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Temporal stability of growth and yield among *Hevea* genotypes introduced to a non-traditional rubber growing region of peninsular India

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Abstract. Extensive cultivation of *Hevea brasiliensis* in India now focus on non-traditional regions for rubber cultivation. As a prelude for selection of genotypes for commercial cultivation, many introduced genotypes are being tested in genotype adaptation experiments in these regions. Present study, reports for the first time, growth and yield adaptation of 28 genotypes in a non-traditional rubber growing region of peninsular India viz., the coastal Karnataka region. Agroclimate of this region was found favoring growth and establishment of all the genotypes evaluated. However, not all the genotypes grew and yielded well. Only four genotypes, RRII 203, KRS 25, PB 260 and PB 235 showed good growth and yield. On grouping, the genotypes fell into categories of moderate high yielders, moderate low yielders and low yielders. The most popular variety of the traditional region, RRII 105 did not perform well in this region. Biological stability in growth and yield of RRII 203 and PB 260 was identified as stable and these genotypes were the best adapted. KRS 25 and PB 235 had unstable yielding pattern. The best identified genotypes can be considered for extensive culture as single clone plantations or as major constituent of clone blends as well as parents in future breeding programmes. Other moderate stable yielders may be used for clone blending in smaller proportions and may be subjected to yield improvement.
Keywords genotype adaptation, growth, yield, stability, genotype x environment interaction.

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Introduction

The Para rubber tree (*Hevea brasiliensis* Muell. – Arg.) was introduced to India a century ago. Since then, it was under cultivation in the west coastal belt of India, confined to the state of Kerala and Kanyakumari district of Tamil Nadu, where first commercial rubber plantation in the country was established. Tremendous industrial expansion of the post independence, India had witnessed increase in demand for natural rubber as an indispensible raw material for automobile tire industry and many other industrial applications. Increasing domestic demand for natural rubber and shrinking cultivable areas in the traditional belt had compelled to push rubber plantations beyond the traditional regions.

Rubber was taken to various locations of India, where annual average rainfall was matching or closer to that of traditional regions. These non-traditional areas include Konkan region, together with the coastal belt of Karnataka, coastal Andhra Pradesh and east Telengana, east coastal and central Orissa, Sub-Himalayan valley, Doorsa regions of North Bengal and north eastern states. Among these, the first two regions as well as the traditional rubber tract fall within peninsular India.

India being a large, climatically diverse country, various agroclimatic zones manifest vivid influence on growth and yield of rubber tree. Thus, being a crop of introduction, a large number of crop adaptation experiments have been initiated in these non-traditional regions to study the adaptability of a large number of *Hevea* genotypes. This is because, to facilitate selection, the breeder is essentially concerned about the genotype adaptation to a particular environment or a limited number of similar environments, as no genotype ever excels over entire range of a widely spread crop (Simmonds 1981). Study of adaptation responses involves two aspects: (i) assessment of biological response including growth analyses and (ii) understanding the nature of adaptation for the formulation of selection strategies (Shorter et al. 1991).

Present study - for the first time - addresses the understanding of crop adaptation by assessing of growth and yield of few indigenous and exotic genotypes, introduced under the agroclimate of coastal Karnataka.

Materials and methods

Plant materials

The study comprised of 28 *Hevea* genotypes, planted in two large scale clone evaluation experiments at Hevea Breeding Station, Nettana, Dakshina Kannada (12°43’ N; 75°32’ E; 120 m MSL). Both the experiments were laid out in randomised blocks with three replications. The first experiment, comprising of 14 genotypes, was planted during 1989, and the second experiment with 15 genotypes was planted during 1990. Among the genotypes, 16 were introduced and 12 were indigenously bred (Table 1). Both the experiments had one common check, RRII 105, the most popular indigenous genotype of the traditional tract. All genotypes were planted as budded stumps, cloned on assorted rubber seedling stocks, with a spacing of 5 m x 5 m. The experiments were given with normal recommended manuring and plant protection schemes, as provided in the traditional rubber regions. A luxuriant leguminous cover crop of *Mucuna bracteata* was maintained in the experimental plots.

