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STUDIES ON DIVERGENCE OF *HEVEA BRASILIENSIS* CLONES FOR YIELD AND RELATED TRAITS DURING PEAK YIELDING SEASONS IN TRIPURA

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A study was carried out in ten oriental clones of *Hevea brasiliensis*, planted in a clone evaluation trial in Tripura (North East India) to understand the clonal variation and environmental influence on phenotypic expression of yield and related traits during two peak yielding seasons. Phenotypic coefficient of variation for plugging index (PI), inorganic phosphorus (Pi), sucrose content (SC), total volume (TV) and dry rubber yield (RY) was high when compared to that for initial flow (IF), dry rubber content (DRC) and total solids content (TSC). Mean performance of clones RRII 105, RRIM 600 and PB 235 was better for yield and related traits. These clones had less outflow of sucrose indicating better efficiency of metabolism. Stability of clones decreased with better yielding nature, except for RRIM 600, which showed better stability. GT 1 and RRII 118 showed higher stability for most of the traits. The 10 clones were grouped into three clusters using non-hierarchical Euclidean cluster analysis. Cluster I included high yielding clones RRII 105, RRM 600 and PB 235, cluster II consisted of RRII 118, RRII 203, PB 86 and GT 1 which were medium yielding clones and cluster III comprised the low yielding clones RRIC 105, GI 1 and Harbel 1. Average inter cluster distance showed that cluster III was more divergent from clusters I and II. Phenotypic variation in the character expression for yield of clones was considerably influenced by factors, which were associated with senescence and low temperature reaction. The clones, which were stable and high yielding like RRM 600 would be more desirable for this region.

Key words : Cluster analysis, Coefficient of variation, Divergence, *Hevea brasiliensis*, Peak yielding season, Phenotypic stability.

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INTRODUCTION

Dry rubber yield, a complex trait controlled predominantly by factors related to latex production and latex flow is affected by seasonal fluctuations induced by the growing environment of the trees. Clonal variation also greatly influences the yield and yield components.

Among the non-traditional rubber growing tracts of India, the north east has emerged as a potential area for extensive rubber cultivation. The general trend of yield of rubber clones in Tripura in North East India is reported to follow a definite pattern of peak yielding during October to January every year. The season coincides with the annual leaf fall (wintering) period as well as the winter months. During this period the plants are believed to experience cold stress. The annual peak yielding season contributes about 60 per cent of the annual rubber yield in Tripura (Vinod *et al.*, 1996a). Thus this short period assumes prominence as it offers an opportunity for studying the yield potential of clones as well as grouping them based on their responses on yield and related traits, which is dealt with in the present paper.

MATERIALS AND METHODS

The study was carried out on 15 oriental clones, planted during 1979, at the Regional Research Farm of Rubber Research Institute of India at Taranagar, Agartala, India (Location: 91° 15' E; 23° 53'N; 30m above msl). Ten clones *viz.*, RRII 105, RRII 118, RRII 203, RRIM 600, PB 86, PB 235, RRIC 105, GT 1, Gl 1 and Harbel 1 were selected for the study. Ten trees per clone having good growth and comparable yield were observed. Dry rubber yield (RY) and related characters *viz.*, initial flow (IF), plugging index (PI), dry rubber content (DRC), total solids content (TSC), inorganic phosphorus (Pi), sucrose content (SC) and total volume (TV) were recorded. The PI was computed from IF and TV as per Milford *et al.* (1969). The latex samples collected from the field were analysed in the laboratory for sucrose as per Tupy (1973) and for Pi as per Taussky and Shorr (1953). The recording of data was done at weekly intervals throughout the peak yielding season from early October to late January of 1993 - 94 and 1994 - 95. The time of observation was recorded as days after first tapping from the beginning of the season.

