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HIGH YIELD AND PRECOCITY IN THE RRII 400 SERIES HYBRID CLONES OF RUBBER

Kavitha K. Mydin and V.C. Mercykutty
Rubber Research Institute of India, Kottayam-686 009, Kerala, India

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Twenty clones comprising 15 of the RRII 400 series, one introduced (Prang Besar) clone, one tetraploid and three clones with normal morphotype (derived from the progeny of the compact canopy type variant) were evaluated in large scale evaluation trials. Mean yield and growth parameters over four years of tapping, clear bole volume, monthly yield trends and early tappability were used as selection parameters. Clones with an overall superior performance were identified based on performance indices. The response to selection for yield was estimated to assess the improvement in yield of selected clones over the high yielding check, RRII 105. Significant variability for the parameters and high heritability for yield helped in identifying four precocious high yielding hybrid clones *viz.*, RRII 430, RRII 422, RRII 414 and RRII 402 of parentage RRII 105 x RRIC 100.

Key words : Clear bole volume, Hybrid clones, Heritability, Performance index, Precocity, Rubber yield.

INTRODUCTION

The major selection parameters in present day *Hevea brasiliensis* breeding include high rubber yield, precocity which constitutes early attainment of tappable girth and timber yield potential (Abdul Aziz, 2002; Mydin *et al.,* 2005), an aspect that has recently gained significance in determining the worth of a rubber clone. Hybridization and clonal selection has resulted in the release of numerous outstanding *H. brasiliensis* clones. The heterogeneous seedling populations produced by hybridization are evaluated in the nursery, following which selected hybrids are cloned and evaluated in a phased manner in small scale trials, large scale trials and on-farm trials (Tan, 1987; Varghese and Mydin, 2000).

In India, crop improvement in rubber was initiated in 1954 with the first hybridization programme which led to the release of the most popular rubber clone RRII 105 (Nair and George, 1968; Nazeer *et al.,* 1986; Mydin *et al.,* 1994). Subsequent hybridization programmes have led to the release of clones of the RRII 200 series (Saraswathyamma *et al.,* 1990) and RRII 300 series (Premakumari *et al.,* 1984). In the attempt to further improve yield levels, RRII 105 was incorporated in crossing programmes from 1982 onwards (Annamma *et al.,* 1989; Licy *et al.,* 1992). A number of high yielding hybrids of the RRII 400 series were produced from the cross RRII 105 x RRIC 100 (Licy *et al.,* 1992) and the heterotic response for yield and related attributes of the limited number of trees in a small scale trial was reported by Licy *et al.* (2003).

The present paper reports on the per-

Correspondence: Kavitha K. Mydin (Email: kavitha@rubberboard.org.in)

formance of the RRII 400 series clones along with a few others in the pipeline, over four years of tapping in the first large scale evaluation trial.

MATERIALS AND METHODS

Twenty clones were evaluated in comparison with clone RRII 105 in large scale trials laid out in 1993 at the Central Experiment Station of the Rubber Research Institute of India at Chethackal in Central Kerala, India. The material evaluated (Table 1) included 15 clones of the RRII 400 series, one introduced Prang Besar (Malaysia) clone, one tetraploid and three clones derived from the progeny of the compact canopy type. The clones were planted in two adjacent field trials employing randomized block design with 16 trees per plot. In Trial 1, 12 clones were replicated six times while in Trial 2, 10 clones were replicated thrice.

The girth of trees was recorded annually from the third year of planting onwards and was used to determine the tappability of clones and girth increment rates during the pre-tapping and tapping phases. The trees were opened for tapping in the eighth year after planting. The tapping system followed was 1/2S d/3 6d/7. Thereafter, yield was recorded by cup coagulation on a fortnightly basis. Annual mean yield over four years, yield in summer (February – May) during the third and fourth year of tapping and the percent drop in yield in summer months during the period were worked out. The height up to the main fork was measured and the clear bole volume per tree was estimated in the 11th year after planting following the quarter girth method (Chaturvedi and Khanna, 1982).