Field measurements

On the completion of second year of planting in the main field, growth of the genotypes was measured in terms of absolute girth at quarterly intervals. Girth was measured at 150 cm height from the bud union. Tappability of the genotypes was determined when more than 70% of the trees under each genotype reached a girth of 50 cm and beyond. When all the genotypes

Table 1 Details of the genotypes used in the study

1989 experiment			1990 experiment		
Genotype	Parentage	Country of origin	Genotype	Parentage	Country of origin
RRII 105	Tjir 1 x Gl 1	India	PB 217	PB 5/51 x PB 6/9	Malaysia
RRII 203	PB 86 x Mil 3/2	India	PB 235	PB 5/51 x PB 5/78	Malaysia
RRII 300	Tjir 1 x PR 107	India	PB 260	PB 5/51 x PB 49	Malaysia
RRII 308	Gl 1 x PB 6/50	India	PB 311	RRIM 600 x PB 235	Malaysia
RRIM 600	Tjir 1 x PB 86	Malaysia	Gl 1	Primary clone	Malaysia
PB 255	PB 5/51 x PB 32/36	Malaysia	HP 185	Tjir 1 x Mil 3/2	India
KRS 25	-	Thailand	HP 187	Tjir 1 x Mil 3/2	India
KRS 128	PB 5/63 x KRS 13	Thailand	HP 204	Tjir 1 x Mil 3/2	India
KRS 163	PB 5/63 x RRIM 501	Thailand	HP 223	Tjir 1 x Hil 28	India
PR 255	Tjir 1 x PR 107	Indonesia	HP 372	Mil 3/2 x Hil 28	India
PR 261	Tjir 1 x PR 107	Indonesia	Hil 28	Primary clone	Sri Lanka
SCATC 88/13	RRIM 600 x Pil B 84	China	Mil 3/2	Primary clone	Sri Lanka
SCATC 93/114	TR 31-45 x HK 3-11	China	GT 1	Primary clone	Indonesia
Haiken 1	Primary clone	China	Tjir 1	Primary clone	Indonesia

constituted in the individual experiment have attained tappability the trees were opened for tapping of rubber latex. The tapping system adopted was ½S d/3 6d/7, without any annual rest period. During rainy period the tress were provided with high density polyethylene rainguards for uninterrupted tapping. Yield was determined as weight of dried cuplumps. Cuplumps were collected from field at fortnightly intervals upon coagulation of latex, by addition of 0.5% formic acid directly into latex collection cups, cleaned and squeezed to remove latex serum and dried well under hot air oven. The yield of the genotypes was expressed as weight of dry rubber in *g* obtained from a tree on every tap ($g \cdot tree^{-1} \cdot tap^{-1}$).

Data analyses

The data obtained from individual experiments were analysed separately. Analysis of variance was carried out with both growth and yield data. The growth data of the first experiment consisted of 198 months' of growth from the planting date, arranged in quarterly intervals starting from 24 months after planting, while that of the second experiment had 187 months' of growth. The yield data used were continuous monthly average data for 43 months in the first experiment and 33 months in the case of the second.

The genotypes were grouped based on their yield performance over the study duration by performing a cluster analysis of the standardised data, employing Ward's method with squared Euclidean distances between the genotypes. To study the stability of yield pattern of the genotypes, a non-parametric approach was employed, in which the rank of the genotypes on each yield evaluation day was subjected to a principal component analysis (Flores et al. 1989). The variation in rank was split into two major dimensions, one relating to the magnitude of the rank and the other relating to dispersion of rank appearance.

Results

The analysis of variance revealed (Table 2) significant genotype variation for the girth and yield for both the experiments. Similarly, temporal variations also showed significance, with girth showed high magnitude of variation

Table 2 Analysis of variance for growth and yield of *Hevea* genotypes

Source of variation	1989 Experiment				1990 Experiment			
	Girth		Yield		Girth		Yield	
	MS	F-ratio	MS	F-ratio	MS	F-ratio	MS	F-ratio
Genotype	3857.0	414.6*	23352.8	133.2*	1203.3	149.3*	18213.7	198.2*
Period	11157.3	1199.3*	4788.0	27.3*	14565.4	1807.7*	5547.1	60.4*
Genotype x Period	19.7	2.1*	183.6	1.1	9.4	1.2*	248.2	2.7*
Residual	9.3		175.3		8.1		91.9	

Note: * - significant at $p = 0.05$, MS - mean squares

than yield. The genotype x period interaction was however significant for girth for both the experiments, while 1989 experiment showed non-significant interaction.