The data was subjected to statistical analysis separately for both seasons. The mean values of all the characters and their phenotypic coefficient of variation (PCV %) were computed. Analysis of variance carried out revealed considerable variation contributed by clones, days and their interaction for all the characters. The result of the analysis was presented in an earlier paper (Vinod *et al.*, 1999). The mean performance of the clones for different characters during two seasons was compared using Spearman's rank correlation.

Since the clones x days interaction in the present study was significant for all the traits, it was clear that the individual clones deviated from the general trend of each character during the season. Since the trend of different traits was linear to curvilinear (Vinod *et al.*, 1999), a non-parametric approach of studying the stability was preferred over a parametric approach. A non-parametric statistic, *viz.*, variance of the rank ($S_i^{(2)}$) suggested by Huehn (1990) was used for this purpose.

The individual phenotypic value was subjected to a data transformation, to remove the genotype effects before ranking. The corrected values were obtained using the expression,

$$x_{ij}^* = x_{ij} - (\bar{x}_i - \bar{x}_{..})$$

where, x_{ij} is the phenotypic value of the clone i (i = 1, 2, ..., N) on j^{th} day (j = 1, 2, ..., M), x_{ij}^* is the transformed value, $\bar{x}_i$ is the marginal mean of genotype i and $\bar{x}_{..}$ is the overall mean in the N x M table. The transformed phenotypic values thus obtained were ranked separately within each day. The ranking of clones separately on all days eliminated the environmental effect and by removing the genotype factor through data transformation, only interaction component was used for ranking purpose (Huehn, 1990). The variance of ranks ($S_i^{(2)}$ value) was computed for each clone and is compared for the indication of stability. If any clone had similar rank on all the days (*i.e.*, most stable) its $S_i^{(2)}$ value should be equal to zero.

Since the correlation of different traits between two peak yielding seasons was significant the data over both the seasons were pooled and the mean data was used for non-hierarchical Euclidean cluster analysis. The intra- and inter-cluster distances were estimated and the clusters were arrived at following the sequential pseudo F-tests (Spark, 1973).

RESULTS AND DISCUSSION

The mean and PCV (%) of different characters per clone during two seasons are presented in Table 1. All the characters studied showed moderate to high variation. Considerable genetic divergence also was present among the clones. The PI, Pi, SC, TV and RY showed higher variation than other traits. The mean performance of the characters showed very high correlation between both the years. The variation of PI contributed by the cumulative variation resulted from that of IF and TV, as the former was derived from the latter traits. Mean comparison of individual clones revealed that RRII 105, RRIM 600 and PB 235 performed better than all other clones for IF, Pi, TV and RY during both the years.

Dry rubber content is an important constituent of rubber yield and PCV values of this trait were less when compared to those of TV, the other important parameter that determines the RY. This trend was true for almost all the clones. Though clonal variation existed for this trait, TV contributed most of the variation for RY in the present study. TSC, which was constituted by DRC, for more than 90 per cent of it, followed the pattern of DRC. Clone RRIC 105 had higher DRC, followed by PB 235 and RRII 105.

It was interesting to note that the clones PB 235, RRII 105, RRIC 105 and RRIM 600 had relatively less sucrose outflow than other clones. These clones had better TV, Pi and/or DRC. Also it was noticed that the clones with higher SC had lower DRC and Pi (GT 1, PB 86, RRII 203). Vinod *et al.* (1999) had found that SC played a predominant role in determining TV during peak yielding season. High quantity of SC seen along with the higher TV during this period could be caused by the drainage of excess, unutilized sucrose through the latex serum. High Pi is a good indicator of high laticifer metabolism, because its direct involvement in isoprene synthesis is well known (Serres *et al.*, 1994). This indicated that these clones had a better mechanism of sucrose utilization and rubber synthesis during the peak yielding season. Lower DRC of RRIM 600, despite having low SC and moderate Pi could be attributed to lower sucrose loading during this period for which other clones were susceptible. Sucrose loading and utilization are two important factors that govern SC in latex serum (Komor and Olrich, 1986). However, direct link between TV and SC could not be established in many clones probably due to the influence of other factors related to latex regeneration.

