Mohanan *et al.* (Eds.), Prospects in Forestry and Agriculture 234-242. KFRI, 2015.

Long term yield performance of certain indigenous and exotic clones of *Hevea brasiliensis* under large scale evaluation in India

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ABSTRACT

The present study was taken up to examine the long term yield performance of certain exotic and indigenous clones in the prevailing local agro climatic condition to identify clones showing high yield and desirable secondary attributes in comparison with the most popular clone RRII 105. The Indian primary clone RRII 5 and hybrid clone RRII 118 were the top yielders in terms of rubber production, desirable growth, timber yield and secondary attributes. The yield of RRII 308 was on par with that of RRII 105. RRII 208, proven latex –timber clone showed promising yield in the virgin panels. The Indonesian clone PR 255 and the Chinese clone SCATC 88-13 were the exotic clones which showed comparable yield with that of RRII 105. The high broad sense heritability for rubber yield offer scope for improvement by selection. Ranking of clones based on immature yield at 3-5 years followed by 4 years of mature yield gives a very high prediction of yield in the long term.

INTRODUCTION

The para rubber tree (*Hevea brasiliensis*) is the single most important commercial crop which plays a pivotal role in the economy of Kerala state. The contribution of Rubber Research Institute of India in developing a handful of high yielding *Hevea* clones has resulted in this remarkable achievement. Hybridization and selection is the most important method of tree improvement in *Hevea*. During the early years, introduced primary/ hybrid clones were used as parents for hybridization which resulted in RRII 100, 200 and 300 series of clones. Among these, RRII 105, the outstanding high yielder (Nair and George 1969; Nazeer *et al*., 1986 and Mydin *et al*., 1994) continues to be widely cultivated. RRII 118, RRII 203 and RRII 208 (Saraswathyamma *et al*., 1987; 1990) and RRII 300 and RRII 308 (Premakumari *et al*., 1984) were the other selections from these series showing region wise performance. Ortet (plus tree) selection and development of primary clones is the oldest method in *Hevea* breeding. More than 100 promising ortets have been identified from vast areas of seedling stands and cloned for further evaluation. The early ortet selections from India are RRII 1 series of which RRII 5 is a vigorous high yielder (Marattukalam *et al*., 1990) and RRII 33 a clone tolerant to Abnormal Leaf Fall disease caused by *Phytophthora spp*. (RRII, 2005-06). Simultaneously, high yielding clones developed by other rubber growing countries have been introduced and evaluated in the prevailing agro climatic conditions. A total of 127 exotic clones have been introduced so far. The earlier introductions were mainly from Malaysia, Indonesia and Sri Lanka. Recent introductions include clones from China, Thailand and Ivory Coast. (Varghese *et al*., 2006, Mydin *et al*., 2009). Introduced exotic clones are being successfully used for larger scale commercial cultivation and concerted efforts are made for bilateral/multilateral exchange of more and more clones (Jacob *et al*., 2013). A three stage field evaluation procedure involving small scale/large scale trials (SSTs and LSTs) and on farm trials (OFTs) are conventionally adopted for the selection and release of high yielding clones. The present study is the final report of a large scale clone trial undertaken with the following objectives: 1) Examine the long term yield performance of certain introduced clones along with a set of indigenously developed hybrid/primary clones 2) Work out the genetic variability for yield in the population 3) Identify clones showing high yield and desirable secondary attributes in comparison with the check clone RRII 105 and 4) Examine the possibility of early selection of potential high yielders based on early vs. mature correlations.

MATERIALS AND METHODS

Study location

The study was conducted in the research farm of RRII, India ($9^0$32'N $76^0$36'E; 73 m above MSL) from a large scale evaluation trial planted in 1989.

