Research Article

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Long term yield of rubber and timber in some promising Prang Besar clones in India

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Abstract

Nine Prang Besar clones were evaluated in a large scale trial laid out in 1989 at the Central Experiment Station of the Rubber Research Institute of India. Rubber yield and its attributes including girth, girth increment rate under tapping, summer yield and secondary traits like incidence of pink disease and tapping panel dryness (TPD), were studied along with stability in long term yield in the clones in relation to the high yielding popular clone RRII 105. Long term yield over 14 years was highest in clones PB 280 (70.7 g $tree^{-1}$ tap^{-1}), PB 312 (70 g $tree^{-1}$ tap^{-1}) and PB 314 (68.8 g $tree^{-1}$ tap^{-1}) which were comparable and superior to rest of the clones. PB 311 was the second best yielding clone with 65.5 g $tree^{-1}$ tap^{-1} over 14 years of tapping. This clone was the only promising yielder with stability in yield over the years. In terms of summer yield , the clone PB 280, recorded the best performance in all the three panels indicating its capability to produce more latex in the summer months too when the trees undergo stresses from refoliation as well as low moisture and high temperatures. The promising yielders from the present study, clones PB 280, PB 312 and PB 314 showed very low incidence of pink disease in the immature stage with only 1.5 to 1.7 per cent trees affected. The occurrence of TPD after 16 years of tapping was lowest in clone PB 280 (10.7%) and high in PB 314 (26.6 per cent). Estimates of genetic parameters revealed rubber yield and bole volume to be highly heritable traits. Correlations revealed yield per unit girth to have a close relationship with yield over 14 years and summer yield over 11 years. Clone PB 280 has proven to be a high yielding clone with very good secondary attributes like low incidence of pink disease and TPD. Clone PB 312 has proved its merit as a very promising latex timber clone. PB 314, among the best rubber yielding clones with a high yield per unit girth (0.8 g dry rubber cm^{-1} girth), though prone to TPD, has shown a low incidence of pink disease. The study indicates scope for further upgradation of clones PB 280, PB 312 and PB 314 in the planting recommendations for the traditional rubber growing regions of India.

Keywords: Correlations, heritability, *Hevea brasiliensis* Prang Besar clones, timber, yield

Introduction

The widespread cultivation of natural rubber (NR) was rendered possible only by the introduction of *Hevea brasiliensis* to different countries and subsequent evolution of clones suited to the local agro-climatic conditions. The pace of its evolution was strengthened by exchange of clones among rubber growing countries and the utilization of such domesticated germplasm in genetic improvement programs like clonal selection for direct cultivation and hybridization for evolving desired recombinants. One of the earliest examples of using a clone developed in one country in the hybridization programme of another country was in development of clone RRIM 600 by Malaysia (Jacob *et al.,* 2013). RRIM 600 was developed in the 1940s by Rubber Research Institute of Malaysia (RRIM) by hybridizing Tjir 1 (a primary selection from Indonesia) with PB 86 (another primary selection from Malaysia). RRII 105, the flagship clone of India that found almost 100 per cent adoption with the Indian growers and thus helped put India at the top of the world in terms of NR productivity, is a hybrid between two imported primary clones, namely Tjir 1 from Indonesia (female) and Gl 1 from Malaysia (male).

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Introduction of exotic clones in India dates back to the 1950s. The clone Tjir 1, introduced prior to 1950 from Indonesia, proved its superiority over polyclonal seedlings in rubber plantations in India and this was planted as the check clone in all early clonal evaluation trials. The early results of evaluation showed that the performance of the RRIM clones in India was comparable to their performance reported in other rubber growing countries. A number of RRIM clones proved to be superior in performance to Tjir 1, the then most widely planted clone in the country, even as variation in their performance under different agro-climatic conditions suggested the need for region-wise recommendation of clones (Nair and Marattukalam, 1975).