Analysis of variance for the parameters was done individually for both trials. A pooled analysis using a weighted 't' test was also done to compare the clones across trials. Clones which showed superiority in overall performance were identified by means of

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

TRIAL 1		TRIAL 2	
Clone	Pedigree	Clone	Pedigree
RRII 402	RRII 105 x RRIC 100	RRII 410	GT 1 x RRIC 100
RRII 403	"	RRII 422	RRII 105 x RRIC 100
RRII 407	"	RRII 427	"
RRII 414	"	RRII 430	"
RRII 417	"	RRII 434	RRII 105 x PR 107
RRII 429	"	RRII 454	GT 1 x RRIC 100
RRII 446	GT1 x RRIC 100	RRII 52	Normal morphotype progeny from compact canopy type
RRII 449	"	RRII 53	"
RRII 453	"	PB 330	PB 5/51 X PB 32/36
RRII 54	Normal morphotype progeny from compact canopy type	RRII 105 (Check clone in both trials)	Tjir1 x Gl 1
RRII 55	Tetraploid (2n = 72)		

a performance index (Mydin *et al.,* 1990) based on six parameters *viz.,* annual mean yield over four years (X_1), summer yield (X_2), girth at opening (X_3), girth increment in the pre-tapping phase (X_4), girth increment under tapping (X_5) and clear bole volume (X_6) as follows:

Performance Index (PI) of a clone = $W_1\overline{X}_1 + W_2\overline{X}_2 + W_3\overline{X}_3 + W_4\overline{X}_4 + W_5\overline{X}_5 + W_6\overline{X}_6$

where, $\overline{X}_1$ ....$\overline{X}_6$ denote means of traits X_1 ....X_6 and

W_1........W_6 = $1/\sigma^2 e_1$ .... $1/\sigma^2 e_6$ are the weights attached to each trait.

$\sigma^2 e_1$ .... $\sigma^2 e_6$ denote environmental variances for the traits X_1 ....X_6 in the respective trial in which the clone was located. The clones were ranked on the basis of their performance indices.

Selection of the best among the promising clones across the two trials was done on the basis of yield improvement and early tappability. The percentage improvement in yield over the check clone RRII 105 was worked out based on the response to selection (Falconer and Mackay, 1996) as,

Response to selection = H^2. S

where, H^2 = Broad sense heritability for yield in the respective trial in which the clone is situated, and

S = Selection differential based on the observed mean yield of the selected clones in the respective trials.

RESULTS AND DISCUSSION

The performance of the clones in terms of annual mean yield of dry rubber over four years of tapping along with the mean summer yield and the extent of yield drop in summer during the third and fourth years of tapping are given in Table 2. Significant clonal variation was evident for these

Table 2. **Mean yield of the clones over four years of tapping**

TRIAL 1				TRIAL 2			
Clone	Yield over 4 years (g/t/t)	Summer yield–3rd & 4th year (g/t/t)	Summer yield drop - 3rd & 4th year (%)	Clone	Yield over 4 years (g/t/t)	Summer yield – 3rd & 4th year (g/t/t)	Summer yield drop -3rd & 4th year (%)
RRII 402	53.04 #	27.87 #	54.56 #	RRII 410	32.67	16.60	59.65
RRII 403	46.02	26.14 #	53.79 #	RRII 422	61.16 #	37.46 #	52.70
RRII 407	38.47	18.09	62.87	RRII 427	50.28	27.45	56.69
RRII 414	56.68 #	30.52 #	56.83 #	RRII 430	61.09 #	28.41	63.86
RRII 417	53.03 #	23.97	64.78	RRII 434	21.15	12.41	55.29
RRII 429	49.42 #	26.62 #	56.28 #	RRII 454	29.79	17.48	50.53
RRII 446	26.86	12.61	56.76 #	RRII 52	54.08 #	40.75 #	28.03 #
RRII 449	25.09	12.36	57.93 #	RRII 53	14.50	8.88	55.50
RRII 453	32.91	10.56	68.63	PB 330	43.38	17.80	68.33
RRII 54	14.46	8.55	53.64 #	RRII 105	49.38	24.14	59.51
RRII 55	41.16	21.98	58.78 #				
RRII 105	40.43	18.47	64.61				
G. Mean	39.82	19.81	59.12	G.Mean	41.75	23.14	55.01
Variance Ratio	28.31**	15.83**	4.25*	Variance Ratio	114.26**	18.89**	9.86*
C.D.(P≤0.05)	6.88	5.19	6.62	C.D.(P≤0.05)	4.57	7.14	10.24

* Significant at P<0.05; ** Significant at P<0.01; # Superior

parameters in both the trials. The yield (g/t/t) of the check clone RRII 105 was 40.43 and 49.38 in the two trials while for the clones under evaluation it ranged from 14.46 to 61.16.