The highest average growth performance was observed in the genotype RRII 203 with 90.9 cm girth in the first experiment, followed by KRS 25 (81.4 cm). In this experiment the lowest growth performance was shown by Haiken 1 with an average girth of 59.9cm (Table 3). In the second experiment planted in 1990, the genotype PB 260 excelled in growth with an average girth of 80.1 cm followed by PB 235 with 80.0 cm girth. Gl 1 with an average girth of 65.9 cm exhibited poor growth performance in this experiment.

In the first experiment, average tree yield per tap for 43 months showed that yield level among genotypes varied between 63.8 g (RRII 203) and 11.3 g (SCATC 93/114). The next highest yielding genotypes were KRS 25 (57.2 g) and KRS 163 (53.0 g). In the other experiment, PB 260 (58.1 g) outperformed all other genotypes in yield. Tjir 1 was the poor yielding genotype in this experiment (17.7 g). The next higher yield was recorded by PB 235 (51.7 g) followed by RRII 105 (49.3 g) and PB 311 (48.1 g).

The non-hierarchical grouping of genotypes based on yield performance (Table 4), deciphered four distinct groups of genotypes under both the experiments independently. The first group consisted of two genotypes each from both the experiments with an average tree yield of 60.6 g and 54.9 g respectively. The second cluster had four genotypes from first experiment, and two from the second with an average yield of 49.0 g. The remaining 57% of genotypes from the first experiment and 73% of genotypes from the other constituted the third and fourth groups, with yield levels ranging between 11.3 to 43.3 g.

Discussion

Genotype adaptation studies in tree crops are quite laborious, time consuming and demand huge resource inputs in terms of money and space. Hence it is prudent to draw maximum conclusions as possible from meticulously laid out genotype evaluation trials at representative sites of the target environment. In this study, both the experiments were very carefully laid out and maintained through out the evaluation period with best management.

Variation in phenotypic adaptation

The variation in growth during the evaluation period showed significant levels of variances by genotypes, observation intervals (quarterly in case of girth and monthly in case of yield) and their interactions (Table 2). The significance of quarterly growth variance and its interactions is apparent since the trees are continuously growing and has no much relevance in further discussion. In the case of yield, however, yield variation may be closely following the growing environment in the month predominantly determined by weather. This has particular relevance in this study, in the context of genotype

Table 3 Average performance of *Hevea* genotype under both 1989 and 1990 experiments

1989 Experiment			1990 experiment		
Genotype	Girth (cm)*	Yield (g/tree/tap)	Genotype	Girth (cm)	Yield (g/tree/tap)
RRII 203	90.92 a	63.97 a	PB 260	80.13 a	58.11 a
KRS 25	81.38 c	57.15 b	PB 235	79.98 b	51.66 b
KRS 163	78.17 c	52.98 bc	RRII 105	73.51 e	49.26 bc
KRS 128	79.68 b	49.42 c	PB 311	72.78 de	48.09 bcd
PR 255	62.92 g	48.54 ef	HP 372	79.35 cd	45.38 cde
RRII 105	73.85 d	47.87 cd	PB 217	72.97 ef	43.91 de
RRII 308	79.85 c	42.78 de	HP 223	77.40 c	42.74 e
SCATC 88/13	66.78 f	40.99 e	GT 1	74.27 c	41.07 e
PB 255	75.17 c	37.50 ef	Gl 1	65.86 i	30.82 f
Haiken 1	59.96 h	35.30 f	HP 187	67.87 g	24.21 g
PR 261	71.03 de	33.97 fg	HP 185	71.21 f	23.42 gh
RRIM 600	72.01 e	29.56 g	Hil 28	69.57 g	23.14 gh
RRII 300	72.47 c	29.16 g	Mil 3/2	74.87 e	22.00 ghi
SCATC 93/114	66.28 fg	11.31 h	HP 204	66.24 gh	19.37 hi
			Tjir 1	62.44 hi	17.69 i
SE(d)	0.3754	1.649		0.3534	1.363

*Mean girth attained at the end of October 2005
The genotype means followed by similar letters are statistically not significant by Tukey's honestly significant difference test (95% confidence level)

