A. No. 386

Research Article

Journal of Plantation Crops, 2010, 38 (2): 125-131

Variability in performance among mature half-sib progenies of *Hevea brasiliensis* (Willd ex Adr. de Juss. Muell. Arg.)

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(Manuscript Received: 13-02-09, Revised: 25-01-10, Accepted: 21-05-10)

Abstract

A study on half-sib progeny testing and selection was undertaken at the Central Experiment Station of the Rubber Research Institute of India during 1993-2004 to evolve new and improved rubber clones of varying parentage. A total of 150 rubber clones comprising open pollinated progenies of ten popular clones, with 15 clones per progeny were evaluated in a Compact Family Block Design over four years of tapping. There was significant variability among and within the mature progenies with respect to rubber yield, growth attributes, timber yield and bark anatomical parameters. Based on estimates of general combining ability for rubber and timber yield, clones PB 28/ 83, Ch 26, RRII 105, PB 215, PB 252 , PB 217, PB 242 and PB 5/51 were identified as promising parent material for polycross breeding via polyclonal seed gardens. More than 50 per cent of the clones within the progeny of parent clone PB 28/83 were high yielding. This clone has also exhibited positive estimates of general combining ability for annual mean yield, summer yield and timber yield, confirming its prepotent ability to produce superior progeny. From the present study, 29 promising clones derived from the half- sib progenies of eight parents of Malaysian and Indian origin could also be identified.

Keywords: Bole volume, clones, general combining ability, prepotency, rubber yield

Introduction

Systematic agricultural research, particularly plant breeding has played a pivotal role in transforming the wild jungle tree of Brazil, *Hevea brasiliensis* into a major domesticated plantation crop in less than a century. This tree is the major source of natural rubber, nature's most versatile industrial raw material.

India with 6.15 lakh ha under cultivation ranks fifth in area and fourth in production (8.53 lakh t) of natural rubber. The country has achieved the highest productivity of 1,799 kg of dry rubber/ha among rubber growing countries (The Rubber Board, 2008). This can be attributed to a single high yielding clone, RRII 105 which occupies more than 80 per cent of the area under rubber in the country. Predominance of this single clone has now become a cause of concern among geneticists and policy makers in view of the potential dangers of monoclonal planting. Evolving superior clones with diversity in genetic constitution has thus become imperative in the present day.

The breeding process in *Hevea*, as in any other perennial tree species is laborious. Being an outbreeder in which the economically important traits are polygenically controlled, large progeny size is the primary prerequisite for effective selection. A bottleneck to this in hybridization programmes is the low fruit set under hand pollination. Problems associated with low fruit set do not arise under selection from advanced generation polycross progenies and the relatively large population, thus obtained allows for more effective selection for multiple characters (Tan, 1987).

Polycross breeding holds great promise in this species in which flowering and fruit production are profuse. This inherent potential to generate large , genetically variable base populations has been exploited through ortet (plus tree) selection (Marattukalam

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et al.,1980; Mydin *et al.*,2005; Mercykutty *et al.*, 2006). However, in the present day, ortets are scarce, with the phasing out of seedling plantations and adoption of clonal planting. Selection from half- sib progenies of improved clones is an area being pursued with renewed interest.

Selection, combined with genetic testing by progeny analysis improves the worth of any tree breeding programme. Progeny testing allows the estimation of the genetic worth of parent clones in terms of combining ability. General combining ability is the average performance of the progeny of any individual parent in combination with several other parents (Otegbeye, 2002). It is equal to one half of the breeding value of the parent in question because it provides only half the genes in the progeny, the other half coming at random from the other parents in the population (Falconer, 1960).

The present study on half- sib progeny testing and selection was undertaken to evolve new and improved rubber clones of varying parentage. Nursery evaluation of the half- sib progenies based on test- tap yield and other juvenile traits in an earlier study had helped in identifying clones that were likely to be prepotent (Mydin *et al.*, 1990 and 1996). This paper reports on the performance of the cloned progenies at maturity in a field evaluation trial.