Seven clones *viz.*, RRII 422, 430, 414, 52, 402, 417 and 429 were significantly superior to RRII 105 in terms of rubber yield in the respective trials. Clones RRII 403 and 427 also showed a slight, though statistically non-significant, improvement in yield over RRII 105. These nine clones were comparable among themselves with respect to yield as determined by the weighted 't' test, with mean yields (g/t/t) ranging from 46.02 to 61.16. Clones RRII 422, 430, 414, 417 and 429 were reported to yield better than RRII 105 in the small scale trial also (Licy *et al.*, 2003).

Figure 1 depicts the annual mean yield of the nine clones and RRII 105 over four years. In the first year of tapping RRII 52 recorded the highest mean yield (55.22 g/t/t) followed by RRII 430 (48.10 g/t/t). Clone RRII 52 maintained the highest yield in the second year also with 47.56 g/t/t, followed by RRII 422 (46.06 g/t/t). Clone RRII 422 was the highest yielder (79.90 g/t/t) in the third year followed by RRII 430 (77.45 g/t/t). Clones RRII 430 and 422 gave the highest mean yields of 79.71 and 78.42 g/t/t respectively in the fourth year of tapping. The mean yield of clone RRII 105 during the first, second, third and fourth years of tapping was 38.36, 29.74, 51.00 and 60.47 g/t/t respectively.

The mean yield of clones in summer during the third and fourth years of tapping (Table 2) ranged from 8.55 to 40.75 g/t/t while the drop in yield in summer during the two years ranged from 28.03 to 68.63

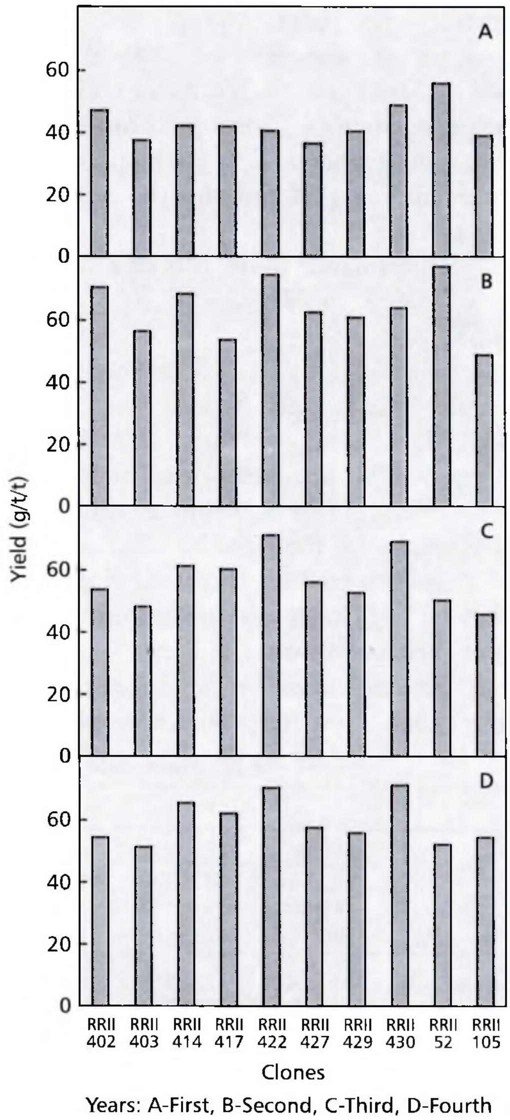

Fig. 1. Yield of promising *H. brasiliensis* clones over four years

per cent. The clones in general gave a mean summer yield of 19.81 and 23.14 g/t/t respectively with a yield drop of 59.12 and 55.01 per cent respectively in trials 1 and 2. Clone RRII 105 recorded a severe drop in yield of 64.61 and 59.51 percent in trials 1 and 2 respectively, during the summer months. Clones RRII 414, 429, 402 and 403 with 30.52 to 26.14 g/t/t in Trial 1 and RRII 52 and 422 with 40.75 and 37.46 g/t/t in Trial 2 exhibited high yield in summer. Of these, the drop in yield was low in clones RRII 52, 403, 402, 429, and 414, indicating their tolerance to summer stress.

Clones RRII 414, 52, 402 and 429 with high annual mean yield, high summer yield and low yield drop in summer are thus the relatively stable clones with less fluctuation in yield over seasons. Clone RRII 422 also had a high annual mean yield and maintained high yield in summer.

