Genotype x Environment Interactions in *Hevea* in Diverse Agroclimatic Conditions in India - Preliminary Growth Results

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Rubber plantation in India, which commenced almost a century ago, is extending to new regions, spread over different parts of the country, in search of ways to bridge the gap between production and demand. The newly established rubber growing regions are different in their agro climatic conditions from the traditional rubber growing tract and hence a study was undertaken to assess the Genotype x environment interactions of proven and new hybrid clones. Data on girth, bark thickness and number of latex vessel rows from 12 clones planted at four locations were used for preliminary assessment of growth. Results showed that there was a significant genotype x environment interaction. Analysis for stability showed that the clone 82/30 is a stable and adaptable clone and is followed by RRII 51, 82/17 and RRII 105. Principal component analysis done for these parameters resulted in the identification of 4 clones as stable. This study also revealed that multivariate analysis could be used in Hevea *for stability studies. Clones 82/29 and 82/30, the new hybrid clones are promising with respect to their growth in different locations and are found to be suitable for cultivation in both traditional and non-traditional regions.*

Keywords: *Clones, Genotype x environment interaction,* Hevea brasiliensis, *stability, girth, bark thickness, number of latex vessel rows.*

Hevea brasiliensis, the natural rubber yielding tree indigenous to the Amazon rain forests was introduced into India during the last part of the nineteenth century and commercial cultivation of this crop started in 1902 in the state of Kerala, situated in the south western

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coast of India. The area under the crop steadily increased over the years and it now covers about 550,000 ha. The consumption of rubber in the country started outstripping production from 1950 onwards and the gap between production and consumption is projected to be a widening one. This situation necessitated expanding cultivation to newer areas outside the agroclimatic limits normally prescribed for rubber plantation.

Hevea rubber had been planted on a very limited scale in areas far removed from the traditional rubber growing belt from early part of this century. Trees were planted on an experimental basis in Assam in North-East India in 1913 and some of the trees are still growing robustly. In many other states also located outside the traditional region, rubber trees were planted on experimental basis and the growth has been observed to be satisfactory. Encouraged by the results, India started to promote rubber cultivation in a commercial way in the North East from 1960s. Exploratory survey conducted by the Rubber Board of India indicated that vast expanses of land are available in the country where rubber could be successfully grown, though these regions have agroclimatic constraints of varying degrees. Locations with potential within these new areas are in the states of Assam, Tripura, West Bengal and Orissa.

Extending cultivation of rubber into the non-traditional region posed various problems warranting R&D intervention and accordingly research activities also were initiated during late seventies. One of the thrust areas identified for research have been screening of various available clones for their suitability. Clone evaluation trials were laid out in various regional research stations of the RRII in the non- traditional regions from 1979 onwards. These multilocational trials were initiated with the objective of identifying clones with better adaptability and stability, which in turn warranted studies on Genotype x Environment interaction. The data generated would be of help in the breeding programmes for evolving clones for different agro environments.

Studies on G x E interactions in *Hevea* are limited. Reports are available from Malaysia (Tan, 1991), Sri Lanka (Jayasekera *et al.,* 1977; Jayasekera, 1984 and Jayasekera & Karunasekera, 1984), Indonesia (Aidi-Daslin *et al.*, 1986), Nigeria (Onokpise *et al.,* 1986), India (Rajeswari Meenattoor *et al.,* 1991) and Brazil (Goncalves *et al.,* 1990b, 1992 and 1998). All these studies establish the existence of G x E interactions in *Hevea.* The present investigation was taken up to assess the performance of a set of clones including hybrid clones yet to be released, in four different locations in the country *viz.*, Agartala (Tripura), Nagrakata (West Bengal), Bhubaneswar (Orissa) and Kanyakumari (the traditional belt).

MATERIALS AND METHODS

The study consists of data collected from experiments planted in 1996 at four locations with

12 clones. The design was Randomised Block Design with three replications. Details about clones and locations are given below.