Materials and Methods

This study was based on 10 progenies (Table 1), each consisting of 15 clones. The evaluation was conducted in a compact family block design with three replications and 4-5 trees per plot. Planting was done in 1993 and the spacing adopted was 4.9 x 4.9 m. A total of 150 progeny clones were evaluated in two field trials, one trial (trial 1) with 10 clones per progeny and the other (trial 2), with five clones per progeny. The field trials were laid out at the Central Experiment Station of the RRII at Chethackal in Ranni, Central Kerala. Clone RRII 105 was planted as the high yielding reference clone

Table 1. Parent clones from which progeny were raised for evaluation

	Parent clone	Country of origin	Parentage
1	RRII 105	India	Tjir 1 x Gl 1
2	PB 242	Malayasia	PB 5/51 x PB 32/36
3	AVT 73	India	Primary clone
4	PB 252	Malayasia	PB 86 x PB 32/36
5	PB 217	Malayasia	PB 5/51 x PB 6/9
6	PB 28/83	Malayasia	Primary clone
7	PB 5/51	Malayasia	PB 56 x PB 24
8	PB 215	Malayasia	Primary clone
9	Ch 26	Malayasia	Selfed progeny of BR 2
10	PB 5/76	Malayasia	PB 56 x PB 24

in both the trials, while PB 217 was the reference clone for drought tolerance in terms of summer yield.

The trees were opened for tapping during 2001 i.e. the eighth year after planting, following the ½ S d/3 6 d/7 system with one day's tapping rest in a week. Trunk girth of the trees was measured in the year of opening and after four years of tapping. The height at forking was also recorded. Yield was recorded from each tree by cup coagulation at fortnightly intervals and weighing of the smoke dried cup lumps. Mean annual yield and yield during the summer period (February to May) were worked out. Timber yield of the clones was assessed in terms of clear bole volume estimated by the Hoppus method (Chaturvedi and Khanna, 1982). Bark samples were collected from two trees per plot in the y of opening. Radial longitudinal sections of the bark were made and observed microscopically for recording thickness of various layers and the number of latex vessel rows in each layer.

Data on 12 different variables were subjected to the analysis of variance. Superior progenies were identified on the basis of general combining ability (Zobel and Talbert, 1984) for rubber and timber yield. The mean performance of each of the progenies with respect to annual mean rubber yield, rubber yield during the summer period (February - May) and clear bole volume along with the percentage recovery of superior clones from within progenies were studied.

Results and Discussion

The variability among ten half-sib progenies of rubber for annual mean yield, summer yield, girth, ar bole volume and bark anatomical attributes like the thickness and number of latex vessel rows in the hard and soft bast layers is evident from Table 2. There was significant variation among and within progenies (Table 3) with respect to annual mean yield over four years which ranged from 26.69- 39.68 and 22.29- 54.92 g/tree/ tap in trial 1 and trial 2, respectively and summer yield which ranged from 12.37-21.38 and 12.27-37.63 g/ tree/ tap in trial 1 and trial 2, respectively. This indicates the possibility of identifying superior progenies as well as selection within superior progenies for realization of high yield of rubber. Selection methods in cross pollinated species are developed to capitalize on the genetic variability within source populations. This inherent genetic variability has been analyzed and estimates of variance components suggest that additive genetic effects are of greater importance than dominance or epistasis. Selection, therefore, if conducted appropriately, should be effective. Half-sib family selection is more appropriate