Figure 2 depicts the monthly trend in yield of the promising clones RRII 52, RRII 402, RRII 414, RRII 417, RRII 422,

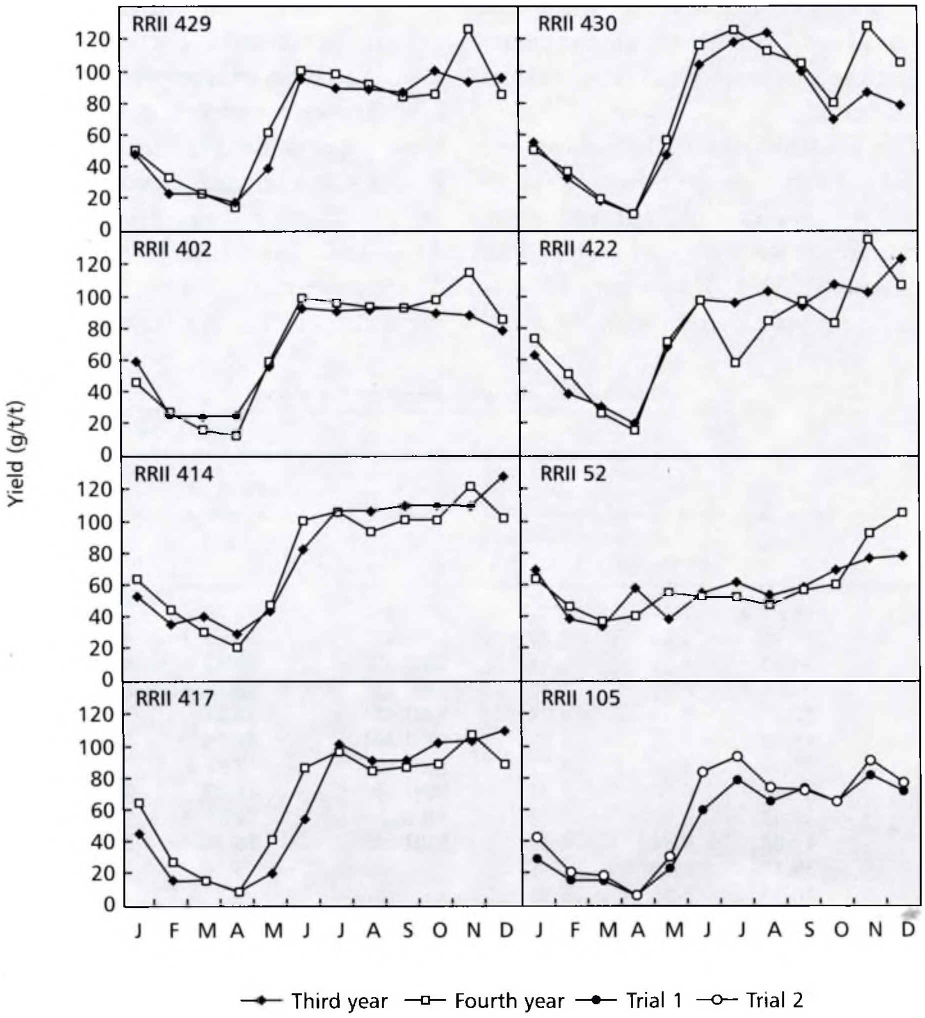

Fig. 2. Yield pattern of some promising clones during the third and fourth years of tapping

RRII 429, RRII 430 and RRII 105 during the third and fourth years of tapping. As indicated by the graphs, February-May was the lean period in the case of all the clones, with a sharp drop in yield in the month of April. It is well documented that this yield depression could be attributed to the stress imposed on the rubber tree due to the dry summer period coupled with refoliation. In general, yield was found to peak in the month of July and later attain a higher peak in the month of November with the clones varying in the extent of yield increase during these periods.

The monthly pattern in yield of the clones did not vary over the third and fourth years, except in the case of RRII 422 where minor variations were noticed in the peak season. Clone RRII 430 maintained a distinctly different yield pattern with the maximum yielding period extending from June to September in both the years. Clone RRII 52 maintained moderately high and stable yields in the stress and peak yielding periods in both the years. In the case of clone RRII 105, rubber yield peaked to the same levels during July and November in both Trial 1 and Trial 2. These observations indicate that the monthly yield pattern constitutes a clonal characteristic.