Clones

The twelve clones used in this project were, RRII 105, RRII 203, RRII 51, RRII 176, RRIM 600, PB 217, 82/14, 82/17, 82/22, 82/29, and 82/30. Of these, the last five clones are the progeny of a cross of RRII105 x RRIC100 from 1982 hybridisation programme. All others are proven clones in the traditional region, of which RRII 105 is the highest yielding clone. The hybrids of 1982 hybridisation were higher yielding than RRII 105 in preliminary yield trials (Licy *et al.*, 1992).

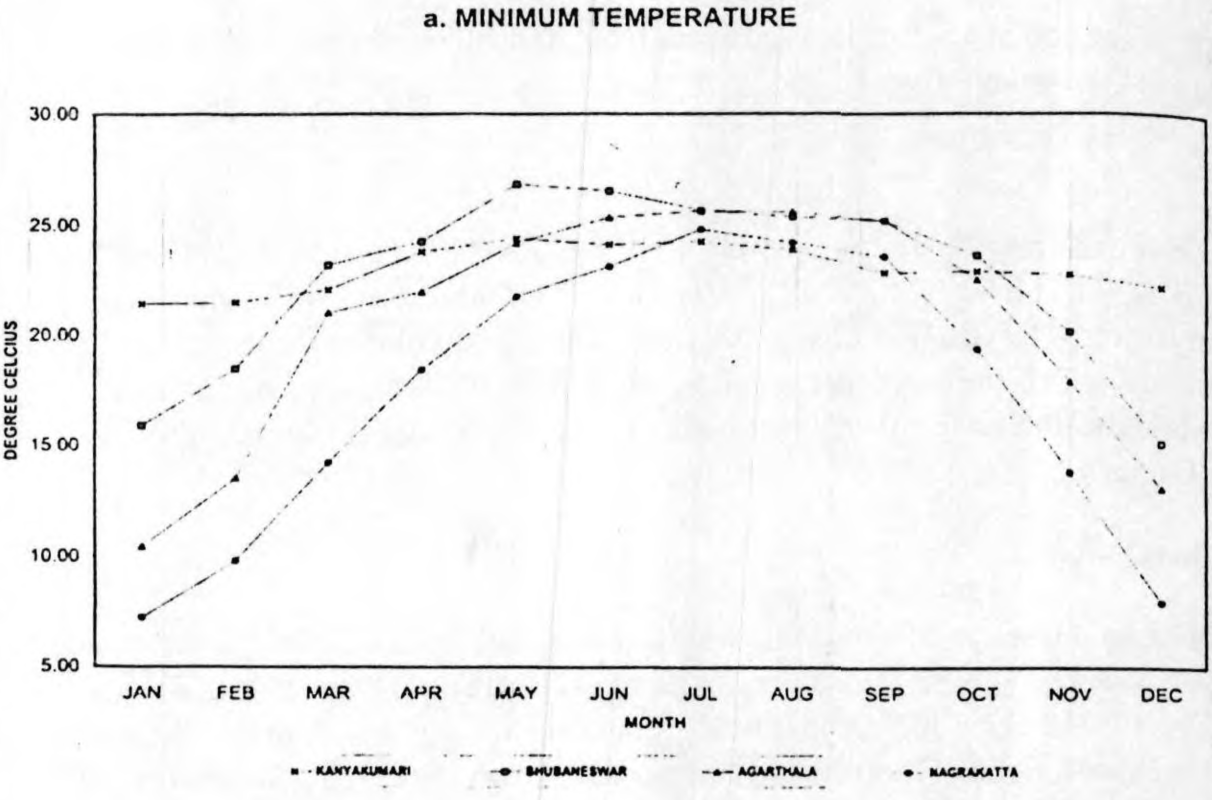
Locations

The four locations selected for the study were Kanyakumari (traditional belt), Bhubaneswar (Orissa), Nagrakata (West Bengal),and Agartala (Tripura). Kanyakumari is situated at 8°26' N and 77° 19' E and 300 m above MSL. Rainfall in this region is moderate and is more or less evenly distributed. Temperature variations are not marked. Soil is lateritic/red soil.