In later years, a number of bilateral clone exchange programmes were effected under the auspices of the Association of Natural Rubber Producing Countries (ANRPC) and International Rubber Research and Development Board (IRRDB), with countries such as Thailand, China, Malaysia, Indonesia, Cote de Ivoire and Sri Lanka. Eight Prang Besar clones were introduced to India during 1960s, 1970s and 1980s from Malaysia (Mydin and Saraswathyamma, 2005). These clones were directly utilised for hybridization programmes in 1986 (Varghese *et al.*, 1989) while their evaluation for suitability for cultivation in the country was initiated in various field trials. The present report is based on the long term performance of these introduced PB clones in comparison to clone RRII 105 under large scale evaluation in South India.

Materials and methods

Nine clones (Table 1) were evaluated at the Central Experiment Station of Rubber Research Institute of India, situated in Pathanamthitta district of Central Kerala. Polybag plants of these clones were planted at a spacing of 4.9 x 4.9 m, with a planting density of 420 trees ha^{-1} in a randomized block design with three replications. The net plot size was 25 trees with a common border row of clone RRII 105 planted around each plot. Latex was harvested by adopting, tapping under the S/2 d3 6d/7 system without stimulation from the eighth year after planting.

Girth of the trees was recorded annually. Yield was collected by cup coagulation at fortnightly intervals and cup lumps from each plot of 25 trees were dried in a smoke house and weighed to record the dry rubber yield. Yield recordings were thus made for a period of six years in Panel BO-1, four years in panel BO-2 and four years in panel BI-1 The summer yield of clones over 11 years was studied panel wise. The panel wise mean yield, yield over 14 years, girth at opening, girth after 16 years of tapping and girth increment rate under tapping were analysed. Stability in yield of clones over the years was studied employing Shukla's stability variance (Prabhakaran and Jain, 1994). As a measure of timber yield potential, clear bole volume was computed by the quarter girth method (Chaturvedi and Khanna, 1982) using girth of the 25 year old trees and forking height. Specific gravity of wood was determined from wood core samples based on the ratio between green volume and oven dry weight (Otegbeye and Kellison, 1980). The incidence of pink disease and TPD was recorded as percentage of affected trees.

The ANOVA and Duncan's multiple range test (DMRT) were employed for identifying clones superior for specific attributes. Inter-relationships among traits by means of simple correlations and estimates of genetic parameters like genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and heritability in the broad sense (H^2) were computed.

Table 1. Pedigree of clones evaluated in the large scale trial

Clone	Pedigree	Year of introduction
RRII 105	Tjir 1 x Gl 1	-
PB 217	PB 5/51 x PB 6/9	1962
PB 260	PB 5/51 x PB 49	1979
PB 235	PB 5/51 x PB S/78	1964
PB 255	Tjir 1 x PR 107	1985
PB 280	Primary clone	1985
PB 311	RRIM 600 x PB 235	1979
PB 312	RRIM 600 x PB-235	1985
PB 314	RRIM 600 x PB-235	1985

Results and discussion

The growth and timber yield potential of the clones (Table 2) indicate no significant clonal variation for girth at opening and girth increment rate under tapping. However, girth in the 25th year, after 16 years of tapping, varied significantly with

Table 2. Growth and timber yield potential of experimental clones

Clone	Girth at opening (cm)	Girth at 23rd yr (cm)	Girth increment rate over 10 yrs of tapping in BO panel (cm yr^{-1})	Clear bole volume (m^3 tree^{-1}) at 23rd yr	Wood specific gravity
PB 235	53.7	98.1 ab	3.28	0.31	0.649
PB 311	50.5	102.5 a	3.66	0.25	0.659
PB 280	43.3	98.4 ab	3.98	0.19	0.664
PB 314	47.2	102.7 a	3.93	0.18	0.652
PB 312	50.5	97.9 ab	3.27	0.28	0.664
PB 217	45.7	97.5 ab	3.57	0.18	0.634
PB 260	51.5	94.5 ab	3.04	0.24	0.631
PB 255	45.8	88.2 bc	2.94	0.22	0.618
RRII 105	46.9	82.8 c	2.73	0.14	0.668