As shown in Table 3, among the growth parameters, there was significant clonal variation with respect to girth at opening. The extent of variation for girth increment rates in the pre-tapping and tapping phases was less, with clonal differences being significant only in Trial 1. Clones PB 330, RRII 430, 422, 414, 402, 417 and 52 were superior in terms of vigour at opening with girth ranging from 47.45 to 54.52

Table 3. **Growth parameters of the clones**

TRIAL 1				TRIAL 2			
Clone	Girth at opening (cm)	Girth increment rate (cm/year)		Clone	Girth at opening (cm)	Girth increment rate (cm/year)	
		At immaturity	Under tapping			At immaturity	Under tapping
RRII 402	48.61 #	7.57	4.55	RRII 410	44.38	7.50	4.62
RRII 403	39.91	6.69	5.10	RRII 422	51.80 #	8.72	2.89
RRII 407	43.23	6.59	5.86	RRII 427	47.33	8.77	2.97
RRII 414	50.76 #	8.38	4.42	RRII 430	54.26 #	8.08	2.41
RRII 417	47.45 #	7.19	4.24	RRII 434	38.14	7.02	5.04
RRII 429	44.23	7.07	3.71	RRII 454	44.04	7.48	3.59
RRII 446	35.91	5.56	5.17	RRII 52	47.81 #	7.84	4.13
RRII 449	37.88	6.70	5.04	RRII 53	41.09	8.38	4.41
RRII 453	39.45	6.90	3.82	PB 330	54.52 #	9.15	4.59
RRII 54	41.02	5.84	4.37	RRII 105	46.36	8.81	3.39
RRII 55	39.17	6.40	4.91				
RRII 105	38.35	6.58	5.58				
G.Mean	42.14	6.79	4.73	G.Mean	47.35	8.18	3.80
Variance Ratio	5.33**	2.05 *	2.50 *	Variance Ratio	5.70**	1.13 NS	1.33 NS
C.D.(P≤0.05)	5.80	1.46	1.19	C.D (P≤0.05)	6.83	—	—

Superior * Significant at P<0.05; ** Significant at P≤0.01; NS Non-significant

cm, while RRII 105 was poor in vigour in both the trials. The weighted 't' test revealed that, among the seven vigorous clones, RRII 414 was superior in girth to RRII 52 while the remaining six clones were comparable. Thirteen clones showed good growth in the pre-tapping phase with girth increment rates ranging from 7.02 to 9.15 cm/year. Clone PB 330 (9.15 cm/year) showed the most vigorous growth followed by RRII 414, 422, 427, 430 and 53. Of these, only RRII 414, 53 and PB 330 maintained good growth rate under tapping. Good growth under tapping is vital to the realization of sustained yield levels. The poor growth rate of clone RRII 105 under tapping was reported to be a possible reason for its declining yield trend in later years (Mydin *et al.*, 1994).

Precocity in rubber culture denotes early attainment of tappability. Normally, a rubber plantation is considered tappable when more than 50 per cent of the trees attain 50 cm girth at a height of 150 cm from the bud union. In India, this is usually achieved by the seventh or eighth year after planting. The practice of tapping trees on attainment of a girth of 45 cm is also widely prevalent in India and is the standard practice recommended in Malaysia and by the IRRDB (IRRDB, 1984).

Table 4 shows the tappability of clones in the sixth year after planting. The percentage of trees that attained a girth of 45 cm and 50 cm are examined separately. Clones RRII 430 and PB 330 showed precocity, the tappability in terms of 50 cm girth being 66.7 and 51.2 per cent respectively. Clones RRII 430, PB 330, RRII 422, 414 and 402 attained more than 50 per cent tappability in terms of 45 cm girth, which also indicates the precocity of these clones.

Clear bole volume is an indicator of the timber yield of a clone since the clear bole contributes 60 per cent of the timber recovered from a rubber tree (Najib *et al.*, 1995). A high branching nature along with high girth leads to a high bole volume. High branching is also favourable for future ex-