The variation in expression of genotype due to difference in environments (phenotypic plasticity) is common in plants especially when exposed to stress (Bradshaw, 1965). The ability of a genotype to withstand the variation in environment is referred to as phenotypic stability. The more

Table 1. **Mean seasonal values and PCV (%) of yield and related traits for different clones in two peak yielding seasons**

Clone	IF (ml)		PI		DRC (% w/v)		TSC (% w/w)		P_i (mg / 100 g)		SC (mg / 100 g)		TV(ml)		RY (g / tree / tap)	
	Mean	PCV	Mean	PCV	Mean	PCV	Mean	PCV	Mean	PCV	Mean	PCV	Mean	PCV	Mean	PCV
S_1 : 1993 - 94 season																
RRII105	16.28 ab	19.96	3.16 a	89.46	30.75 c	22.50	37.41 bcd	19.31	204.15 b	46.27	4.31 e	37.81	172.96 b	49.74	48.74 d	46.07
RRII 118	14.02 cd	26.60	2.52 b	79.49	29.00 de	17.25	34.55 e	11.92	128.92 e	36.85	4.55 d	39.24	136.55 e	30.00	53.30 c	31.04
RRII 203	10.02 fg	29.37	1.56 d	68.12	28.18 de	19.29	34.60 e	16.84	173.85 c	25.57	4.77 bc	46.90	151.40 d	33.14	47.55 d	36.77
RRIM 600	17.30 a	30.33	2.02 c	89.94	27.63 ef	21.41	35.75 de	16.21	170.15 c	31.39	4.42 e	44.75	224.29 a	28.38	61.30 a	30.91
PB 86	12.87 de	18.03	2.45 b	71.96	28.23 de	17.38	35.09 e	13.00	142.62 d	44.31	6.51 a	37.86	134.76 e	31.10	39.75 e	33.74
PB 235	15.18 bc	20.76	2.61 b	79.42	32.52 b	16.28	38.77 b	14.89	232.46 a	45.49	2.93 f	34.33	166.30 c	45.43	57.14 b	44.30
RRIC 105	11.08 ef	21.70	2.55 b	55.02	34.96 a	16.12	43.15 a	13.60	121.31 f	40.97	2.55 g	35.77	108.16 f	41.84	37.48 f	26.73
GT 1	10.89 f	30.97	1.89 c	58.04	26.28 f	19.73	35.64 de	12.16	148.31 d	25.17	4.65 c	31.25	138.79 e	23.95	35.32 g.	26.01
GI 1	8.46 gh	25.61	3.11 a	57.72	28.75 de	19.37	36.31 cde	16.67	75.62 g	52.60	4.41 e	30.46	73.10 g	38.94	24.60 h	35.90
Harbel 1	7.78 h	33.48	3.01 a	66.5	29.81 cd	23.73	37.70 bc	20.19	144.92 d	35.70	4.81 b	62.39	69.18 g	40.48	25.06 h	33.73
S_2 : 1994-95 season																
RRII 105	17.05 cd	27.20	2.35 b	64.42	30.73 cd	19.28	36.94 bc	16.64	187.37 b	45.12	4.19 f	34.85	187.27 c	36.84	48.77 c	38.38
RRII 118	13.63 bc	19.46	2.01 cd	49.89	29.83 cd	17.25	35.42 c	15.63	141.65 d	26.00	5.23 d	42.51	156.40 e	26.74	47.57 c	32.15
RRII 203	11.78 d	18.01	1.35 f	29.69	29.09 d	16.23	35.43 c	12.06	159.70 c	13.98	6.45 b	48.20	178.05 d	17.27	45.05 d	24.28
RRIM 600	17.41 a	26.91	1.62 e	54.39	29.72 cd	20.14	37.28 b	19.18	183.80 b	27.44	5.64 c	35.78	235.91 a	22.56	51.68 b	28.73
PB 86	14.81 b	10.73	2.00 cd	54.02	29.75 cd	18.83	36.31 bc	15.52	156.36 c	26.28	7.69 a	49.50	176.85 d	34.40	42.09 e	23.40
PB 235	17.81 a	24.22	1.78 e	26.69	33.49 b	9.70	39.93 a	6.21	276.47 a	18.57	4.15 f	45.69	210.59 b	25.75	56.33 a	33.20
RRIC 105	12.81 cd	20.14	2.13 e	49.67	36.01 a	7.11	40.93 a	8.01	120.27 e	24.97	2.99 g	34.40	143.47 f	26.53	40.21 f	24.10
GT 1	10.08 e	24.63	1.39 f	38.98	26.00 e	17.36	32.62 d	16.37	160.31 c	18.13	5.78 c	30.93	152.90 e	17.48	35.37 g	25.97
GI 1	8.72 e	19.38	2.00 d	37.06	31.03 c	13.19	37.36 b	13.56	90.45 f	28.28	4.74 e	42.01	115.61 g	25.10	24.56 i	28.49
Harbel 1	9.75 e	18.08	3.01 a	21.41	34.68 ab	9.19	39.95 a	7.95	136.20 d	27.17	5.67 c	44.84	82.79 h	28.82	29.58 h	38.52
$r(S_1, S_2)$¶	0.927*		0.745*		0.903*		0.879*		0.927*		0.952*		0.939*		0.976*	