Means followed by a common letter are not significantly different by DMRT

clones. PB 314 and PB 311 were superior while RRII 105 was inferior in growth. Significant clonal variation for clear bole volume was evident, but the wood specific gravity did not vary with clones. Clone PB 235 (0.30 m^3 tree^{-1}) was superior in clear bole volume in the 25th year followed by clones PB 312, PB 311 and PB 260 with clear bole volume ranging from 0.24 to 0.28 m^3 tree^{-1}, indicating these clones to be potentially high timber yielders as also reported earlier (John *et al.*, 2004, 2009; Mydin *et al.*, 2009) from evaluations done in other locations.

In the first virgin panel, rubber yield (Table 3) in comparison to the high yielding check clone RRII 105 (49.7 g tree^{-1} tap^{-1}) was significantly higher in clones PB 312 (59.7 g tree^{-1} tap^{-1}) and PB 314 (58.3 g tree^{-1} tap^{-1}), followed by PB 280 (54.2 g tree^{-1} tap^{-1}). This corroborates the earlier report on superior yield of PB 314 and PB 312 in the first four years of tapping in another location (John *et al.*, 2004). In the second virgin panel, clone PB 280 showed significant improvement with a superior yield of 95.4 g tree^{-1} tap^{-1}. Clones PB 311 (88.7 g tree^{-1} tap^{-1}), PB 312 (87.9 g tree^{-1} tap^{-1}) and PB 260 (86.2 g tree^{-1} tap^{-1}) were also superior to RRII 105 (72.6 g tree^{-1} tap^{-1}) in this panel. Yield when considered over 10 years in the virgin panel was highest in clones PB 280, PB 312 and PB 314 which were significantly superior to the check and the rest of the clones.

In the renewed panel, BI-1, clone PB 280 which was superior to the rest of the clones, maintained a very high yield level of 123.3 g tree^{-1} tap^{-1}, followed

Table 3 Yield of the clones in the virgin and renewed panels

Clone	Yield over 6 yrs in BO-1 panel (g t^{-1} t^{-1})	Yield over 4 yrs in BO-2 panel (g t^{-1} t^{-1})	Mean yield over 10 yrs in BO panel (g t^{-1} t^{-1})	Yield over 4 yrs in BI-1 panel (g t^{-1} t^{-1})	Mean yield over 14 years (g t^{-1} t^{-1})	Yield per unit girth over 14 yrs (g cm^{-1})
PB 235	45.63 cd	73.58 cde	56.81 cd	61.93 de	58.27 d	0.625 d
PB 311	50.02 bc	88.74 ab	65.51 ab	87.75 bc	71.87 bc	0.738 c
PB 280	54.18 ab	95.39 a	70.66 a	123.33 a	85.71 a	0.898 a
PB 314	58.33 a	84.56 abcd	68.82 a	100.08 b	77.75 ab	0.844 ab
PB 312	59.75 a	87.87 ab	70.00 a	76.50 cde	72.57 bc	0.785 bc
PB 217	38.37 d	79.21 bcd	54.71 d	100.07 b	67.67 cd	0.738 bc
PB 260	48.30 bc	86.23 abc	63.47 abc	74.51 cde	66.62 cd	0.743 bc
PB 255	43.28 cd	66.44 e	52.54 d	81.38 bcd	60.78 d	0.741 c
RRII 105	49.65 bc	72.60 de	58.83 bcd	56.64 e	58.20 d	0.718 cd

Means followed by a common letter are not significantly different by DMRT

Table 4. Summer yield (SY) of the clones (g tree^{-1} tap^{-1})