Table 4. **Tappability of the clones in the sixth year after planting**

TRIAL 1			TRIAL 2		
Clones	Percentage of trees that attained girth of		Clones	Percentage of trees that attained girth of	
	45cm	50 cm		45cm	50 cm
RRII 402	51.90 #	26.58	RRII 410	28.90	18.40
RRII 403	8.22	4.11	RRII 422	59.50 #	32.40
RRII 407	25.81	12.90	RRII 427	38.50	23.10
RRII 414	54.32 #	37.04	RRII 430	81.25 #	66.70 #
RRII 417	40.00	18.80	RRII 434	0.00	0.00
RRII 429	28.13	15.63	RRII 454	20.50	5.13
RRII 446	4.20	0.00	RRII 52	38.50	15.40
RRII 449	7.25	2.89	RRII 53	6.06	0.00
RRII 453	7.23	2.41	PB 330	69.80 #	51.20 #
RRII 54	20.90	7.41	RRII 105	32.40	18.90
RRII 55	12.16	2.70			
RRII 105	5.36	0.00			

Superior

ploitation of high panels of the virgin bark by modern tapping techniques.

Clonal variation for clear bole volume and height at forking (Table 5) was significant in both the trials. Ten year old trees in both the trials had mean clear bole volumes of 0.06 and 0.08 m^3/tree respectively. The clones superior in terms of clear bole volume were PB 330 and RRII 430 in Trial 2 (0.17 and 0.09 m^3/tree respectively) followed by RRII 414 (0.08 m^3/tree) in Trial 1. Clones RRII 402, RRII 417 and RRII 54 in Trial 1 and RRII 410, 422 and 52 in Trial 2 recorded bole volume of 0.07m^3/tree. As revealed by the weighted 't' test, clone RRII 414 with the highest bole volume in Trial 1 was statistically on par with clones PB 330, RRII 430, RRII 422 and RRII 52 in Trial 2. The mean height at forking was 3.06m in Trial 1 and 3.37 m in Trial 2. Clone PB 330 showed a distinctly high branching nature with a forking height of 5.66 m. Clone RRII 54 in Trial 1 had a forking height of 3.89 m which was the highest. Clones PB 330 and RRII 430 were superior to RRII 105 in terms of clear bole volume and PB 330, RRII 54, 417 and 449 showed a significantly higher branching habit than RRII 105.

Vigour in terms of tree girth is as important as the yield of rubber. Early opening and good early yield are only possible for a tree which grows very vigorously when young (Simmonds, 1989). An ideal rubber clone would be one which maintains both high rubber yield as well as vigorous growth so as to sustain a high yield trend for many years. An index incorporating yield and growth attributes would therefore be of value in the selection of superior clones. The overall performance of the clones in the two field trials over four years of tapping is shown in terms of performance indices (Table 6) computed on the basis of the six major variables.

Table 5. **Clear bole volume and forking height at the age of 10 years**

TRIAL 1			TRIAL 2		
Clones	Clear bole volume (m^3/tree)	Height at forking (m)	Clones	Clear bole volume (m^3/tree)	Height at forking (m)
RRII 402	0.07 #	3.02	RRII 410	0.07	3.09
RRII 403	0.05	2.73	RRII 422	0.07	3.23
RRII 407	0.06	2.78	RRII 427	0.06	2.78
RRII 414	0.08 #	3.20	RRII 430	0.09 #	3.87
RRII 417	0.07 #	3.43	RRII 434	0.05	2.90
RRII 429	0.05	2.68	RRII 454	0.06	3.01
RRII 446	0.05	3.11	RRII 52	0.07 #	3.25
RRII 449	0.06	3.35	RRII 53	0.05	2.88
RRII 453	0.04	2.79	PB 330	0.17 #	5.66 #
RRII 54	0.07	3.89 #	RRII 105	0.06	3.03
RRII 55	0.05	2.86			
RRII 105	0.06	2.92			
G. Mean	0.06	3.06	G. Mean	0.08	3.37
Variance Ratio	5.93**	7.13**	Variance Ratio	9.45**	5.70**
C.D.(0.05)	0.01	0.38	C.D.(0.05)	0.03	1.07

* Significant at P≤0.05; ** Significant at P≤0.01; # Superior

Table 6. **Performance indices of the clones**

TRIAL 1			TRIAL 2		
Clones	Performance index	Rank	Clones	Performance index	Rank
RRII 402	13.82	2	RRII 410	16.76	7
RRII 403	13.32	3	RRII 422	22.39	1
RRII 407	13.31	4	RRII 427	20.07	6
RRII 414	14.53	1	RRII 430	21.27	3
RRII 417	13.12	5	RRII 434	14.35	9
RRII 429	12.37	7	RRII 459	15.77	8
RRII 446	11.31	10	RRII 52	21.36	2
RRII 449	11.92	9	RRII 53	14.10	10
RRII 453	10.96	11	PB 330	20.24	4
RRII 54	10.49	12	RRII 105	20.21	5
RRII 55	12.32	8			
RRII 105	12.97	6			

The rankings show that clones RRII 414, RRII 402, RRII 403 and RRII 407 in Trial 1 and RRII 422, RRII 52, RRII 430 and PB 330 in Trial 2 performed better than RRII 105.