Table 2. Analysis of variance between progenies

Trait	General Mean		Range		Variance Ratio		C.D. (P= 0.05)	
	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
Mean yield (g/tree/tap)								
First year	31.87	35.18	26.74-39.60	19.05-45.12	3.40*	12.44**	7.02	7.32
Second year	25.56	30.09	19.38-32.85	16.08-48.86	5.18**	13.19**	5.96	7.97
Third year	37.27	45.11	27.87-47.15	27.16-67.16	15.59**	12.11**	4.26	10.20
Fourth year	37.23	43.69	32.63-47.83	26.86-58.83	21.59**	8.36**	3.70	10.20
Mean over 4yrs	32.98	38.52	26.69-39.68	22.29-54.92	23.41**	15.93**	2.90	7.19
Summer yield (g/tree/tap)								
Second year	13.06	15.52	9.27-15.71	9.82-27.20	6.29**	13.75**	2.47	3.96
Third year	19.79	24.53	15.47-27.06	14.73-48.06	5.93**	9.79**	4.09	8.70
Mean over 2yrs.	16.43	21.78	12.37-21.38	12.27-37.63	8.24**	18.36**	2.69	6.20
Girth at opening (cm)	43.91	48.07	39.49-45.77	43.55-56.20	0.75	1.83	-	-
irth 11th year (cm)	55.20	57.41	51.13-57.03	51.60-65.24	2.16*	4.71**	5.41	5.62
Forking height (m)	3.31	3.03	2.88-3.57	2.82-3.34	1.75	1.32	0.49	-
Soft bast thickness (mm)	1.61	1.47	1.53-1.74	1.25-1.77	2.67*	3.20*	0.13	0.24
Hard bast thickness (mm)	4.73	4.61	4.31-4.96	4.25-5.06	2.15	1.41*	-	0.70
Total bark thickness (mm)	6.36	6.10	5.94-6.56	5.74-6.55	2.12	1.37	-	-
LVR (soft bast)	6.34	5.86	5.33-7.78	4.29-7.56	3.49*	4.66**	1.20	1.32
LVR (hard bast)	3.46	3.26	3.04-3.98	2.61-4.16	1.39	3.11*	-	0.93
Total no. of LVR	9.80	9.17	8.82-11.02	8.22-10.44	2.15	1.68	-	-
Clear bole vol. (m^3/tree)	0.07	0.06	0.05-0.07	0.05-0.09	1.14	2.73*	-	0.021

*Significant at P = 0.05 **Significant at P = 0.01

Table 3. Yield performance of progenies

Progeny of	Annual mean yield over 4 years (g/tree/tap)				Mean summer yield 2nd & 3rd yr (g/tree/tap)			
	Trial 1		Trial 2		Trial 1		Trial 2	
	Mean	Variance Rati (within progenies)	Mean	Variance Ratio (within progenies)	Mean	Variance Ratio (within progenies)	Mean	Variance Ratio (within progenies)
RRII 105	39.68	3.68*	38.60	12.95*	18.64	4.99**	18.30	8.25*
242	28.98	16.15**	34.89	0.91	15.67	10.32**	16.47	0.59
AVT 73	26.69	11.52**	22.29	2.70	12.84	8.99**	12.27	27.53**
PB 252	29.87	5.18**	46.93	16.37**	12.37	2.76	22.27	13.83*
PB 217	29.38	2.75*	33.32	12.29*	17.42	5.63**	20.08	12.71*
PB 28/83	38.82	12.12**	54.92	2.81	21.38	20.69**	37.63	6.11*
PB 5/51	33.23	33.04**	38.50	8.37*	16.56	24.90**	18.95	3.64
PB 215	36.11	8.32**	41.38	10.20*	16.53	11.29**	18.29	10.67*
Ch 26	37.58	3.99*	46.83	13.70*	16.10	3.32*	22.34	10.81*
PB 5/76	29.50	14.52**	27.57	5.42*	16.76	8.23**	13.64	2.68
G. Mean	32.98		38.50		16.43		20.08	
V.R. (between progenies)	23.41**		15.93**		8.24**		18.36**	
CD (P = 0.05)	2.90		7.19		2.69		6.20	

*Significant at P = 0.05 **Significant at P = 0.01

for cross - pollinated species (Hallauer, 1991) and *Hevea brasiliensis* being a perennial outbred species, there is immense scope for such selection as evident from the range of variability in the population studied here.