Experimental materials

Details of the clones and their parentage are given in Table 1. A set of l3 clones including RRII 105 as the check clone was evaluated employing a Randomized Block Design (RBD) with seven replications and seven trees per plot. The exotic clones included three Chinese clones (SCATC 88-13, SCATC 93-114 and Haiken 1), two Malaysian clones (RRIM 600 and RRIM 703) and two Indonesian clones (PR 255 and PR 261). Indian clones included both primary (RRII 105, RRII 118, RRII 208, RRII 300 and RRII 308 and hybrid (RRII 5) clones. The trees were opened for tapping during the 7^{th} year after planting. The tapping system followed was S/2 d3 6d/7. Methodology adopted for recording secondary characters was as per John *et al*. (2009).

Dry rubber yield recording

Early yield was recorded in the immature phase at 3-5 years after planting. Three rounds of test tapping following S/2 d3 6d/7 system were done consisting of 10 tappings per round in the 3^{rd}, 4^{th} and 5^{th} year of growth. Latex collected from 10 consecutive tappings was coagulated and dried to determine the early yield potential.

Yield recording at maturity was done at fortnightly intervals by cup coagulation method. After cessation of latex flow, latex from individual trees was coagulated in the collection cup itself, using 3 percent formic acid. The coagula were collected separately, the cup lumps dried in the smoke house, and the dry weight of lumps expressed as gram per tree per tap (g/t/t). Mean annual dry rubber yield was computed for a period of 14 years of tapping.

Table 1. Details of clones included in the study

Clone	Parentage	Country of origin	Year of introduction
RRII 5	Primary	India	-
RRII 118	Mil 3/2 x Hil 28	-do-	-
RRII 208	Mil 3/2 x AVROS 255	-do-	-
RRII 300	Tjir 1 x PR 107	-do-	-
RRII 308	Gl 1 x PB 6/50	-do-	-
RRIM 600	Tjir 1 x PB 86	Malaysia	1956
RRIM 703	RRIM 600 x RRIM 500	-do-	1966
PR 255	Tjir 1 x PR 107	Indonesia	1988
PR 261	Tjir 1 x PR 107	-do-	1988
SCATC 88/13	RRIM 600 x Pil B 84	China	1984
SCATC 93/114	TR 31-45 x HK 3-11	-do-	1984
Haiken 1	Primary	-do-	1984
RRII 105	Tjir 1 x Gl 1	India (Control)	-

Table 2. Mean dry rubber yield of clones

Clone	Mean test tap yield	Mean yield in BO-1 panel	Mean yield in BO-2 panel	Mean yield over 4 years in B1-1 panel	Mean dry rubber yield over 14 years
RRII 5	13.68	61.42	69.01	73.25	67.89
RRII 118	12.07	46.00	64.32	73.58	61.30
RRII 208	11.40	43.04	50.38	28.74	40.72
RRII 300	10.70	37.22	41.96	35.31	38.16
RRII 308	18.51	45.20	49.53	56.15	50.29
RRIM 600	10.29	38.14	43.63	40.36	40.71
RRIM 703	12.04	42.86	36.09	35.39	38.11
PR 255	14.33	43.39	45.79	50.83	46.67
PR 261	15.33	36.33	40.41	33.71	36.82
SCATC 88-13	14.29	43.96	45.54	39.85	43.12
SCATC 93-114	4.44	16.68	25.17	21.86	21.24
Haiken 1	8.50	29.54	23.49	16.21	23.08
RRII 105	14.93	47.12	51.77	58.49	52.46
Mean	12.35	40.83	43.08	43.36	44.75
CD (P=0.05)	3.59	6.52	8.17	13.08	8.97

Statistical analysis

Standard statistical techniques were used for analyzing the data. Genetic variability was estimated in terms of genotypic and phenotypic coefficient of variation and broad sense heritability. The Spearman's coefficient of rank correlations for immature yield and yield over different years was estimated and the significance of correlation coefficients was tested for the possibility of early prediction of long term yield (Steel and Torrie, 1980).