Table 4 Cluster membership and centroid yield value (g/tree/tap) of each cluster

Cluster	1989 Experiment			1990 Experiment		
	Label	Member density	Centroid	Label	Member density	Centroid
I	KRS 25, RRII 203	14.29	60.56	PB 235, PB 260	13.33	54.89
II	KRS 128, KRS 163, PB 255, RRII 105	28.57	49.70	PB 311, RRII 105	13.33	48.68
III	HAIKEN 1, PR 255, PR 261, RRII 300, RRII 308, RRIM 600, SCATC 88/13	50.00	35.61	GT 1, HP 223, HP 372, PB 217	26.67	43.27
IV	SCATC 93/114	7.14	11.31	Gl 1, Hil 28, HP 185, HP 187, HP 204, Mil 3/2, Tjir 1	46.67	22.94

adaptation. Genotype adaptation is prevalently dictated by the genotype x environment interaction. If the environment is favourable genotype grows and if otherwise it perishes.

Growth performance

From the two experiments, it was seen that RRII 105, the most popular commercial clone performed uniformly showing comparable growth and yield (Table 3). In case of growth wise adaptation of genotypes, it is discernible that all the genotypes in the trial could grow and establish themselves in the agroclimate prevailing in the coastal Karnataka region. *Hevea* genotypes are known to possess wide adaptability and furthermore, this region being closer to the traditional region for rubber cultivation, unfavourable climatic situations are relatively low (Vinod et al., 2003). However, most challenging factors on the growth and establishment were prevalence of some of the serious diseases of rubber in this region, viz., pink disease (*Corticium salmonicolor*), shoot rot and abnormal leaf fall (*Phytophthora palmivora*) and Corynespora leaf fall (*Corynespora cassiicola*). Besides abiotic stress factors like high soil temperature and surface moisture deficit are common here during summer months. Albeit the establishment, not all the genotypes grew well under both experiments. Genotypes like RRII 203, PB 260, KRS 128 and PB 235 put forth good growth while genotypes like Haiken 1, Gl 1 and Tjir 1 lagged behind prominently. All those better grown genotypes had significantly higher growth than RRII 105, the check genotype. Interestingly, it was seen that both the parents of RRII 105, Tjir 1 and Gl1 were also poor growth performers in this region.

Yield performance

More than that of growth, yield performance of genotypes should indicate local adaptability, because under yielding phase, *Hevea* trees are under constant stress of latex exploitation. This stress, in addition to the stress imposed by the agroclimate and other biotic and abiotic factors should dictate the genotypic performance under commercial cultivation. In the present study, three genotypes viz. RRII 203 and KRS 25 in 1989 experiment and PB 260 in 1990 experiment out performed the check variety, RRII 105 (Table 3). RRII 105 was lagging behind few other genotypes as far as growth and yield was concerned. Though this genotype has potential to yield, it requires right environment to showcase its performance. This reiterates the earlier reports that RRII 105 exhibits high yield potential at traditional regions (Marattukalam et al., 2005), but show specific adaptation behaviour for early growth Meenatoor et al. (1991) and yield (Vinod et al. 1996) under non-traditional environments. This clone is also susceptible to biotic stresses like *Corynespora* leaf spot disease prevalent in this tract.

Empirical grouping of genotypes performed by the cluster analyses revealed four clusters of genotypes which are well separated and perceptible under both experiments (Figure 1). The first clusters of both the trials had four high yielding genotypes viz., RRII 203, KRS 25, PB 260 and PB 235. This group of four varieties can produce an average annual yield of 2021 kg/ha to 2242.0 kg/ha considering 105 tappings under ½S d/3 6d/7 system with an average stand of 350 trees/ha (Table 4). The second cluster consisted of moderately high yielding genotypes, contained RRII 105, the check variety. This group of genotypes having a mean yield value of about 50 g/tree/tap could yield on an average of 1838 kg/ha annually. The third group accommodated rest of the genotypes from the 1989 experiment except for the poor yielding genotype SCATC 93/114. The corresponding group in the 1990 experiment had four genotypes. These were moderately low yielding genotypes; with an average annual yield of less than 1600 kg/ ha and above 1300 kg/ha. Important members from this group of genotypes were RRIM 600 and GT1, the primary recommended genotypes for the non-traditional regions of India. This data shows that these genotypes may not be suitable for large scale cultivation in this region, notwithstanding the fact that they can be used as component genotypes in clone blends in smaller proportions. One of the introduced genotypes from China, SCATC 88/13 falls under this group. The fourth cluster of genotypes from the two experiments had wide range of variation. These were low yielding genotypes of this study. There were seven of them emerged from 1990 experiment, which consisted of three hybrid clones from 1954 hybridisation (Nazeer et al., 1989) and four introduced primary clones (Gl 1, Hil 28, Mil 3/2 and Tjir 1). The lowest yielding genotype among all was SCATC 93/114, a prominent cold tolerant clone from