Clone means followed by same letters are not significantly different at 5% level, by Duncan's Multiple Range Test. ¶ Spearman's rank correlation for characters between two years (peak yielding seasons), *significant at 5% level. PCV = Phenotypic coefficient variation; IF = Initial flow; PI = Plugging index; DRC = Dry rubber content; TSC = Total solids content; P*i* = Inorganic phosphorus; SC = Sucrose content; TV = Total volume; RY = Dry rubber yield

Table 2. **Variances of ranks ($S_i^{(2)}$ values) for yield and related traits of clones during the peak yielding seasons**

Clone	Variance of ranks ($S_i^{(2)}$ values)							
	IF	PI	DRC	TSC	P*i*	SG	TV	RY
1993-94								
RRII 105	12.42	8.76	12.90	15.97	12.59	11.60	17.58	10.26
RRII 118	1.44	12.06	3.03	7.36	6.64	5.42	11.24	9.19
RRII 203	6.67	7.09	8.81	9.53	14.08	12.56	13.09	9.90
RRIM 600	6.27	14.91	9.06	2.59	4.58	8.40	2.42	5.58
PB 86	8.91	6.09	9.44	2.47	5.06	4.44	6.92	11.92
PB 235	17.58	6.47	15.14	12.58	7.76	8.97	10.97	6.58
RRIC 105	8.60	8.83	4.83	7.31	7.14	9.59	7.26	4.86
GT 1	7.56	5.69	7.10	4.74	6.26	6.86	8.14	4.74
Gl 1	13.42	9.92	12.60	12.27	11.59	9.94	6.86	8.00
Harbel 1	5.59	7.44	5.77	6.14	10.10	9.14	3.73	15.94
1994-95								
RRII 105	10.67	11.76	13.67	14.58	10.56	8.94	19.09	9.14
RRII 118	7.64	4.19	2.81	3.41	6.42	6.10	6.50	7.92
RRII 203	5.06	5.58	6.86	9.76	5.60	2.86	10.44	13.08
RRIM 600	8.31	12.24	7.09	3.76	8.53	11.83	10.23	4.44
PB 86	5.41	12.31	14.59	10.91	11.09	7.86	3.91	16.58
PB 235	13.03	13.91	18.42	15.31	13.83	11.56	12.42	5.17
RRIC 105	11.41	9.17	3.64	6.23	10.24	11.17	3.08	10.00
GT 1	5.42	2.90	6.69	5.50	1.06	4.81	5.81	6.40
Gl 1	9.19	6.56	7.60	3.26	8.97	7.47	10.60	6.90
Harbel 1	10.9	7.91	6.91	11.64	11.73	15.76	5.09	8.56