Agartala is situated at 25°53'N, 91°15'E and 21 m above MSL. This place has the shortest dry spell among the North-Eastern states. It has a winter season with lowest minimum temperature observed during January. The highest maximum temperature is in March. Occurrence of storm/hailstorms is an annual feature in Tripura, which cause injury to the foliage and bark of trees.

Bhubaneswar, the capital city of the state Orissa, is located at 20°15'N and 85°52'E at an altitude of 25.9 m above MSL. The soil is sandy loam, lateritic in nature. Low availability of moisture in the soil is likely to create stress. Nagrakata is located in North Bengal at 28°54'N 88°25'E and 69m above MSL. This place is located in the foothills of the Himalayas. Soil is sandy loam.

Details of meteorological parameters are given in *Figure.1*. Experimental clones were planted in 1996 in Randomised Block Design with three replications. Data on girth collected at quarterly intervals, and anatomical parameters *viz.*, bark thickness, and latex vessel rows were utilised for the present study. For anatomical measurements, bark samples were collected using a 1.5 cm^2 punch at a height of 30 cm from the bud union of the three year old plants, and the samples were preserved in FAA. Radial longitudinal sections of 80 µm thickness were taken with a base sledge microtome and stained with Sudan 111. Number of latex vessel rings and bark thickness were observed from 2 trees per replication for all the clones in the four locations; using a light microscope. Stability analysis of all the parameters were



