9364	1.715**	0.032	0.932	a
General equation (clones and trials pooled)					
	GI =616.012 X-1.8982	1.648**	0.012	0.973	a

The equations having same letters are homogeneous by test of homogeneity of regression equations at $P \leq 0.01$
** Significant at $P \leq 0.01$

ity revealed that they did not deviate significantly from the common slope for the individual trials. The variation in mean GI of clones also was found non-significant. Therefore, a general equation as given below was derived using the pooled data,

$$GI = y16.012\ X^{-1.8982} \quad .... (1)$$

This equation was considered to be the most appropriate regression equation to estimate the growth in terms of girth increment for the given age of the tree during early years. However, it may not be appropriate to use a common equation for different clones under different conditions, though the pattern and variation under such conditions in the estimates of coefficients from the present equation may be small.'

Further, the girth increment at quarterly intervals was compared over years to know the pattern of growth during individual quarters in a year. Contribution of each quarter's growth to the annual growth also was computed. The average values are presented in Table 6. It was seen that, in general, the period from April – October contributed maximum to the annual growth. This period coincides with the South-West monsoon and maximum annual rainfall is received during this period. But, there was no definite pattern of growth attributable to quarters, as there were differences for this during different years. However, the correlation analysis revealed no consistent relation between girth increment and the antecedent weather parameters at quarterly intervals.

Identification of adaptive responses of genotypes, involve mainly two aspects; use of biological information including growth analysis to understand the nature of adapta-

Table 6. **Girth increment (%) and contribution to annual growth (% in parentheses) for quarters and half-years in two experiments (clones pooled)**

Year	Apr-Jul	Jul-Oct	Half yearly	Oct-Jan	Jan-Apr	Half yearly
1987 Trial						
1994-95	6.171(54.84)	2.876(27.22)	9.218(82.06)	0.976(9.58)	0.864(8.36)	1.848(17.94)
1995-96	2.214(18.97)	2.664(23.12)	4.939(42.09)	3.107(27.89)	3.414(30.02)	6.631(57.91)
1996-97	3.666(39.19)	1.557(32.21)	5.279(56.54)	0.769(8.65)	3.023(34.81)	3.815(43.46
1988 Trial						
1994-95	7.965(49.44)	5.168(32.21)	13.523(81.65)	2.002(13.69)	0.660(4.66)	2.675(18.35)
1995-96	4.431(26.06)	4.492(27.82)	9.119(53.88)	2.348(15.13)	4.713(30.99)	7.172(46.12)
1996-97	3.464(29.43)	2.201(19.83)	5.736(49.37)	2.353(21.28)	3.105(29.36)	5.532(50.63)
1997-98	4.561(44.99)	1.629(16.46)	6.261(61.45)	2.347(24.46)	1.362(14.09)	3.740(38.55)

Means squares of significant interaction effects

	1987 Trial	1988 Trial
For girth increment		
Clone x Quarter	0.07*	13.91*
Year x Quarter	2.99**	2.53**
For quarterly contribution		
Clone x Quarter	35.89**	205.74**
Year x Quarter	931.89**	1579.72**

Correlation (r) of girth increment with weather parameters

	1987 Trial	1988 Trial
Tmax	0.158	0.075
Tmin	-0.033	0.308
RH (%)	-0.258	-0.112
Rainfall	0.118	0.233
SH	0.263	0.212

tion differences and information suitable to be used in a selection programme for improved adaptation (Shorter *et al.*, 1991). The present study has divulged the pattern of growth of *H. brasiliensis* clones in the early growth phase in this region. The study has to be extended to the tapping phase of the trees, where, tapping by itself is a stress factor on growth. The harmonised information on genotypic response and genotype x environment interaction in all stages of plant growth, thus, can form a key to evaluate clonal adaptation of *H. brasiliensis* to this non-traditional region.

ACKNOWLEDGEMENT

The authors wish to express their gratitude to Dr. N.M. Mathew, Director, Rubber Research Institute of India, for support throughout the preparation of this paper.

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