The progenies had uniform girth at opening but showed significant variability in respect of girth 11 years after planting i.e., after four years of tapping. This is an indication of the differential growth pattern of clones under tapping. Variation in girth among clones under tapping was evident only within six progenies in trial 1 and two progenies in trial 2 (Table 4). The progenies also exhibited significant variability in the number of latex vessel rows and thickness of the soft and hard bast layers (Table 2). The progenies were comparable in terms

Table 4. Girth of progenies

Progeny of	Girth at opening (cm) Trial 1 Mean	Trial 1 Variance Ratio (within progenies	Trial 2 Mean	Trial 2 Variance Ratio (within progenies)	Girth after 4 years of tapping (cm) Trial 1 Mean	Trial 1 Variance Ratio (within progenies)	Trial 2 Mean	Trial 2 Variance Ratio (within progenies)
RRII 105	44.14	3.90*	51.79	3.68	55.02	5.76**	61.03	4.43
PB 242	42.85	5.11**	45.10	1.69	56.96	9.91**	56.08	3.08
AVT 73	44.49	11.01**	48.71	0.93	54.98	15.65**	58.34	0.26
PB 252	43.26	1.93	56.20	1.67	55.84	2.93	65.24	2.64
PB 217	45.77	2.66	46.87	15.35**	57.03	1.98	56.36	12.19**
PB 28/83	45.46	2.85	49.94	1.27	55.71	2.35	59.03	2.15
PB 5/51	43.43	4.89	43.55	3.82	53.51	3.21	51.61	8.13*
PB 215	45.07	3.72	44.93	0.37	56.20	13.14**	55.03	0.45
Ch 26	45.17	3.95*	49.17	1.82	55.59	4.82*	59.24	4.05
PB 5/76	39.49	4.41*	44.41	0.58	51.13	4.05*	52.11	0.71
G. Mean	43.91		48.07		55.20		57.41	
Variance Ratio (between progenies)	0.76		1.83		2.16*		4.71**	
CD (P=0.05)	-		-		5.41		5.62	

*Significant at P = 0.05; **Significant at P = 0.01

of forking height which did not show clonal variation within progenies either (Table 5). Clear bole volume ranged from 0.05- 0.07 m^3 / tree in trial 1 and 0.05-0.09 m^3 / tree in trial 2 with significant variability among the progenies in trial 2 alone. Six progenies in trial 1 and one progeny in trial 2 showed clonal variation within the progeny.

Yield of the ten progenies over four years of tapping (Table 3) indicated that progeny of PB 28/ 83 was superior in both the trials, with a mean yield of 38.82 g/tree/tap in trial 1 and 54.92 g/ tree/ tap in trial 2. The seedling progeny of clones PB 28/83, RRII 105 and Ch 26 were reported to give high mean yield in the juvenile phase (Mydin *et al.*, 1996). Progeny of RRII 105 with a mean yield of 39.68 g/ tree/ tap in trial 1 and 38.60 g/ tree/ tap in trial 2 and that of Ch 26 with a mean progeny yield of 37.58 g/ tree/tap in trial 1 and 46.83 g/tree/tap in trial 2 also maintained superior performance. The mean summer yield in the third and fourth years also reflects

Table 5. Forking height and clear bole volume of progenies

Progeny of	Forking height (m) Trial 1 Mean	Trial 1 Variance Ratio (within progenies)	Trial 2 Mean	Trial 2 Variance Ratio (within progenies)	Clear bole volume (m^3 / tree) Trial 1 Mean	Trial 1 Variance Ratio (within progenies)	Trial 2 Mean	Trial 2 Variance Ratio (within progenies)
RRII 105	3.24	1.18	2.92	0.36	0.06	3.13*	0.07	7.25*
PB 242	3.25	3.43*	3.44	1.05	0.07	7.32**	0.07	2.79
AVT 73	3.37	1.29	2.82	2.08	0.07	5.79**	0.06	1.01
PB 252	3.20	2.92	3.26	0.58	0.07	4.30*	0.09	1.73
PB 217	3.53	2.27	2.82	1.81	0.07	1.71	0.06	4.85
PB 28/83	3.57	2.15	3.06	0.63	0.07	2.19	0.07	1.67
PB 5/51	3.57	1.39	2.93	1.72	0.06	1.91	0.05	2.75
PB 215	3.37	2.08	3.12	0.44	0.07	5.14**	0.06	0.32
Ch 26	3.12	2.43	3.05	1.30	0.06	2.15	0.07	1.40
PB 5/76	2.88	1.62	2.86	0.04	0.05	3.13*	0.05	0.72
G. Mean	3.31		3.03		0.07		0.06	
Variance Ratio (between progenies)	1.75		1.32		1.14		2.73*	
CD (P = 0.05)	-		-		-		0.02	