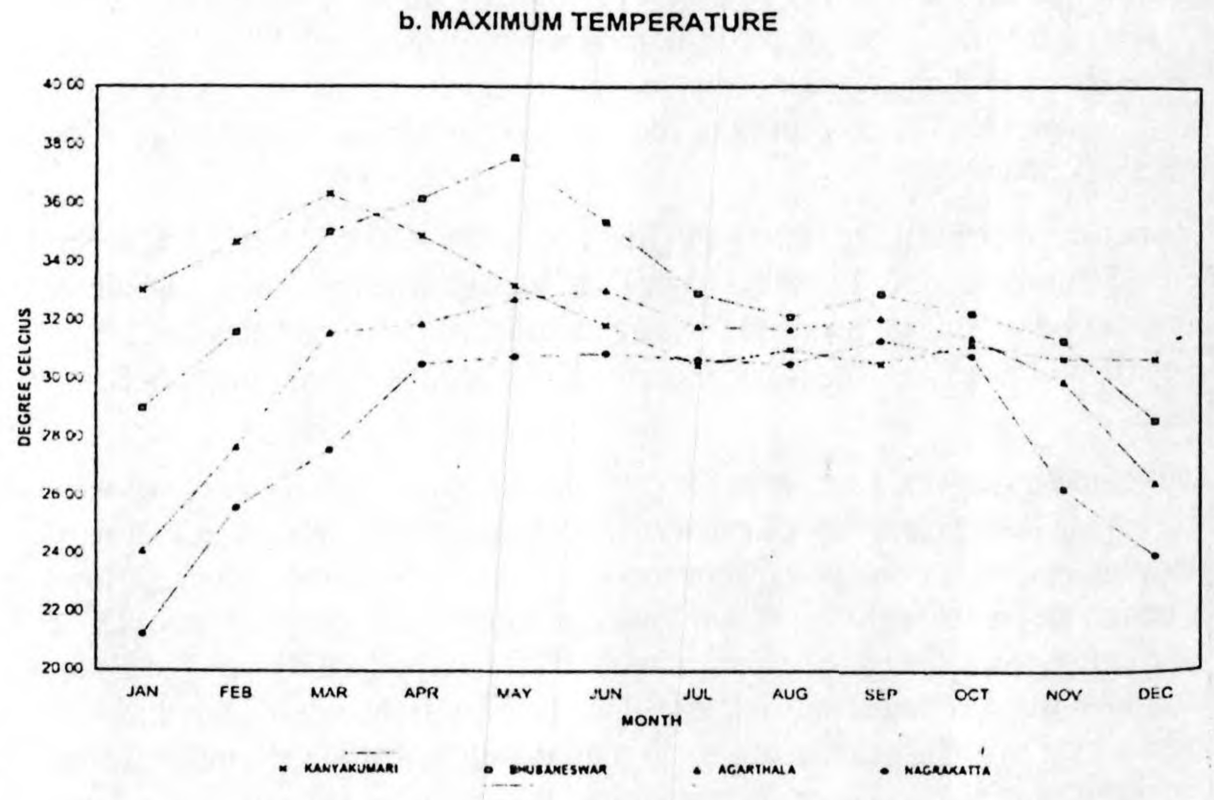


Figure 1. Meteorological parameters of the four locations

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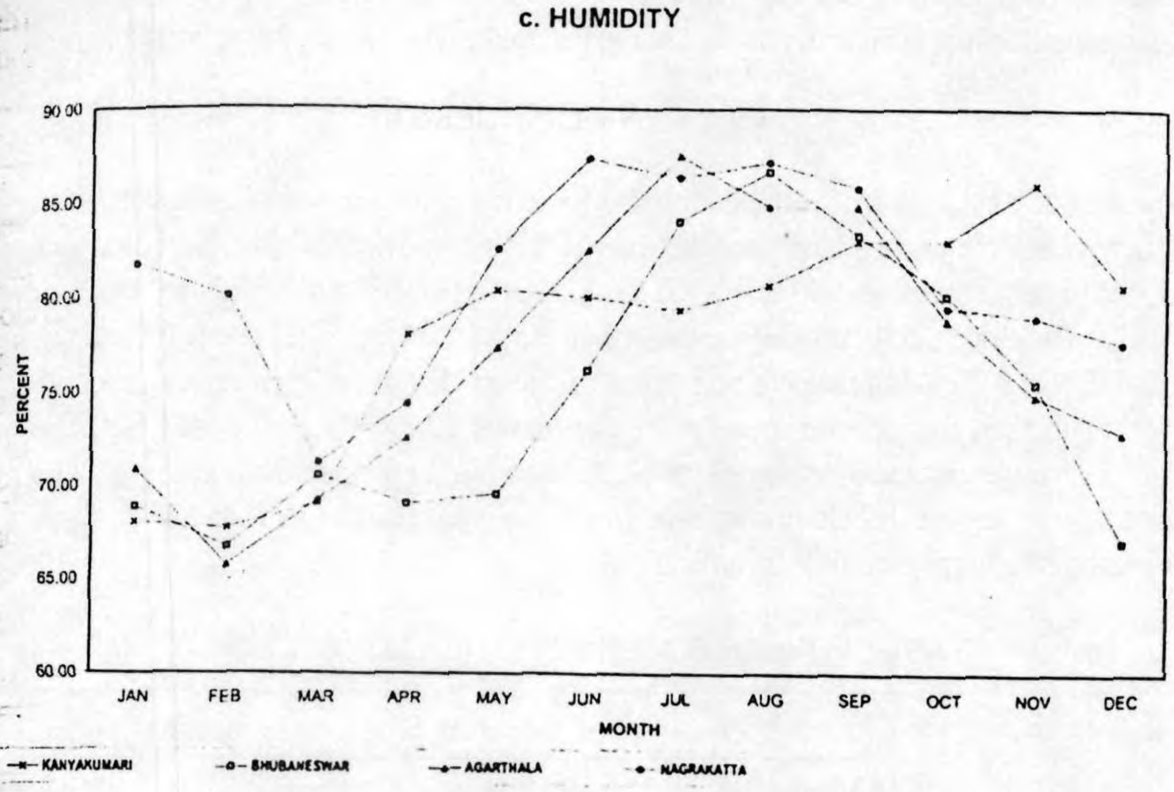