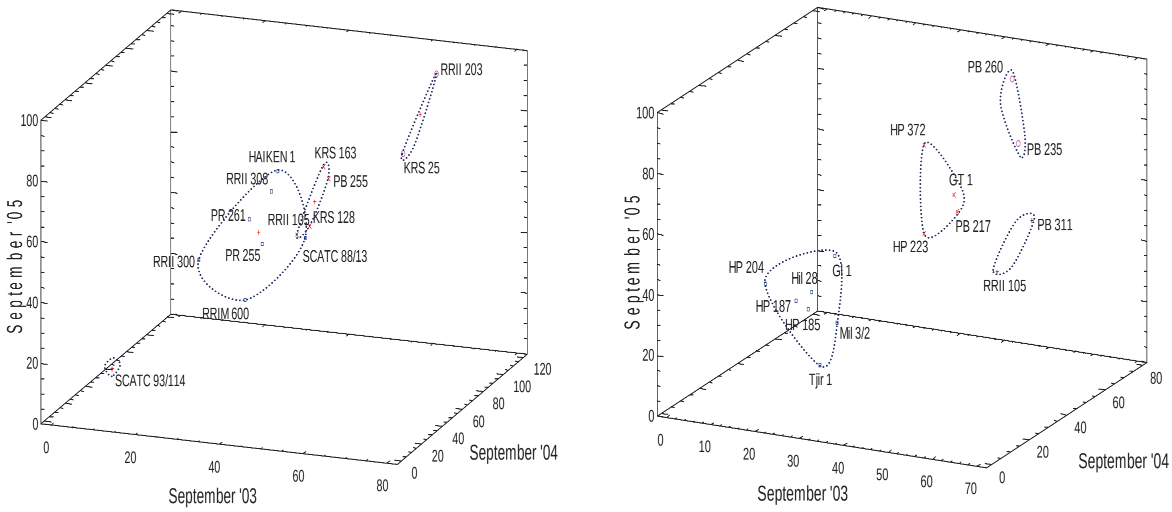

Figure 1 Cluster diagram showing the grouping of genotypes based on yielding pattern in 1989 experiment (left) and 1990 experiment (right)

China. SCATC 93/114 grows well and yields under northeast Indian conditions (Varghese 2002, Dey et al., 2004) as well as under sub-Himalayan agroclimate of North Bengal (Meti et al., 1999) where annual cooler period prevails. This can be a candidate for specifically adapted genotype that requires cooler climate, which is not common in Coastal Karnataka.

Temporal stability in growth and yield adaptation

The genotype adaptability to newly introduced environment depends on the genetic homeostasis. Homeostasis is a biological phenomenon which helps the genotype to perform similarly in a wide range of environments (Becker and Leon, 1988). The fundamental information required to study the genotype adaptation to a new environment is to assess the genotype x environment interaction on spatial scale and/or on temporal scale. When genotype x environment interactions are apparent on yield or other traits, the breeders' objective may be either to evade it by defining a narrow range of environment for the genotype (specific adaptation) or to negate it by using a stable widely adapted genotype (Simmonds, 1981).

There are several methods available to assess the stability of the genotypes under wide range of environments. However, the non-parametric approach of ranking the genotype performance across the environments is a useful and simpler approach in assessing the biological stability (Flores et al. 1998). The principal component analysis of this data helps in dispersing the total rank variation in two-dimensional plane, one deal with the magnitude of the rank other with stability of rank occurrence.