The efficiency of selection largely depends on the extent of genetic variability and heritability of the traits selected for. Generally yield in most economically important species has low heritability and direct selection for the trait is not sufficiently effective. Rubber is an exception. Rubber yield, as evidenced from the present study (Table 7) and as also reported earlier (Simmonds 1989; Mydin *et al.*, 1992; Licy *et al.*, 1993) is highly heritable. Broad sense heritability is of value in a clonally propagated species like rubber since the entire genetic variability is usable. It is a measure of the proportion of the phenotypic variance observed for rubber yield that is due to genetic effects and can be used to predict the actual gain achievable by selection. Heritability is thus a useful parameter for improving the efficiency of selection.

Table 7. **Improvement in yield from promising selections**

Clone	Mean yield over 4 years (g/t/t)	Response to selection: Rubber yield (g/t/t)	Response to selection: Improvement over RRII 105 (%)
RRII 422	61.16	11.48	23.25
RRII 430	61.09	11.43	23.14
RRII 52	54.08	4.58	9.28
RRII 414	56.68	13.32	32.95
RRII 402	53.04	10.34	25.58
RRII 417	53.03	10.32	25.53
RRII 427	50.28	0.88	1.78
RRII 429	49.42	7.37	18.22
RRII 403	46.02	4.71	11.65

H^2 (Trial 1) = 81.99% ; H^2 (Trial 2) = 97.42%

The response to selection for yield in the present study takes into account the proportion of variance attributable to genetic effects for yield of a particular clone in the respective trial. The actual yield that can be expected from each of the selected clones, worked out utilizing this estimate of selection response constitutes an unbiased means of comparison of clones across the two trials. The improvement in yield achievable over clone RRII 105, estimated using this approach, gives a better basis for identifying the clones in the population that meet/ cross the target of 20 per cent that is normally set in *H. brasiliensis* breeding programmes of India.

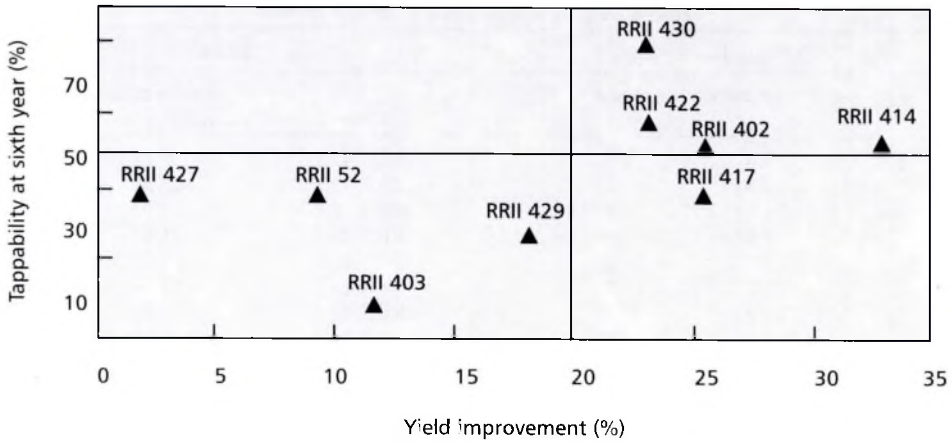

Fig. 3. Improvement in yield and early tappability

As shown in Table 7, among the clones with promising yield, RRII 414, RRII 402, RRII 417, RRII 422 and RRII 430 have shown, and are expected to maintain, more than 20 per cent improvement in yield over RRII 105, the most popular high yielding clone of India. The present results corroborate the significant improvement in the yield of these clones over RRII 105 reported from small scale evaluation (Licy *et al.,* 2003).

Clones RRII 430, RRII 422, RRII 414 and RRII 402 exhibited more than 20 per cent yield improvement coupled with more than 50 per cent tappability by the sixth year after planting (Fig. 3). These clones were ranked superior in terms of their overall performance also, thus proving their superiority in terms of precocity and high yield.

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