Natural Rubber Research, **24**(2): 211-219, 2011

FURTHER EVALUATION OF SELECTED WILD *HEVEA* GERMPLASM ACCESSIONS IN INDIA: 1. PERFORMANCE IN THE IMMATURE PHASE

G. Prabhakara Rao, Jayashree Madhavan and C.P. Reghu

Rubber Research Institute of India, Kottayam - 686 009, Kerala, India

Rao, G.P., Madhavan, J. and Reghu, C.P. (2011). Further evaluation of selected wild *Hevea* germplasm accessions in India: 1. Performance in the immature phase. *Natural Rubber Research*, **24**(2): 211-219.

A set of 22 potential wild *Hevea brasiliensis* accessions selected for juvenile yield, girth and number of laticifer rows on the basis of preliminary nursery studies, was evaluated along with three modern clones, *viz*. RRII 105, RRIM 600 and RRII 208, for their early performance in the first seven years of growth in a replicated trial planted in 2003 in the traditional rubber growing region of Kerala, India. Highly significant clonal differences were observed for juvenile yield, number of latex vessel rows and all other growth characters, except bole height. The accession AC 2629 had the highest juvenile yield of 7.7 g/t/t followed by AC 4149 (7.5 g/t/t) and AC 716 (5.1 g/t/t) respectively, while that of the controls ranged from 4.0 g/t/t in RRII 208 to 7.5 g/t/t in RRII 105. AC 2629 also had the highest girth, bole volume and bark thickness. The number of latex vessel rows of these three wild accessions ranged from 8.42 to 8.83, while in the controls it ranged from 7.56 (RRII 208) to 10.13 (RRII 105). However, the highest number of latex vessel rows was observed in MT 999 (12.9), the character for which it was originally selected from the nursery. Girth, bark thickness and number of latex vessel rows were also high in AC 626, which had originally been selected on the basis of girth in the nursery. The accessions were ranked for overall performance using seven parameters. AC 2629 and AC 4149 ranked first and second respectively with the maximum number of desirable traits. Correlations worked out between the eight quantitative traits revealed that yield was significantly correlated with girth, bark thickness and number of latex vessel rows.

Keywords: Correlations, Crop improvement, *Hevea brasiliensis,* Rank sum, Wild germplasm

INTRODUCTION

Natural rubber (*Hevea brasiliensis* Muell. Arg.), with its centre of origin in the Amazon rainforests of Brazil, is a strategic industrial crop cultivated mainly in the South East Asian countries. In view of the narrow genetic base of cultivated rubber in this region (Wycherly, 1969), a huge collection of wild *Hevea* germplasm was made by the IRRDB (Ong *et al.,* 1983) during 1981 from three states in Brazil, *viz.* Acre (AC), Rondonia (RO) and Mato Grosso (MT), and distributed to member countries including India. Around 4500 accessions are being conserved in source bush nurseries in India, and are under different stages of evaluation. Preliminary nursery studies in some of these accessions showed indications of promising yield and other yield contributing secondary traits. This has to be confirmed by carrying out further detailed evaluation in various field trials. One such set of wild accessions, selected for juvenile yield, girth and number

Correspondance: G. Prabhakara Rao (Email: raogprao@gmail.com)

of latex vessel rows on the basis of preliminary information from the conservation nurseries, was planted in a field trial for further evaluation. The present study was undertaken to evaluate their performance in the early growth phase, to ascertain the extent of genetic variability in this population and to understand the association among different traits.

MATERIALS AND METHODS

The study was conducted at the Central Experiment Station of the Rubber Research Institute of India, Chethackal, Kerala, India. Twenty two accessions selected based on juvenile yield, girth and number of latex vessel rows from the conservation nurseries and three controls, *viz*. RRII 105, RRII 208 and RRIM 600, were planted for further evaluation in a field trial in simple lattice design during 2003 with four replications. The spacing adopted was 4.9 x 4.9 m with four plants per plot and the recommended cultural practices of Rubber Board were followed. Among the 22 wild accessions, five were from Acre, eleven from Mato Grosso and six from Rondonia.