Clone	SY over 3 yrs in BO-1 panel	SY over 4 yrs in BO-2 panel	SY over 7 yrs in BO panel	SY over 4 yrs in BI-1 panel	Mean SY over 11 years	Summer yield depression (%)
PB 235	28.16 ^{de}	51.05 ^{e}	41.24 ^{de}	45.79 ^{cd}	42.89 ^{d}	31.56 ^{b}
PB 311	34.27 ^{cde}	66.62 ^{a}	52.76 ^{ab}	67.08 ^{b}	57.97 ^{b}	28.30 ^{a}
PB 280	42.48 ^{a}	67.83 ^{a}	56.96 ^{a}	90.73 ^{a}	69.24 ^{a}	27.26 ^{a}
PB 314	35.47 ^{bc}	51.10 ^{bcd}	44.41 ^{cde}	68.54 ^{b}	53.18 ^{bc}	36.63 ^{b}
PB 312	41.91 ^{ab}	55.40 ^{bc}	49.62 ^{abc}	45.00 ^{d}	47.94 ^{cd}	36.82 ^{b}
PB 217	31.67 ^{cde}	59.89 ^{ab}	47.80 ^{bcd}	62.91 ^{bc}	53.29 ^{bc}	27.84 ^{a}
PB 260	27.53 ^{e}	51.07 ^{bcd}	40.98 ^{de}	52.96 ^{bcd}	45.34 ^{cd}	39.09 ^{b}
PB 255	27.11 ^{e}	47.99 ^{cd}	39.04 ^{e}	45.97 ^{cd}	41.56 ^{d}	35.76 ^{b}
RRII 105	34.89 ^{cd}	42.57 ^{d}	39.28 ^{e}	56.85 ^{bcd}	45.67 ^{cd}	34.20 ^{ab}

Means followed by a common letter are not significantly different by DMRT

by PB 314 (100.1 g tree^{-1} tap^{-1}) and PB 217(100.1 g tree^{-1} tap^{-1}). Long term yield over 14 years was highest in clones PB 280 (70.7 g tree^{-1} tap^{-1}), PB 312 (70 g tree^{-1} tap^{-1}) and PB 314 (68.8g tree^{-1} tap^{-1}) which were comparable and superior to the rest. Clone PB 311 was the second best yielding clone with 65.5 g tree^{-1} tap^{-1} over 14 years of tapping (Table 3). This clone was the only promising yielder with stability in yield over the years as per Shukla's stability statistics (Table 5) which shows no significant variability in yield over years in this clone coupled with an yield level above the general mean. The highest yielding clone PB 280 showed highly significant fluctuations in yield over the years. Clone PB 255 was reported to be among the high yielders elsewhere (John *et al*., 2004; Soman *et al.* 2012), but the present data does not indicate the high yield potential of this clone, though it is comparable in yield to RRII 105.

In all the three tapping panels, PB 280 recorded the best yield indicating its capability to produce more latex in the summer months too when the trees are exposed to stress due to refoliation as well as low moisture and high temperatures (Table 4). This clone has been reported to possess some intrinsic drought tolerance attributes like high thermostability which may have enabled its survival under moisture stress in pot culture (RRII, 1994). The two other high yielding clones PB 312 and PB 314, however, did not exhibit high yield in summer.

The general trend in rubber yield over 16 years of tapping in PB clones is shown in Figure 1. In general, the clones exhibited increasing rising trends in yield with the exception of clones RRII 105 and PB 312. Clones PB 312 and PB 260 showed similar yielding patterns over years as RRII 105 but at higher levels of yield. PB 280 was an outstanding clone with high yield levels and increasing trend in yield over the years. Clone PB 314 after exhibiting extremely high yield showed a drop in yield in the later years when tapping proceeded towards the renewed panel. However, it maintained high yield levels compared to the check clone, RRII 105. Clone PB 217 exhibited a steadily increasing trend in latex yield, PB 255 exhibited only moderately high, but rising yield trend over the years while PB 311 showed stable and high yield levels from the fifth year of tapping onwards.