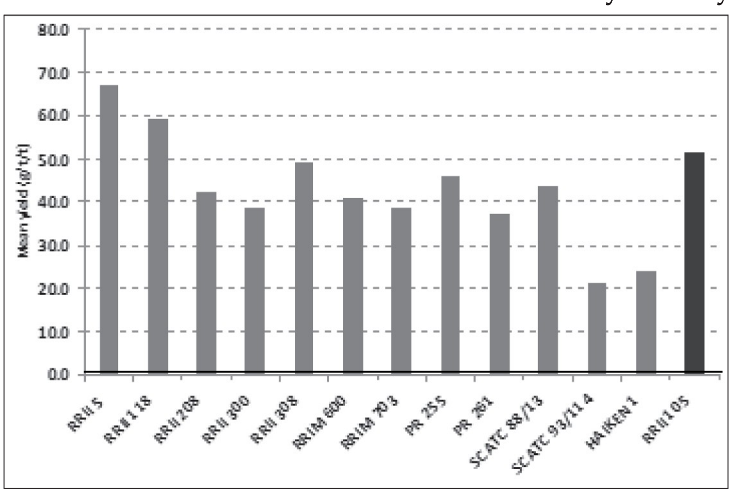

Fig. 1. Mean yield of clones over 14 years of tapping

RESULTS AND DISCUSSION

Test tap yield in the immature phase

Teat tap yield among the 13 clones ranged from 8.50 g/t/t (Haiken 1) to 18.51 g/t/t (RRII 308). Mean yield over three rounds of test tapping was the highest for RRII 308. This was followed by PR 261, RRII 105, PR 255 and SCATC 88-13, RRII 5 and RRII 118 which showed comparable test tap yield with that of RRII 105.

Dry rubber yield at maturity

Clonal variations for annual dry rubber yield were significant in both virgin and renewed panels as well as overall yield for 14 years of tapping (Table 2, Fig. 1). Among the 13 clones, RRII 5 recorded the highest mean yield in the first virgin BO-1 panel (61.42 g/t/t) and the performance of this clone was significantly superior to RRII 105 (47.12 g/t/t). Six clones *viz.*, RRII 118, RRII 208, RRII 308, RRIM 703, PR 255 and SCATC 88-13 recorded