*Significant at P = 0.05; **Significant at P = 0.01

the superiority of progenies of RRII 105, PB 28/83, PB 215 and Ch 26. Clone PB 217 is proven to be drought tolerant in terms of its high summer yield in the traditional rubber growing regions of India (Saraswathyamma *et al.*, 2000) and the progeny of this clone in both the trials exhibited superiority in terms of mean yield in the summer months. The inherent vigour of progenies of PB 28/83, PB 217 and PB 252 are evident from the girth and timber traits shown in Tables 4 and 5.

Among the anatomical parameters studied, significant variability was observed only for the thickness and number of latex vessel rows of the soft bast (Table 2). The soft bast being that layer of the bark which holds the larger proportion of functional laticifers in the rubber :e (Premakumari and Saraswathyamma, 2000), the results signify scope for effective selection from among the progenies. The number of latex vessel rows in the soft bast was the highest among the progeny of clone PB 28/83 in both the trials (Fig. 1).

While the extent of variability indicates the possibilities for selection based on the various traits, the practical significance of the present results lie in the number of improved clones that have evolved by this approach of polycross breeding. Additive inheritance predominates the variation for yield and girth in rubber (Tan, 1987), which suggests that selection among appropriate polycross progenies should be effective. Tables 6 to 8 provide details of the range in variability within progenies for annual mean yield, summer yield, timber yield potential in terms of clear bole volume and the recovery of superior clones from within each progeny. The reference clones were RRII 105 for annual mean yield and PB 217 for mean yield in summer. The reference point for high timber yield of the 11 year old clones was fixed as 0.10 m³/ tree based on the range of variability for the trait among the 150 clones evaluated. The general combining ability (GCA) of the ten parent clones in respect of annual mean yield, summer yield and clear bole volume are given in Table 9.