Table 5. Stability of clones for yield performance

Clone	Shukla's stability variance	F	Mean yield over 14 yrs
PB 311	19.17	0.46 ^{ns}	71.87
PB 260	71.26	1.71 ^{ns}	66.62
PB 235	85.54	2.05 *	58.27
B 255	91.20	2.18 *	60.78
PB 312	107.43	2.57 *	72.57
PB 314	129.04	3.09 **	77.75
PB 217	196.60	4.70 **	67.67
RRII 105	203.39	4.87 **	58.20
PB 280	309.21	7.40 **	85.71
General mean	68.83		

*Significant at P=0.05; **Significant at P=0.01; ns - not significant

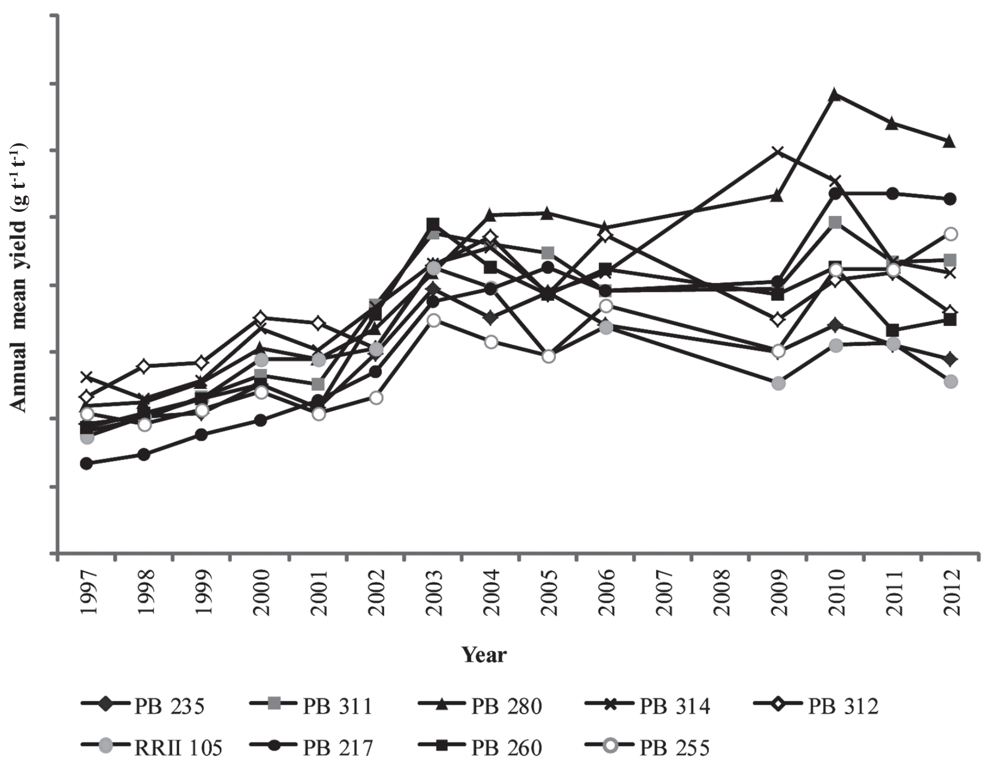

Fig. 1. Long term yield trends of the clones evaluated

The promising yielders from the present study, clones PB 280, PB 312 and PB 314 showed very low incidence of pink disease in the immature stage with only 1.5 to 1.7 per cent trees affected (Table 6). The occurrence of TPD after 16 years of tapping was lowest in clone PB 280 (10.7%) while clone PB 314 had high TPD incidence (26.6%) The occurrence of TPD in clone RRII 105 was 18.5 per cent.