IF = Initial flow; PI = Plugging index; DRC = Dry rubber content; TSC = Total solids content; P*i* = Inorganic phosphorus; SC = Sucrose content; TV = Total volume; RY = Dry rubber yield.

stable the genotype, less would be the variation it expresses over environments. The analysis of stability revealed that RRII 105 had shown more variation for most of the traits followed by PB 235. These clones were considered to be less stable in yield performance during peak yielding season. More stable reaction was exhibited by lower yielding clones. The decrement in stability over months for clones with higher yield potential was reported earlier (Vinod *et al.*, 1996b). The stability in yield of clones between years was found to differ in many clones, especially for those that had lower yield than RRII 105 and PB 235. The clone RRIM 600, however, was found relatively more stable as well as high yielding. This clone has wider adaptability for girth increment, especially during winter in Tripura (Menattoor *et al.*, 1991). The clones GT 1 and RRII 118 were found more stable among all the clones for most of the traits conforming to the better stability of these clones over yielding months observed earlier (Vinod *et al.*, 1996b). From the above observations it is clear that stable clones had a mechanism of buffering the slight fluctuations in environment. Kang (1998) proposed that a genotype that performed consistently across many environments would possibly possess broad-based durable resistance/tolerance to the biotic and abiotic environmental factors that it ecountered during development.

Grouping of clones based on the non-hierarchical Euclidean cluster analysis, brought out three clusters of clones based on the genetic diversity for yield and related

Table 3. **Mean values of yield and related traits for different clusters**

Cluster	IF (ml)	PI	DRC (% w/v)	TSC (% w/v)	P_i (mg/100 g)	SG (mg/100g)	TV (ml)	RY g/tree/tap)
I	16.84	2.26	30.81	37.68	209.07	4.27	199.55	53.99
II	12.26	1.90	28.30	34.96	151.46	5.70	153.21	43.25
III	9.77	2.63	32.54	39.23	114.79	4.19	98.72	30.25

Cluster I (3 clones) : RRII 105, RRIM 600 and PB 235; Cluster II (4 clones) : RRII 118, RRII 203, PB 86 and GT 1
Cluster III (3 clones): RRIC 105, Gl 1 and Harbel 1
IF = Initial flow; PI = Plugging index; DRC = Dry rubber content; TSC = Total solids content; Pi = Inorganic phosphorus; SC = Sucrose content; TV = Total volume; RY = Dry rubber yield.

traits (Table 3). Cluster I had three clones, RRII 105, RRIM 600 and PB 235; cluster II contained four clones, RRII 118, RRII 203, PB 86 and GT 1; and cluster III had RRIC 105, Gl 1 and Harbel 1. The mean values of traits that contribute to performance of the clones revealed that cluster I had high yielding clones, cluster II had medium and cluster III had low yielding clones. The distance between clusters showed that cluster III is more divergent than clusters I and II (Table 4). The average intra cluster distance was similar in all three clusters.

Table 4. **Average intra (bold) and inter cluster distances of ten clones**

Cluster	I	II	III	SS*
I	**1.568**			7.39
II	3.116	**1.385**		7.67
III	4.458	3.698	**1.914**	10.9

*Deviation

The results revealed that the observed variation in character expression in different clones during the peak yielding season is considerably influenced by the variation in environment. The onset of senescence and the leaf fall that followed, triggered by the onset of winter could be causing a natural stimulation mechanism. Clonal efficiency in metabolic process, utilisation of sucrose *etc.*, along with factors that determine the stability for yield as observed in RRIM 600, configure the ability to mitigate the low temperature stress in North East India. Such clones are more desirable for extensive cultivation, as they are believed to be more adaptable to biotic and abiotic stress.

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