The assessment of stability of genotypes showed wide pattern of genotype performance, both in terms of growth and yield. Stability of growth performance, adjudged RRII 203 as the best genotype from 1989 experiment showing better growth with high stability (Figure 2a). The next best genotype KRS 128 also was consistently keeping its position. Among the clones which showed moderate growth vigour, none of them showed stability in performance. Among the poor performers Haiken 1 was the last ranking genotype, which consistently maintained its position. This genotype had highly unstable yielding pattern. Among the genotypes of the 1990 experiment, PB 260, RRII 105 and PB311 had best ranks for growth, and all of them were stable (Figure

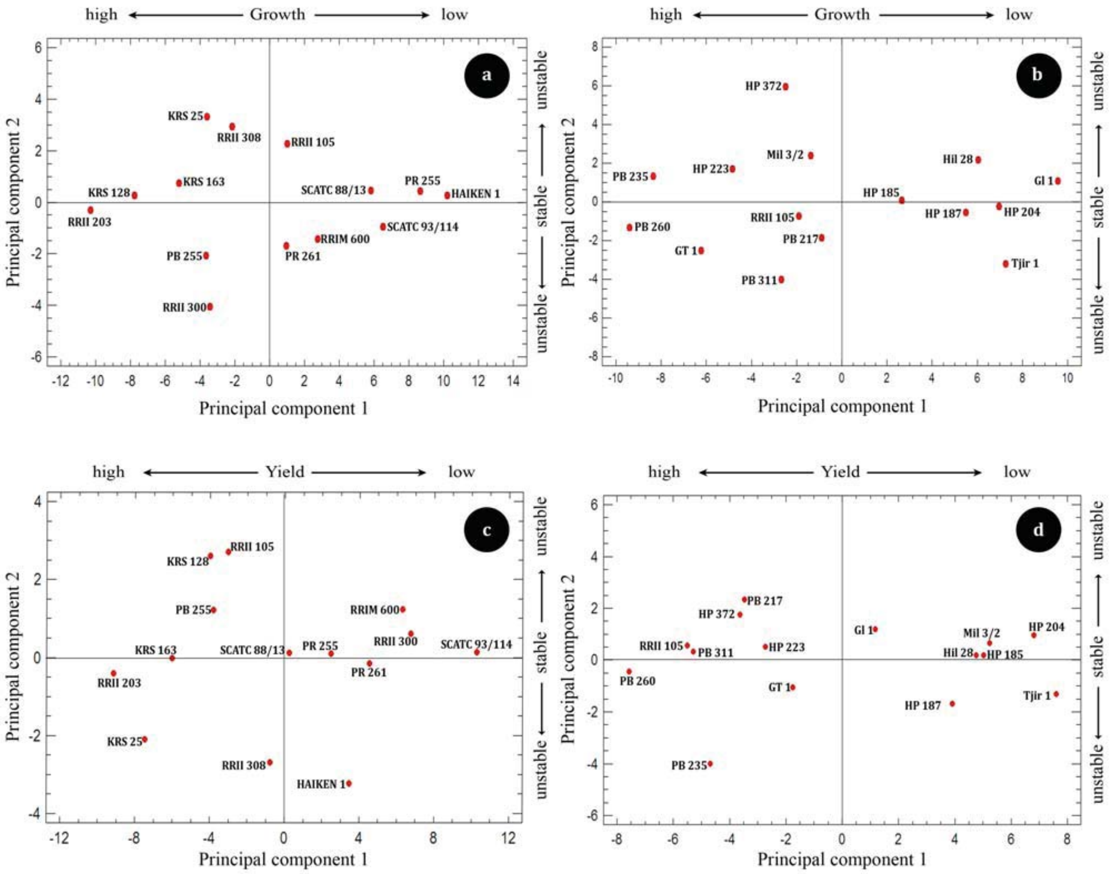

Figure 2 Genotype stability for growth and yield adaptation in the Hevea genotypes in 1989 experiment (a, c) and 1990 experiment (b, d)

2b). One of the best yielding genotypes in this experiment PB 235 was highly unstable as far as growth was concerned. Slow growers which showed better consistency included HP 185, HP 187 and HP 204.

It was interesting to note that the high yielding genotype from 1989 experiment, RRII 203 was consistently high yielding throughout the study period, without showing much temporal fluctuations determined by the changing weather cycle (Figure 2c). Whereas, next best high yielding genotype of this experiment KRS 25 showed temporal variations in yielding thus was less stable. Stable yield performance coupled with high yield was observed for KRS 163 also. Other moderate high yielding genotypes showed less stability. RRII 105 was prominent among this category of genotypes. Furthermore, few of the moderate low yielding genotypes SCATC 88/13, PR 255 and PR 261 showed better stability. SCATC 93/114 on the other hand was stable but extremely low yielding.