Data on girth (cm) was recorded annually at 150 cm height from the fifth year onwards. In the fifth year, test tapping was carried out in S/2 d3 system at a height of 30 cm, for two months. The average yield of the last 10 tappings of each tree was expressed as gram per tree per tap (g/t/t). Bark samples were collected simultaneously to assess bark thickness (mm) and number of latex vessel rows (NLVR). In the seventh year after planting, bole height (m) was measured as the distance from the bud union to the first branching level. The clear bole volume was estimated from the data on girth and bole height by quarter girth method (Chaturvedi and Khanna, 1982). The average girth increment (cm) per year over two years was calculated using the girth data of fifth and seventh years. The data were subjected to analysis of variance for lattice design (Gomez and Gomez, 1984). Genetic components of variation were estimated as per Singh and Choudhary (1985). Simple correlations between yield and various growth parameters were computed following the method of Panse and Sukhatme (1978). Overall performance of all these genotypes was assessed by rank sum method (Kang, 1988) using all the traits except girth in the fifth year.

RESULTS AND DISCUSSION

The mean values of the accessions for each of the eight traits in the early growth phase are given in Table 1, while the range and population mean values in comparison with the three control clones are presented in Table 2. The genotypes exhibited highly significant clonal differences (P = 0.01) for all the quantitative traits studied except bole height (NS) and bark thickness (P = 0.05). The test tap yield ranged from 0.18 (AC 605) to 7.68 g/t/t (RO 2629) with a general mean of 2.30 g/t/t. Among the wild accessions, RO 2629 was the highest yielder followed by AC 4149 (7.47 g/t/t), and AC 716 (5.02 g/t/t), whereas the control clones RRII 105, RRII 208 and RRIM 600 recorded 7.49, 4.01 and 4.36 g/t/t, respectively.

Girth and number of latex vessel rows are two important structural traits contributing to yield (Gomez, 1982; Hu, 2005; Zeng *et al*., 2005). Latex vessels are present in concentric rings in the bark of the tree. Bark thickness ranged from 2.70 (MT 196) to 5.16 mm (RO 2629) in the wild accessions, while it ranged from 3.38 (RRII 208) to 4.19 mm (RRII 105) in the check clones. The highest number of latex vessel rows was displayed by MT 999 (12.94), compared to the check clone RRII 105 (10.13). The number of latex vessel rows of four wild accessions AC 4149, RO 2629, AC 716 and AC 626, was relatively high, ranging from 8.21 to 8.81, compared to RRIM 600 (8.56) and RRII 208 (7.56). Varghese *et al*. (1989), Mercy *et al*. (1995), Rao *et al*. (1999) and Abraham *et al*. (2002) have also reported wide variation in the wild germplasm with respect to growth and yield in traditional rubber growing region in India.