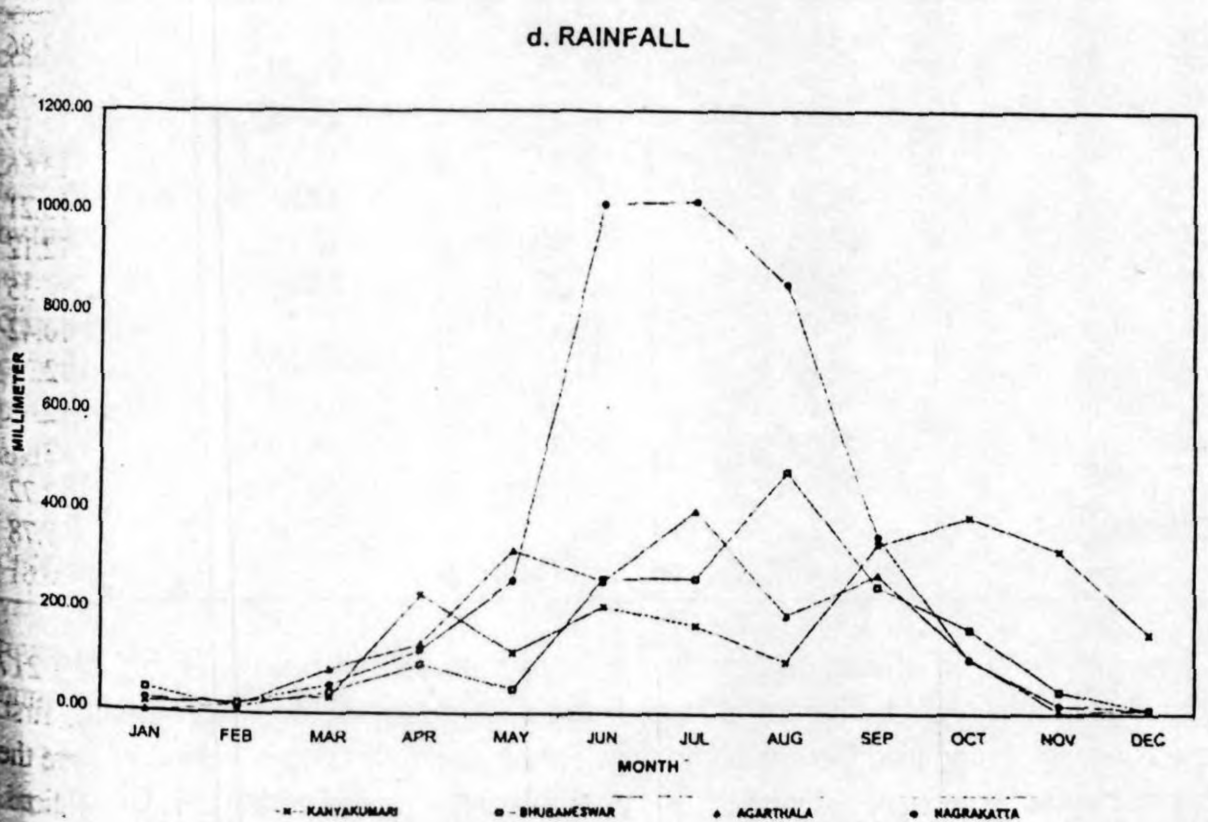

Figure 1. Meteorological parameters of the four locations (Continued)

done using the method of Eberhart and Russel (1966). Multivariate analysis was also done using principal component analysis, following the method of Balakrishnan and Jain (1988a).