Table 6. Pink disease and tapping panel dryness among the clones

Clone	*Pink disease incidence (%)	Tapping panel dryness (%)
PB 235	17.87 (4.25)	24.40
PB 311	8.26 (3.02)	14.38
PB 280	1.67 (1.48)	10.73
PB 314	2.78 (1.69)	26.62
PB 312	2.67 (1.67)	18.24
PB 217	10.37 (3.02)	19.71
PB 260	4.76 (1.97)	14.96
PB 255	10.58 (3.03)	16.50
RRII 105	23.02(4.88)	18.51
CD	1.88	ns

*Square root transformed values are given in parenthesis

Estimates of genetic parameters (Table 7) revealed rubber yield to be a highly heritable trait with $H^2 = 0.74$ for yield over 14 years and 0.77 for summer yield over 11 years. High heritability for rubber yield has been reported earlier (Mydin *et al*., 1992; Licy *et al*., 1992 ; Reju *et al*., 2014) Narayanan and Mydin (2009) have reported high narrow sense heritability for rubber yield as well, based on progeny analysis. Selection based on annual mean yield and summer yield will thus bring about a marked improvement in performance of populations. The high estimate of heritability for yield also implies scope for utilization of high yielding parents in hybridization programmes for yield improvement. Timber yield is also a highly heritable trait as evidenced by the high heritability estimate for clear bole volume. Selection from among the progeny of clones like PB 235 and PB 312 which possess high timber yield potential would help in identification of good timber clones and the

Table 7. Estimates of genetic parameters for yield, girth and pink disease

Clone	G.C.V.	P.C.V.	H^2
Yield over 6 yrs in BO-1 panel	13.06	15.53	0.71
Yield over 4 yrs in BO-2 panel	10.32	13.27	0.61
Mean yield over 10 yrs in BO panel	10.47	12.64	0.69
Yield over 4 yrs in BI-1 panel	23.30	26.93	0.75
Yield over 14 years	12.69	14.78	0.74
Yield per unit girth ($g^{-1}cm^{-1}$ of bark)	9.40	11.72	0.64
Summer yield over 3 yrs in BO-1 panel	15.78	19.44	0.66
Summer yield over 4 yrs in BO-2 panel	14.23	17.60	0.65
Summer yield over 7 yrs in BO panel	12.92	15.76	0.67
Summer yield over 4 yrs in BI-1 panel	23.22	27.95	0.69
Summer yield over 11 years	16.49	18.72	0.77
Summer Depression (%) over 11 years	11.54	16.57	0.49
Pink disease incidence (%)	36.75	53.74	0.46
Bole volume (m^3)	23.23	26.65	0.76

use of PB 312 as a parent in hybridization programmes could result in dual purpose clones with high rubber and timber yields.

The correlations (Table 8) revealed yield per unit girth to have a close relationship with yield over 14 years (r=0.906, P<0.01) and summer yield over 11 years (r = 0.738, P < 0.05), indicating its importance in deciding yield potential of a clone. High yielding clones, in general, possess high summer yield also, as reflected in the positive correlations among annual mean yield and summer yield in the three tapping panels. Girth at opening in *Hevea* is positively correlated with yield (Mydin *et al*., 1992), but growth rate under tapping can vary with the response in growth of clones to the process of controlled wounding. The positive correlation of girth after 16 years of tapping with rubber yield, though non-significant, in the present study could be a reflection of varied response to tapping injury in the clones. In general, growth parameters like girth at opening, girth after 16 years of tapping and bole volume showed no relationship with yield of the clones studied indicating partitioning of photosynthates towards the production of biomass at the expense of yield in the present population of clones studied. Alika (1980) had reported negative and non-significant relationship between girth and rubber yield as observed in the case of girth at opening in the present study. The non-significant relationship of bole volume with yield indicates these two traits to be independent and requiring specific selection for objectives like evolving timber clones and latex clones.