Table 1. **Performance of wild germplasm accessions in the early growth phase**

Accession	Girth -5th year** (cm)	Girth -7th year** (cm)	GI** (cm/year)	Bole height (m)	Bole volume** (m^3)	Bark thickness (mm)	NLVR**	Yield** (g/t/t)
AC 4149	35.09	43.25	4.08	2.51	0.029	4.90	8.83	7.47
MT 3930	28.55	36.29	3.87	2.36	0.020	4.16	7.54	1.10
RO 2629	36.50	47.75	5.63	2.89	0.041	5.16	8.81	7.68
RO 3624	27.13	37.38	5.13	2.30	0.021	3.88	7.38	1.31
RO 3804	19.70	30.44	5.37	2.19	0.013	3.24	6.50	1.52
MT 1707	30.58	36.77	3.09	2.64	0.023	4.49	6.90	0.79
MT 1012	28.33	35.44	3.55	2.47	0.020	3.66	7.96	1.76
MT 2233	30.75	38.25	3.75	3.07	0.028	3.69	6.88	1.51
RO 1739	24.20	32.21	4.01	2.42	0.016	3.83	7.00	0.51
MT 1057	26.73	36.71	4.99	2.29	0.019	4.02	6.79	0.67
MT 4435	24.18	29.81	2.82	2.53	0.015	3.86	6.79	1.43
RRII 208	27.81	32.69	2.44	2.18	0.015	3.38	7.56	4.01
MT 4529	22.16	26.23	2.04	2.44	0.011	3.72	6.06	1.08
RRII 105	29.31	36.19	3.44	2.46	0.021	4.19	10.13	7.49
RRIM 600	28.38	34.25	2.94	2.91	0.022	3.77	8.56	4.36
AC 626	29.92	42.79	6.44	2.49	0.029	4.17	8.21	1.22
MT 999	29.20	35.25	3.03	2.34	0.019	3.60	12.94	1.49
AC 716	24.76	33.08	4.16	2.57	0.018	3.91	8.42	5.02
MT 1002	25.84	32.19	3.17	2.60	0.018	3.80	6.11	0.89
MT 1009	24.40	33.15	4.38	2.30	0.016	3.37	5.83	1.38
AC 163	23.03	34.56	5.77	2.36	0.021	4.29	7.33	1.42
AC 605	22.43	31.27	4.42	2.44	0.015	3.22	7.08	0.18
MT 196	25.74	30.81	2.54	2.83	0.017	2.70	5.44	1.50
RO 297	27.59	36.38	4.39	2.72	0.023	3.23	6.38	1.17
RO 287	19.65	26.85	3.60	2.41	0.011	3.79	5.10	0.56
CD (P=0.05)	5.70	6.23	1.37	NS	0.014	1.11	2.51	2.09

** Significant at P=0.01

Table 2. **Variability for yield and growth-related characters in wild *Hevea* germplasm**

Character	Wild accessions			Control clones		
	Minimum	Maximum	General mean	RRII 105	RRII 208	RRIM 600
Yield (g/t/t)	0.18 (AC 605)	7.68 (RO 2629)	2.30	7.49	4.01	4.36
Bark thickness (mm)	2.70 (MT 196)	5.16 (RO 2629)	3.84	4.19	3.38	3.77
NLVR	5.10 (RO 287)	12.94 (MT 999)	7.46	10.13	7.56	8.56
Girth - 5th year after planting (cm)	19.65 (RO 287)	36.50 (RO 2629)	26.88	29.31	27.81	28.38
Girth - 7th year after planting (cm)	26.23 (MT 4529)	47.75 (RO 2629)	34.80	36.19	32.69	34.25
Girth increment over 2 years (cm/year)	2.82 (MT 4435)	6.44 (AC 626)	3.96	3.44	2.44	2. 49
Bole height (m)	2.19 (RO 3804)	3.07 (MT 2233)	2.51	2.46	2.18	2.91
Bole volume (m^3)	0.011(MT 4529, RO 287)	0.041 (RO 2629)	0.02	0.021	0.015	0.022

In general, yield and vigour in *H. brasiliensis* are hardly separable (Simmonds, 1989). Girth of the trees at the age of five years ranged from 19.65 to 36.50 cm. RO 2629 had the highest girth (36.50 cm) followed by AC 4149 (35.09 cm), MT 2233 (30.75 cm), MT 1707 (30.58 cm) and AC 626 (29.92 cm). The girth of the control clones ranged from 27.81 (RRII 208) to 29.31 cm (RRII 105). Girth increment per year, showed significant clonal differences with AC 626 recording the highest growth rate (6.44 cm/year), which was higher than that of RO 2629 (5.63 cm/year). Consequently, girth recorded in the seventh year showed a slightly altered trend, with AC 626 recording the next highest girth (42.79 cm) after RO 2629 (47.75 cm) and AC 4149 (43.25 cm).