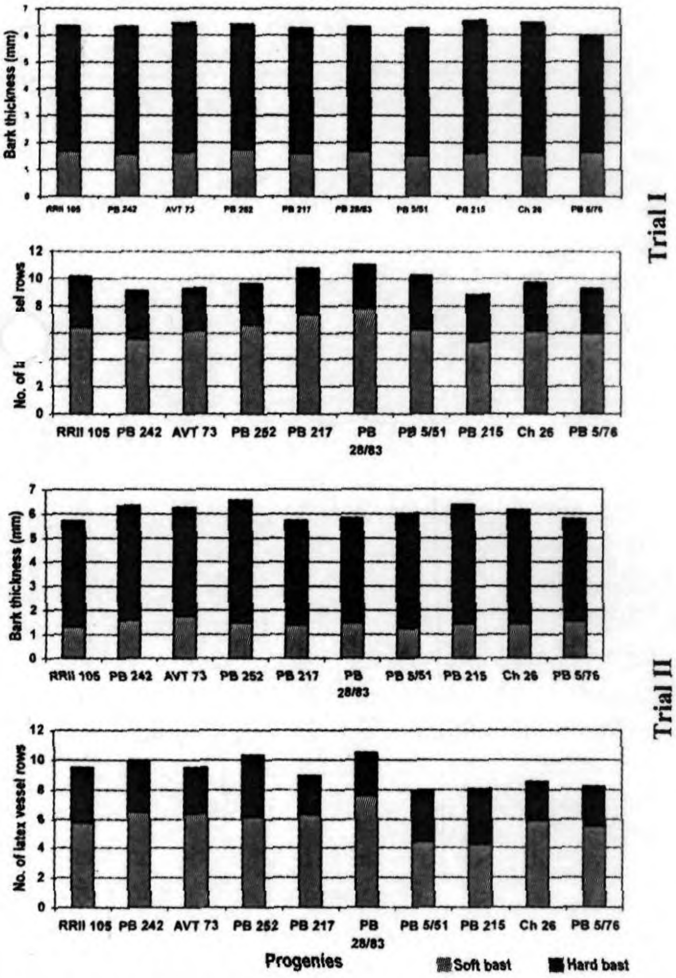

Fig. 1. Bark anatomical parameters in the progenies

The recovery of high yielding clones from the various progenies ranged from 6.66 to 53.33 per cent (Table 6). The parent clone PB 28/83 gave the highest recovery of 53.33 per cent high yielding clones within its progeny, as also reported from seedling progeny analysis based on test tap yield in the juvenile phase (Mydin *et al.*, 1996) which indicated a high recovery of more than 62 per cent superior seedlings from its progeny. More than 25 per cent of the clones within progenies of Ch 26, PB 5/51 and PB 215 were high yielding corroborating the findings from the earlier seedling progeny analysis. None of the clones within progenies of PB 242 and AVT 73 exhibited high annual mean yield in the mature phase, contrary to the report that these two parent clones produced a high recovery of more than 57 per cent superior seedlings in the juvenile phase (Mydin

Table 6. Recovery of high yielding clones within progenies

Progeny of	Yield over 4 years* (g/tree/tap) Mean	Range in yield of progeny clones	Recovery of high yielding clones** No.	%
RRII 105	39.14	28.52 - 57.52	2	13.33
PB 242	31.94	17.56 - 44.63	-	-
AVT 73	24.49	11.60 - 41.02	-	-
PB 252	38.40	18.16 - 81.34	3	20
PB 217	31.35	22.97 - 49.72	1	6.66
PB 28/83	46.88	21.42 - 65.96	8	53.33
PB 5/51	35.87	12.46 - 62.87	5	33.33
PB 215	38.75	18.50 - 59.49	4	26.66
Ch 26	42.21	16.93 - 80.40	5	33.33
PB 5/76	28.54	13.77 - 46.64	1	6.66

*Pertaining to 15 clones within each progeny

**Yield of high yielding reference clone RRII 105 : 44.85 g/tree/tap *et al.*, 1996). This reflects the low though positive correlation (r = 0.30* P < 1.05) of juvenile yield of seedlings with the mature yield of corresponding clones reported earlier (Tan, 1987).

Maintenance of high yield in the summer months is an indication of the potential of clones to withstand drought. The recovery of such clones with potential for drought tolerance from within the ten progenies ranged from 6.66 to 53.33 per cent (Table 7) with more than 25 per cent of the clones in six progenies viz., PB 28/ 83, PB 217, PB 5/51, Ch 26, PB 215 and RRII 105 showing high yield in summer. The recovery of clones with promising timber yield potential was the highest (40 per cent) in the progeny of PB 217, while more than 25 per cent of the progeny clones of PB 252, PB 242, Ch 26, PB 28/83, AVT 73 and RRII 105 exhibited a timber yield of more than 0.10 m^3 / tree (Table 8).

Table 7. Recovery of clones with high summer yield from progenies

Progeny of	Summer yield - mean of 2nd and 3rd year (g/tree/tap)*		Recovery of high yielding clones**	
	Mean	Range in yield of progeny clones	No.	%
RRII 105	18.47	11.77 - 27.50	4	26.66
PB 242	16.07	8.94 - 26.58	1	6.66
AVT 73	12.55	8.10 - 20.34	-	-
PB 252	17.32	7.85 - 22.99	1	6.66
PB 217	27.53	10.78 - 27.87	5	33.33
PB 28/83	29.51	8.49 - 57.07	8	53.33
PB 5/51	17.76	7.58 - 28.17	5	33.33
PB 215	17.41	7.00 - 34.98	4	26.66
Ch 26	19.22	7.64 - 47.51	5	33.33
PB 5/76	15.20	7.19 - 25.86	2	13.33