Clone PB 280 has proven to be a high yielding clone with very good secondary attributes like low incidence of pink disease and TPD. Yield per unit girth (Table 3) which reflects the real yield potential of a clone (Mydin *et al*., 2011) was also highest in this clone (0.9 g dry rubber cm^{-1} girth). Incidence of pink disease in this clone was moderate while Corynespora disease incidence was low as per earlier reports (Varghese *et al*., 2009).

Clone PB 312 has proved its merit as a very promising latex timber clone. Clone PB 314, among the best rubber yielders with a high yield per unit girth (0.8 g dry rubber cm^{-1} girth), though prone to TPD has shown low incidence of pink disease. Judicious employment of a suitable latex harvesting system may help to reap the benefits of this clone. However, earlier reports (Varghese *et al.,* 2009) have shown the clones PB 312 and PB 314 to be prone to all major diseases in general and thus require prophylactic care. These three clones along with PB 255 were upgraded to Category 2 of the planting recommendations for the traditional rubber growing regions of India based on observations from a number of field evaluations (Varghese *et al*., 2009). Clone PB 311 has emerged as a promising rubber yielding clone with good timber yield potential and stability in yield over the long term,

Table 8. Correlations among yield attributes, girth and bole volume

	Yield 14 yrs	Yield per unit girth (g cm^{-1})	Yield BO-1	Yield BO-2	Yield B1-1	Yield BO	Summer yield 11 yrs	Summer yield BO-1	Summer yield BO-2	Summer yield B1-1	Summer yield BO	Girth at opening (cm)	Girth 17th yr. tap (cm)	Bole vol. (m^3)
Yield 14 yrs	1													
Yield per unit girth (g cm^{-1})	0.906 **	1												
Yield BO-1	0.591	0.589	1											
Yield BO-2	0.872 **	0.674 *	0.589	1										
Yield B1-1	0.870 **	0.813 **	0.156	0.614	1									
Yield BO	0.811 **	0.705 *	0.904 **	0.878 *	0.417	1								
Summer yield 11 yrs	0.871 **	0.738 *	0.304	0.786 *	0.851 **	0.596	1							
Summer yield BO-1	0.731 *	0.705 *	0.732 *	0.681 *	0.466	0.794 *	0.677 *	1						
Summer yield BO-2	0.722 *	0.449	0.093	0.748 *	0.742 *	0.451	0.846 **	0.47	1					
Summer yield B1-1	0.793 *	0.740 *	0.229	0.654	0.826 **	0.482	0.947 **	0.543	0.670 *	1				
Summer yield BO	0.830 **	0.613	0.354	0.830 **	0.743 *	0.649	0.904 **	0.743 *	0.940 **	0.718 *	1			
Girth at opening (cm)	-0.425	-0.666	0.057	-0.058	-0.663	0.003	-0.516	-0.359	-0.201	-0.621	-0.291	1		
Girth 17th yr of tapping	0.642	0.301	0.325	0.661	0.54	0.542	0.515	0.274	0.687 *	0.365	0.627	0.226	1	
Bole vol. (m^3)	-0.161	-0.439	0.065	0.061	-0.31	0.071	-0.293	-0.184	0.139	-0.503	0.034	0.793 *	0.398	1

** Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed).

but reports on the susceptibility to wind in this clone prevents its recommendation for large scale cultivation. The present results suggest scope for release of clones PB 280, PB 312 and PB 314 under category 1 planting materials.

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References

Alika, J.E. 1980. Possibilities of early selection in *Hevea brasiliensis*. *Silvae Genetica* **29**: 161-162.

Chaturvedi, A.N. and Khanna, L.S. 1982. *Forest Mensuration*. International Book Distributors, Dehradun, India, 310 p.

Jacob, J., Othman, R., Mydin, K.K., Lam, L.V., Tuy, L.M., Woelan, S., Teerawatanasuk, K., Weiguo, L., Seneviratne, W.M.G., Omokhafe, K.O. and Mathurin, O.K. (2013). International clone exchange and genetic enhancement research in *Hevea brasiliensis. Rubber Science* **26**(1): 1-12.