In the 1990 experiment, among the best yielding genotypes, PB 260 was stable but PB 235 was not (Figure 2d). Other moderate high yielding genotypes showed better stability. RRII 105 in this case showed better stability, than in the other experiment because the distribution of genotypes based on the yield hierarchy was not uniform in this experiment when compared to the 1989 experiment. This was evident from the cluster membership data from this experiment which showed first and second clusters sharing 13.3% each of the total genotypes thus allowing these genotypes to enjoy their rank positions more consistently throughout the study period. Apart from this, only other stable yielding genotypes were few low yielding ones (HP 28 and HP 185).

The results of this study revealed that out of 28 genotypes evaluated under coastal agroclimate of Karnataka, two genotypes, RRII 203 and PB 260 were apparently showing better adaptation for growth and yield. This represents a mere 7% of the population, implying that genotype adaptation of *Hevea* from the existing gene pool remains low at this region. This warrants crop improvement for further extensive cultivation. Notwithstanding, the high yielding stable genotypes have immediate potential for extensive cultivation in this region as monoclonal plantations or as predominant constituent of clone blends. They can also be used as the starting materials for the further breeding programmes for this region. The next best yielding genotypes KRS 25 and PB 235 was less stable in yield performance. The moderately performing genotypes can be used for constituting clone blend gardens in smaller proportions. However, it is reminded that the categorisation of genotypes based on the 'static' biological stability in the present study has little agronomic meaning, because it does not involve an assessment based on agronomic management. This type of stability, called 'dynamic' stability is often determined under multi-environment trials, where genotypes are tested for their feasibility in target population of environments (TPE). Such studies necessitate multivariate approaches for making meaningful recommendations. However, for the assessment of genotype adaptation wherein a set of genotypes are newly introduced and evaluated, and especially in a tree species, the information generated are worthy and provide useful guidelines for the genotype selection for commercial plantings in the TPE either as monoclonal plantations or as blended clone gardens and for future crop improvement.

References

Becker, H.C. and Leon, J. (1988). Stability analysis in plant breeding. Plant Breeding 101: 1-23.

Dey, S.K., Singh, R.S., Sathisha, G.C and Pal, T.K. (2004): Performance of *Hevea brasiliensis* clones in Mizoram. Natural Rubber Research 17, 41-46.

Flores, F., Moreno, M.T. and Cubero, J.I. (1998). A comparison of univariate and multivariate methods to analyze G x E interaction. Field Crops Research 56: 271-286.

Marattukalam, J.G., Premakumari, D., George, P.J. and Chandrasekhar, T.R. (2005). Long term performance of a few Indian and exotic clones of *Hevea brasiliensis* in large scale trials in India. Natural Rubber Research 18, 113-119.

Meenattoor, J.R., Vinod, K.K., Krishnakumar, A.K., Sethuraj, M.R., Potty, S.N. and Sinha, R.R. (1991). Clone x environment interaction during early growth phase of *Hevea brasiliensis*. I. Clonal stability on girth. Indian Journal of Natural Rubber Research 4, 51-54.

Meti, S., Chaudhuri, D., and Varghese, Y.A. (1999). Growth performance of *Hevea* clones in Northern region of West Bengal. Indian Journal of Natural Rubber Research 12: 39-48.

Nazeer, M.A., George, P.J., Premakumari, D. and Panikkar, A.O.N. (1989). Second selections from the 1954 hand pollination programme. Indian Journal of Natural Rubber Research 2: 131-133.

Shorter, R., Lawn, R.J. and Hammer, G.L. (1991). Improving genotype adaptation in crops: a role for breeders, physiologists and modellers. Experimental Agriculture 27: 155-175.

Simmonds, N.W. (1981). Principles of Crop Improvement. English Language Book Society, Longman, England, 408 p.

Varghese, Y.A. (2002). Crop improvement in the non-traditional rubber growing areas in India. In: Jacob C.K. (ed.), Global Competitiveness of India Rubber Plantation Industry. Rubber Research Institute of India, Kottayam, India, pp. 117-131.

Vinod, K.K., Meenattoor, J.R., Krishnakumar, A.K., Pothen, J, Potty, S.N., Sethuraj, M.R. (1996). Clonal selection combining yield and stability in *Hevea brasiliensis* Muell.-Arg. Journal of Plantation Crops. 24(supplement): 458-463.

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