*Pertaining to 15 clones within each progeny

**Mean summer yield of drought tolerant reference clone PB 217 over 2nd and 3rd year : 21.08 g/tree/tap

Table 8. Recovery of clones with good timber yield potential among progenies

Progeny of	Clear bole volume at the age of 11 years (m^3/tree)*		Recovery of high timber clones**	
	Mean	Range among progeny clones	No.	%
RRII 105	0.07	0.04 - 0.10	4	26.67
PB 242	0.08	0.05 - 0.10	5	33.33
AVT 73	0.06	0.04 - 0.09	4	26.67
PB 252	0.08	0.04 - 0.13	5	33.33
PB 217	0.07	0.03 - 0.09	6	40.00
PB 28/83	0.07	0.04 - 0.10	4	26.67
PB 5/51	0.06	0.04 - 0.08	2	13.33
PB 215	0.06	0.05 - 0.11	3	20.00
Ch 26	0.07	0.04 - 0.08	4	26.67
PB 5/76	0.05	0.03 - 0.06	-	-

* Pertaining to 15 clones within each progeny

** Clones with Clear Bole Volume > 0.10m^3/tree

A total of 29 clones derived from eight parents exhibited superiority in annual mean yield, 35 clones derived from nine parents were superior in terms of summer yield and 37 clones from nine progenies were good timber yielders (Tables 6 to 8). Clones from a diversity of parents of varying lineage as indicated in Table 1 were thus generated by this study.

Positive estimates of general combining ability for annual mean yield were observed in the case of clones (Table 9) PB 28/ 83, Ch 26, RRII 105, PB 215, PB 252 and PB 5/51, while only three clones viz., PB 28/83, PB 217 and Ch 26 showed positive GCA estimates for summer yield. Clones PB 252, PB 242, RRII 105, PB 28/ 83 , Ch 26 and PB 217 showed positive estimates of GCA for timber yield potential. These results point to the superi[illegible] of clones PB 28/83, Ch 26, RRII 105, PB 215, PB 252, [illegible] 217, PB 242 and PB 5/51 as parent material for polycross breeding via polyclonal seed gardens, as also reported from the earlier study on analysis of seedling progeny of these clones (Mydin *et al.*, 1996).

Table 9. General combining ability for rubber and timber yield

Parent clone	GCA estimates for		
	Mean yield of rubber		Timber yield in the 11th yr.
	Annual	Summer	
RRII 105	3.39	- 0.64	0.009
PB 242	- 3.81	- 3.04	0.011
AVT 73	- 11.26	- 6.56	- 0.002
PB 252	2.65	- 1.79	0.012
PB 217	- 4.4	8.42	0.001
PB 28/83	11.13	10.4	0.004
PB 5/51	0.12	- 1.35	- 0.008
PB 215	3.0	- 1.70	- 0.0[illegible]
Ch 26	6.46	0.11	0.00
PB 5/76	- 7.21	- 3.91	- 0.016

Clone PB 28/83 produced progeny with superior performance and high recovery of high yielding clones in respect of annual mean yield and summer yield. More than 50 per cent recovery of high yielding clones within its progeny is an indication of prepotency in this Malaysian clone. PB 28/83 also exhibited more than 25 per cent recovery of clones with high timber yield potential within its progeny. The positive estimates of GCA for annual mean yield, summer yield and timber yield lend further support to confirm the prepotent ability of clone PB 28/ 83 to produce superior progeny. This clone could, therefore, be effectively utilized as a parent in hybridization programmes and as a component in polyclonal seed gardens for the production of good quality seeds. The present study was also able to identify 29 promising clones derived from eight parents of varying origin.

Acknowledgements

The authors thank Dr. James Jacob, Director of Research and Dr. Y. Annamma Varghese, Joint Director (Crop Improvement), Rubber Research Institute of India for encouragement and facilities provided. The help rendered by Sri. Ramesh B. Nair, Assistant Director (Agricultural Statistics), RRII in the analysis of data is gratefully acknowledged.

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