RESULTS AND DISCUSSION

Analysis of data on girth from all the locations revealed that there was significant difference in girth between clones in all the locations except in Bhuvaneswar *(Table 1)*. Pooled analysis for stability on girth has shown that RRII 51, 82/30, RRII 105, and 82/17 are stable clones *(Table 2)*. The clone 82/30 has a higher mean than the grand mean. The criteria for adaptability and stability *viz.*, bi value nearing one, non significant deviation from regression and also higher mean than the general mean place the clones 82/30, RRII 105 and 82/17 in the category of stable clones. Since the clone 82/30 has a higher girth in Bhuvaneswar, which is a drought prone region, this clone may have drought tolerant characteristics which is supported by an earlier study (personal communication).

TABLE 1: MEAN GIRTH FROM FOUR LOCATIONS

Clone	Mean girth (cm) by location			
	Kanyakumari	Bhubaneswar	Nagrakata	Agarala
RRIM 600	24.03	18.13	18.87	12.96
82/29	27.43	18.33	21.77	16.54
RRII 203	24.81	18.97	21.48	14.19
PB 217	27.77	19.37	18.85	13.66
RRII 51	26.32	17.23	18.33	13.21
82/14	22.96	16.40	18.28	12.12
82/30	26.16	19.27	18.13	14.35
RRIC 100	27.22	19.17	15.37	10.42
82/22	25.93	17.33	13.83	12.35
RRII 105	24.03	17.93	18.08	12.42
82/17	25.27	18.80	18.40	12.41
RRII 176	27.61	16.70	19.15	12.72
LSD(P<0.05)	3.03	NS	2.07	1.78
SE	1.03	0.95	0.70	0.61

It was observed from data on girth that in Kanyakumari and Bhuvaneswar, PB 217 recorded the highest girth whereas in Nagrakata and Agartala, clone 82/29 ranked first. These two sets of regions differ mainly in experiencing a similar winter period where the temperatures can be very low. Clone RRII 203 generally showed good girthing in all locations. Mean girth was found to be very high in the case of clone 82/29 in almost all locations. The

TABLE 2. STABILITY ANALYSIS FOR GIRTH (EBERHART & RUSSEL 1966) (POOLED DATA)

Sl.no.	Clones	Mean	bi	Deviation
1	RRIM 600	18.50	0.87	NS
2	82/29	21.02	0.89	S
3	RRII 203	19.86	0.83	NS
4	PB 217	19.91	1.13	NS
5	RRII 51	18.77	1.06	NS
6	82/14	17.44	0.86	NS
7	82/30	19.48	0.95	NS
8	RRIC 100	18.05	1.34	S
9	82/22	16.86	0.94	S
10	RRII 105	18.12	0.92	NS
11	82/17	18.72	1.01	NS
12	RRII 176	19.05	1.20	NS
General mean		18.82		

clone RRIC 100 recorded good girth in Kanyakumari and Bhuvaneswar but has performed poorly in Nagrakata and Agartala. This clone has shown clear evidence of susceptibility to cold weather by recording maximum number of plants dying off during winter. The low girthing can also be attributed to the susceptibility to low temperature. Plants of this clone in Nagrakata has started drying off during winter period from the very first year. However, later in the year during rainy season the trees started to put forth new flush very slowly, but by three years they died off completely. The bark of this clone in these two locations showed abnormalities as they split and developed cracks. As observed by Steffen *et al.,* (1989), climatic adaptation at non freezing cold stress depends upon the maintenance of normal growth and development of a cultivar. Retardation of growth and development at immature phase itself establishes that this clone cannot survive in the climatic conditions of Nagrakata and Agartala.

Analysis of mean number of latex vessel rows showed that there were significant differences in all the locations except Bhuvaneswar *(Table 3)*. The clone 82/30 had high values for this character in all the locations. Stability analysis of number of latex vessel rows revealed that clones 82/29, 82/30, 82/17 and RRII 176 were not stable with respect to number of latex vessel rows (*Table 4*).