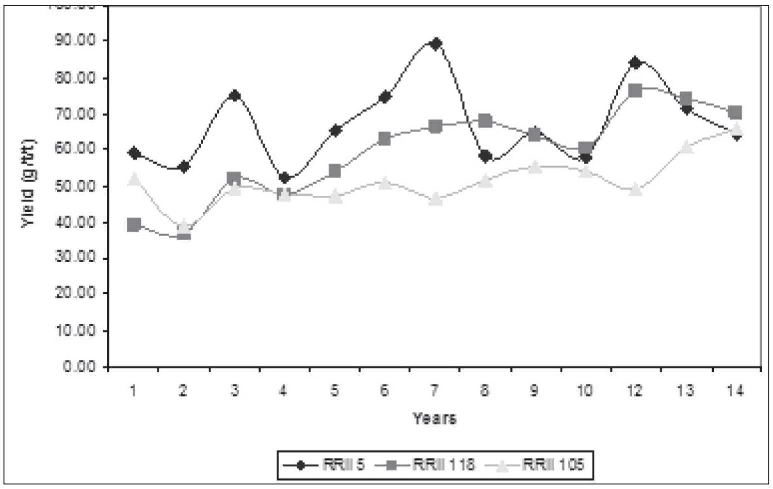

Fig. 2. Yielding pattern of high yielding clones

comparable yield with the check clone. In the second virgin panel BO-2, RRII 118 the second highest yielder (64.32 g/t/t), after RRII 5 (69 g/t/t) showed a rising yield trend with significantly superior yield than the control. RRII 5 and RRII 118 were the top yielders in the renewed panel also. Over 14 years of tapping, RRII 5 recorded the maximum annual yield of 67.89 g/t/t followed by RRII 118 (61.30 g/t/t). RRII 308 (50.29 g/t/t), PR 255 (46.67 g/t/t) and SCATC 88/13 (43.12 g/t/t) produced comparable yield to that of RRII 105 (52.46 g/t/t). For most of the clones the yielding pattern in the virgin bark panels was similar whereas in the renewed panel the clones showed differential behavior. RRII 208 and RRIM 703 showed a declining trend in yield in the renewed panel. Both RRII 208 and RRIM 703 are however proven to be high yielders in the cold prone north east India (Antony *et al*., 2012). RRII 208 was also reported to maintain high yield over long term in the drought prone non-traditional areas of Dapchari (Sing *et al*., 2012). The consistent superiority in yield of RRII 5 and RRII 118 over RRII 105 during the entire study period was noteworthy (Fig. 2). The long term data substantiates the early results from large scale (John *et al*., 2009; Mydin *et al*., 2009) and on farm trials (Saraswathyamm *et al*., 1987; Narayanan *et al*., 2013). RRII 118 is a high yielder in the non-traditional areas also (Antony *et al*., 2012). However, the superior performance of RRII 5 and RRII 118 was not maintained in all OFTs in the traditional region (Mydin *et al*., 2009), implying the specific adaptation of these two clones. The exotic clones, PR 255 and SCATC 88-13 respectively showed comparable yield performance to RRII 105. Similar results were reported from other locations also in both large scale and on farm trials (Mydin *et al*., 2009, Mercykutty *et al*., 2009). Among the 13 clones SCATC 93-114, Haiken 1 and PR 261 were the low yielders. High genetic variability for rubber yield was reported by several workers including Tan *et al*. (1975), Mydin *et al*. (1992) and Licy *et al*. (2003). The present results corroborate these findings.

Estimates of genetic parameters

The genetic variability in terms of Phenotypic Coefficient of Variation (PCV) for yield was estimated to be 44.22. Genotypic Coefficient of Variation (GCV) estimates was lower (37.1) than that of PCV value due to the environmental influence on rubber yield. Broad sense heritability was 0.7 reconfirming the earlier findings (Simmonds, 1989, Mydin *et al*., 2011) that rubber yield is highly heritable.

Growth and bole volume

The growth characteristics of the clones studied are presented in the Table 3. RRII 118 exhibited 100% tappability at the time of opening. Two other clones *viz*., RRII 308 and RRII 5 also recorded very high tappability (90%). Girth at opening and GI rate was the highest for clone RRII 118 which was exhibited in the initial growth phase itself (Varghese *et al*., 1996). The clone also recorded the highest clear bole volume of 0.17 m^3/tree followed by RRII 308 (0.13 m^3/tree) and RRII 5 (0.12 m^3/tree). RRII 5 exhibited very high yield and desirable secondary characters including girth, girth increment, bark thickness and number of latex vessel rows in the preliminary evaluation trial (Marattukalam *et al*., 1990). Vigorous growth rate, high bark thickness and low summer yield depression of RRII 118 have been reported in on farm trials also (Saraswathyamma *et al*., 1987). Growth curve plotted up to 19th year of planting indicated consistent and high GI rate of RRII 5 and RRII 118, before and after tapping (Fig. 3). Vinod *et al*. (1996b) reported high girth and bark thickness for RRII 5 and RRII 118 in the non traditional rubber growing areas which was comparable to that in the traditional belt. According to Webster and Baulkwill (1989) the relative growth rate of the trees