John, A., Varghese, Y.A. and Mushriff, S.K. 2009. Performance of indigenous and exotic clones of rubber in India. *Journal of Plantation Crops* **37**(2): 92-96.

John, A., Mydin, K.K., Varghese, Y.A., Nair, R.B. and Saraswathyamma, C.K 2004. Selection for yield and stability over seasons in *Hevea brasiliensis. Journal of Plantation Crops* **32**(Suppl.): 82-86.

Licy, J., Panikkar, A.O.N., Premakumari, D., Varghese, Y.A. and Nazeer, M.A. 1992. Genetic parameters and heterosis in *Hevea brasiliensis*: 1. Hybrid clones of RRII 105 x RRIC 100. *Indian Journal of Natural Rubber Research* **5**(1&2): 51-56.

Mydin, K.K. and Saraswathyamma. C.K. 2005. *A Manual on Breeding of Hevea brasiliensis*. Rubber Research Institute of India, 97 p.

Mydin, K.K., Varghese, Y.A., Reghu, C.P., Meenakumari, T., Joseph, A. and Jacob, J. 2009. Improved clones of rubber (*Hevea brasiliensis* Willd. ex Adr. de Juss. Muell Arg.). In: *Towards Inclusive Rubber Development – Proceedings of the International Conference on Natural Rubber Extension and Development, Cochin, India*, 8-9 May 2008, 175-189.

Mydin, K.K., Nair, G.V., Sethuraj, M.R., Panikkar, A.O.N. and Saraswathy. P. 1992. Estimates of genetic parameters for yield and certain yield components in rubber. Gregor Johann Mendel Foundation International Symposium, 1992, Calicut, Kerala.

Mydin, K.K., Thomas, V. and Mercykutty. V.C. 2011. Yield and related attributes of certain new generation clones of *Hevea brasiliensis* under large scale evaluation. *Journal of Rubber Research* **14**(3): 167-183.

Nair, V.K.B. and Marattukalam, J.G. 1975. Report on the performance of RRIM clones in India (500 and 600 series). *Rubber Board Bulletin* **12**(2): 41-49.

Narayanan, C. and Mydin, K.K. 2011. Heritability of yield and secondary traits in two populations of Para rubber tree (*Hevea brasiliensis*). *Silvae Genetica* **60**(3): 132-139.

Otegbeye, G.O. and Kellison, R.C. 1980. Genetics of wood and bark characteristics of *Eucalyptus viminalis. Silvae Genetica* **29**: 27-31.

Prabhakaran, V.T. and Jain, J.P. 1994. *Statistical Techniques for Studying Genotype x Environment Interactions*. South Asian Publishers Pvt. Ltd, New Delhi, 221 p.

Reju, M.J., Mydin, K.K. and Abraham, T. (2014) Growth and yield over the long term in certain W x A hybrids evolved under the first programme on utilization of wild *Hevea* germplasm in India. IRRDB Plant Breeders' and Transfer of Technology Workshop, Phnom Penh, Cambodia 28-30, April 2014.

Rubber Research Institute of India. 1994. *Annual Report,* 1993-'94. pp. 35-40

Soman, T.A., Suryakumar, M., Mydin, K.K. and Nazeer, M.A. 2012. Performance of certain exotic *Hevea* clones in Kanyakumari region. *Natural Rubber Research* **25**(1): 60-67.

Varghese, Y.A., Licy, J., John, A. and Panikkar, A.O.N. 1989. An incision method for early selection of *Hevea* seedlings. *Indian Journal of Natural Rubber Research* **2**(2): 112-117.

Varghese,Y.A., Mydin, K.K. and Meenakumari, T. 2009. *Performance of the RRII 400 Series and Certain Prang Besar Clones in Various Locations in India- A Report*. Rubber Research Institute of India, Kottayam, p. 64.