Mean values for bark thickness from the four locations are given in *Table 5*. Bark thickness data when evaluated for stability showed that clones 82/29, RRII 203 and RRII 176 were not stable (*Table 6)* Several earlier workers stressed the significance of bark structural

TABLE 3: MEAN NUMBER OF LATEX VESSEL ROWS

Clone	Mean number of latex vessel rows			
	Kanyakumari	Bhubaneswar	Nagrakata	Agarala
RRIM 600	4.53	2.90	3.23	2.37
82/29	5.07	2.03	2.57	3.03
RRII 203	5.17	2.50	2.93	2.47
PB 217	4.47	2.87	3.93	2.0
RRII 51	4.23	2.83	3.43	1.77
82/14	4.30	2.50	3.47	2.20
82/30	6.43	3.63	4.63	2.90
RRIC 100	4.00	2.23	3.80	2.63
82/22	3.83	1.90	3.23	1.67
RRII 105	4.23	2.37	3.33	1.90
82/17	4.90	3.43	5.43	3.77
RRII 176	5.13	2.53	2.50	2.03
LSD($P<0.05$)	1.1	NS	1.24	0.87
SE	0.37	0.39	0.42	0.29

TABLE 4: STABILITY ANALYSIS OF LATEX VESSEL ROWS

Clone	Mean	bi	Deviation from regression	Significance
RRIM 600	3.2975	0.86428	-0.082908	NS
82/29	3.175	1.040876	0.7486932	
RRII 203	3.2675	1.169615	0.1222	NS
PB 217	3.3175	0.9934798	0.06398	NS
RRII 51	3.065	0.9361797	0.05092	NS
82/14	3.1175	0.9148525	-0.1236	NS
82/30	4.3975	1.463071	-0.10067	
RRIC 100	3.165	0.7441718	0.09287	NS
82/22	2.6575	0.9747635	-0.05417	NS
RRII 105	2.9575	0.9879689	-0.1111	NS
82/17	4.3029	0.0090348	0.4090	
RRII 176	3.0475	1.242085	0.32957	

NS - Not significant

TABLE 5: MEAN BARK THICKNESS (MM) FROM FOUR LOCATIONS

Clone	Mean bark thickness at different locations			
	Kanyakumari	Bhubaneswar	Nagrakata	Agarala
RRIM 600	4.78	3.57	3.67	2.89
82/29	6.06	3.06	3.43	2.86
RRII 203	3.83	3.95	4.21	3.58
PB 217	5.42	4.23	4.13	3.23
RRII 51	5.03	3.93	3.51	3.33
82/14	4.31	3.17	3.52	2.9
82/30	4.60	3.55	3.97	3.0
RRIC 100	4.60	3.50	3.46	2.88
82/22	4.43	2.94	3.25	2.66
RRII 105	4.91	3.99	3.61	3.31
82/17	4.90	4.05	4.09	3.26
RRII 176	4.97	3.49	3.64	2.78
LSD(P<0.05)	0.59	0.58	0.54	0.38
SE	0.20	0.20	0.18	0.13

TABLE 6: STABILITY ANALYSIS - BARK THICKNESS

Clone	Mean	bi	Deviation from regression	Significance
RRIM 600	3.7275	1.059573	-0.296889	NS
82/29	3.8525	1.940438	0.2282879	
RRII 203	3.8925	0.7919	0.06525	
PB 217	4.275	1.195389	0.0149	NS
RRII 51	3.95	0.9847488	0.048859	NS
82/14	3.475	0.813857	-0.01135	NS
82/30	3.78	0.8816902	0.018272	NS
RRIC 100	3.61	0.9717188	-0.02894	NS
82/22	3.32	1.038998	-0.00459	NS
RRII 105	3.955	0.9067613	0.02094	NS
82/17	4.075	0.8889049	-0.0042	NS
RRII 176	3.72	1.238725	-0.031508	