Table 3. Important growth characters of the clones

Clone	Girth at opening (cm)	Tappability (%)	Mean girth increment before tapping (cm/yr)	Mean girth increment on tapping (cm/yr)	Clear bole volume (m^3/tree)
RRII 5	55.91	90.00	6.50	2.76	0.12
RRII 118	61.82	100.00	7.01	4.14	0.17
RRII 208	53.36	80.63	5.94	1.92	0.11
RRII 300	52.51	67.08	5.78	2.10	0.10
RRII 308	55.78	90.03	6.68	3.8	0.13
RRIM 600	49.72	49.02	5.67	2.91	0.09
RRIM 703	49.93	58.00	5.51	1.7	0.09
PR 255	50.54	55.44	5.98	2.15	0.08
PR 261	51.22	52.32	5.62	1.71	0.08
SCATC 88-13	49.95	52.14	5.72	2.41	0.10
SCATC 93-114	50.44	61.02	6.30	3.06	0.10
Haiken 1	45.62	25.66	4.48	1.50	0.08
RRII 105	52.16	62.55	5.94	2.51	0.10
Mean	52.22	64.19	5.93	2.51	0.10
CD (P=0.05)	5.12	-	1.08	1.06	0.03

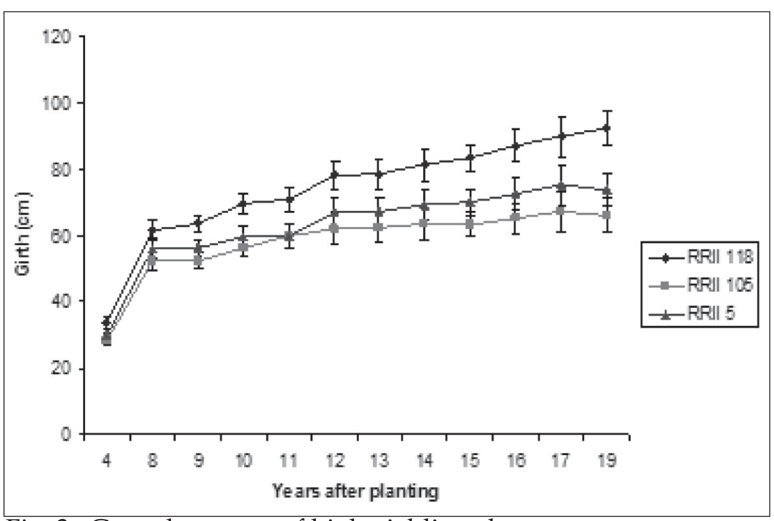

Fig. 3. Growth pattern of high yielding clones

Table 4. Rank correlation for mean yield (g/t/t) over successive years of tapping

	Test Tap yield	1st yr.	2nd yr.	3rd yr.	4th yr.	5th yr.	6th yr.	7th yr.	8th yr.	9th yr.	10th yr.	12th yr.	13th yr.	14th yr.
Test Tap yield	1	0.417 **	0.436 **	0.365 **	0.371 **	0.271 **	0.304 **	0.280 **	0.296 **	0.243 *	0.257 *	0.394 **	0.446 **	0.416 **
1st yr.		1	0.680 **	0.572 **	0.546 **	0.486 **	0.463 **	0.482 **	0.474 **	0.506 **	0.551 **	0.545 **	0.557 **	0.528 **
2nd yr.			1	0.803 **	0.762 **	0.720 **	0.722 **	0.697 **	0.532 **	0.606 **	0.576 **	0.625 **	0.590 **	0.568 **
3rd t yr.				1	0.790 **	0.832 **	0.836 **	0.810 **	0.680 **	0.720 **	0.721 **	0.729 **	0.666 **	0.698 **
4th t yr.					1	0.801 **	0.768 **	0.732 **	0.677 **	0.706 **	0.655 **	0.665 **	0.669 **	0.664 **
5th yr.						1	0.824 **	0.784 **	0.697 **	0.79 **	0.725 **	0.800 **	0.734 **	0.726 **
6th yr.							1	0.797 **	0.661 **	0.741 **	0.661 **	0.719 **	0.654 **	0.710 **
7th yr.								1	0.736 **	0.776 **	0.703 **	0.701 **	0.595 **	0.657 **
8th yr.									1	0.884 **	0.800 **	0.706 **	0.669 **	0.742 **
9th yr.										1	0.838 **	0.752 **	0.667 **	0.750 **
10th yr.											1	0.745 **	0.664 **	0.753 **
12th yr.												1	0.901 **	0.861 **
13th yr.													1	0.866 **
14th t yr.														1