NS - Not significant

characteristics in determining the yield in young *Hevea* plants, among which the number of latex vessel rows is one of the principal yield determinants (Narayanan *et al.*, 1973, 1974; Narayanan & Ho 1973; Ho *et al.*, 1973; and Premakumari & Panikkar (1989,1992). Annamma Varghese *et al.*, (1993) observed high number of latex vessel rows associated with high yield in three year old plants, but no similar trend was noticed in the case of bark thickness. Girth, latex vessel rows and bark thickness were however observed to be unrelated and contributing independently to yield. For some clones girth is more important than latex vessel rows and *vice versa* for others (Narayanan *et al.*, 1973). According to Wycherly (1969) and Ho (1972), as quoted by Premakumari and Panikkar(1992), these characters are unreliable as a single factor to assess the clones in their early growth phase owing to the mutual interference and unfavourable associations. Results of the analysis of girth and structural parameters in this study also show that they are unrelated.

As reported by Prabhakaran and Jain (1994), the response pattern of different traits might be quite dissimilar in nature and in this context the usual single trait analysis will not help in reconciling the contrasting assessments into a unified conclusion. Hence in the present study we have applied the procedure by Balakrishnan and Jain (1988) based on principal component analysis to conclude as to which are the stable clones with respect to the traits studied. In the analysis, the first given value accounting for 82% (*Table 7*) itself proves the applicability of this technique in the present data. This analysis revealed that clones RRII 203, PB 217, 82/30, and 82/17 are stable clones (*Table 8* and *9*).

TABLE 7: LATENT VECTORS (PRINCIPLE COMPONENT ANALYSIS)

Variables	Principle 1	Principle 2	Principle 3
1	0.548	0.836	0.039
2	0.594	-0.355	-0.722
3	0.590	-0.419	0.691
% Variation	81.77	12.60	5.60

CONCLUSION

This study has revealed that there is significant G x E interaction in *Hevea*. This interaction has been reported from various rubber growing countries of the world and referred to earlier in this paper. The present study has shown that, of the different clones tested, the hybrid clones 82/29 and 82/30 are stable and adaptable and are suitable for cultivation both in the traditional and non traditional rubber growing regions of India. Results of the analysis clearly shows that in the case of stability studies in *Hevea,* principal component analysis could be applied successfully. Further studies on yield and yield attributes are being carried out to establish the results drawn from this study.

TABLE 8: MEAN TABLE - PRINCIPLE COMPONENT ANALYSIS

Clone	Mean			
	Kanyakumari	Bhubaneswar	Agarala	Nagrakata
RRIM 600	19.49	14.40	10.65	15.08
82/29	22.55	13.74	13.11	16.28
RRII 203	19.73	14.9	11.85	16.77
PB 217	22.04	15.56	11.07	16.72
RRII 51	20.82	14.05	10.73	14.77
82/14	18.45	12.92	10.07	14.77
82/30	21.68	15.46	11.83	15.59
RRIC 100	20.97	14.60	9.29	13.20
82/22	18.84	13.01	9.77	11.86
RRII 105	19.40	14.24	10.33	14.63
82/17	20.49	15.37	11.32	16.26
RRII 176	22.05	13.31	10.27	14.83
CD	2.31	NS	1.22	1.59

TABLE 9: STABILITY ANALYSIS (PRINCIPLE COMPONENT ANALYSIS)

Clone	Mean	bi	Deviation from regression	Significance
RRIM 600	14.915	0.8990	-0.2131	NS
82/29	16.42	1.0272	1.991	
RRII 203	15.813	0.8029	0.4284	NS
PB 217	16.1	1.122	-0.2807	NS
RRII 51	15.0975	1.0475	-0.3808	NS
82/14	14.1	0.8631	0.1092	NS
82/30	16.14	1.0163	-0.3224	NS
RRIC 100	14.525	1.1891	0.8175	
82/22	13.37	0.9430	0.7698	
RRII 105	14.65	0.9223	0.2436	NS
82/17	15.86	0.9284	0.0117	NS
RRII 176	15.125	1.2388	0.01185	NS
General mean	15.17			

NS - Not significant

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