* Correlation is significant at the .05 level (2-tailed)   ** Correlation is significant at the .01 level (2-tailed)

was found to steadily decline with age. Yield and girth increment under tapping tend to be negatively correlated (Nazeer *et al*., 1986) and the genotypic influence of girth and yield are observed to vary differentially with age (Jayasekara *et al*., 1994). The capability of RRII 5 and RRII 118 to maintain high growth rate before and after tapping reflect on their early tappability and sustainable high yield potential. The high yield coupled with bole volume qualifies these clones as latex- timber clones also.

Secondary characters

Resistance to various biotic and abiotic stresses has been reported by Rajalakshmi *et al*. (1994 and 1997) and John *et al*. (2009). RRII 208 and RRIM 703 recorded lowest incidence of TPD (2-4 %) as against RRII 105 (10 %). RRII 105 recorded the maximum leaf retention (85 %) on infection due to ALF disease followed by RRII 5 (79 %), RRII 118 (73.1 %) and RRII 308 (73 %). RRIM 703 and Haiken 1 recorded low leaf retention. SCATC 93-114 and RRIM 703, showed relatively low disease intensity with respect to pink and powdery mildew disease. Pink disease incidence was the lowest in the clone RRII 208 (12 %).

Correlation studies

Latex yield in rubber is a complex multi factorial trait. A period of over 15 years is required after maturity, for a reliable assessment of yield performance and secondary characters. With more and more pressure on land resources and climatic constraints, long years of yield recording for final selection of high yielding varieties continue to be the major challenge for *Hevea* breeders. Attempts for early selection of potential clones based on correlation of test tap yield in the immature phase with yield in the later years have shown promising results in the present study. However, the magnitude of correlation was higher with respect to ranking for mature yield in the 3rd and 4th year with that of the subsequent years (Table 4). Ong (1980) and Mydin *et al*. (2011) opined that, the first three years yield data is adequate for selecting superior clones to shorten the testing time. However, Chandrasekhar *et al*. (2007) concluded that six years of yield recording would be required for optimizing selection of top yielding clones from LSTs.

These results reconfirm the findings of Licy *et al*. (1998) on the significance of immature yield (4 ½ years) with that of yield in the mature phase as well as yield between different years (Vinod *et al*., 1996). Age-age correlations for yield could be employed with a reasonable accuracy for interim recommendation of clones for further field testing (Goncalves, 2005) and three years of regular tapping is sufficient for yield stabilization so that selection for yield could be exercised from the 4th year of tapping (Mydin *et al*., 2011). Tan (1978) suggested that selection based on early mature yield would be more effective than nursery yield of young seedlings.

CONCLUSION

The Indian primary clone RRII 5 and hybrid clone RRII 118 were the top yielders in terms of rubber production, desirable growth, timber yield and secondary attributes. The yield of RRII 308 was on par with that of RRII 105. RRII 208, proven latex –timber clone showed promising yield in the virgin panels. The Indonesian clone PR 255 and the Chinese clone SCATC 88-13 were the exotic clones which showed comparable yield with that of RRII 105. The high broad sense heritability for rubber yield offer scope for improvement by selection. Ranking of clones based on immature yield at 3-5 years followed by 4 years of mature yield gives a very high prediction of yield in the long term.

ACKNOWLEDGEMENT

The authors thank Dr. James Jacob, Director, Rubber Research Institute of India for facilities provided. The assistance from Mr. P. Aneesh, Asst. Statistician, RRII in analyzing the data is gratefully acknowledged.

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