A higher bole height is desirable as it increases the clear bole volume, and hence the timber potential of a tree. Bole height ranged from 2.19 (RO 3804) to 3.07 m (MT 2233), and the clonal differences were not statistically significant. Branching habit in rubber tree is a clonal character and many clones were found to branch at higher levels in the plantations of Malaysia (MRB, 2003). Azwar *et al*. (1995) and Rao *et al*. (1999; 2006) have reported the tendency of wild *Hevea* germplasm to branch at a higher level than the Wickham clones. However, significant clonal differences were observed for clear bole volume, which ranged from 0.011 (MT 4529 and RO 287) to 0.041 m^3 (RO 2629). The accessions RO 2629 (0.041 m^3), AC 4149 (0.029 m^3), AC 626 (0.029 m^3), MT 2233 (0.028 m^3) and MT 1707 (0.023 m^3) recorded the highest timber volume while control clones RRII 105, RRII 208 and RRIM 600 recorded 0.021 m^3, 0.015 m^3 and 0.022 m^3, respectively.

Components of variation and broad sense heritability were estimated in the population (Table 3). Very high phenotypic coefficient of variation (PCV) was observed for yield (118.22) and bole volume (57.99), whereas it ranged from medium to low for the remaining traits. The high variation in yield (Table 2) was reflected in the high PCV values. Very high PCV (153.58%) was also

Table 3. **Phenotypic and genotypic coefficients of variation and heritability for quantitative characters**

Character	PCV	GCV	Heritability (H^2)
Yield	118.22	99.00	0.70
Bark thickness	23.89	11.05	0.21
NLVR	33.42	22.72	0.46
Girth	20.37	13.81	0.46
Girth increment	33.13	22.44	0.46
Bole height	16.60	4.64	0.078
Bole volume	57.99	25.93	0.20

reported by Abraham *et al*., (1992) in another set of wild *Hevea* germplasm. Very low variability was recorded for bole height (16.60). The genotypic coefficient of variation (GCV) was also high for yield (99.00) and bole volume (25.93). The wide difference between PCV and GCV estimates for traits like bole height and bole volume indicate the greater role of environment in the expression of these traits. This was also reflected in the heritability (broad sense) values. Yield showed the highest heritability (70%), followed by NLVR, girth and girth increment (46% each). Heritability of bole height was very low (8%). Earlier studies also reported that broad sense heritability for yield in rubber is high (Simmonds, 1989). Rao *et al*. (1999) and Abraham *et al*. (2002) have reported moderate to high H^2 in the wild germplasm with respect to growth parameters like girth, branching height and bark thickness.

Simple correlation coefficients between pairs of different characters are presented in Table 4. Yield was significantly and positively correlated with girth of the same year (5th year) (0.604), bark thickness (0.533) and NLVR (0.504). Similar trend was observed in the seventh year also. It did not show any significant relationship with crotch height. Earlier studies by Narayanan *et al*. (1973), Ho (1976), Hamazah and Gomez (1982), Madhavan *et al*. (1996), Rao and Reghu (2000) and Zeng *et al*. (2005) also reported positive correlations between yield and girth, NLVR and bark thickness. The

Table 4. **Correlation coefficients among the quantitative characters**

Character	Character						
	Bark thickness	No of laticifer rows	Girth (5th year)	Girth (7th year)	Girth increment	Bole height	Bole volume
Yield	0.533 **	0.504 *	0.604 **	0.521 **	0.022	0.241	0.549 **
Bark thickness		0.352	0.613 **	0.672 **	0.333	0.119	0.672 **
NLVR			0.526 **	0.461 *	0.036	-0.029	0.398 *
Girth in 5th year after planting				0.888 **	0.093	0.457 *	0.873 **
Girth in 7th year after planting					0.541 **	0.316	0.954 **
Girth increment						-0.151	0.467 *
Bole height							0.545 **

*, ** Significant at P=0.05 and P=0.01 levels, respectively

high correlation observed here between yield and bole volume (0.549) was probably due to the correlation of both traits with girth. Bark thickness was also positively correlated with girth (0.613) but did not show any relationship with NLVR. Rao and Reghu (2000) also did not find any correlation between bark thickness and number of laticifer rows, though other studies have found these traits to be positively correlated (Hamzah and Gomez, 1982; Madhavan *et al*., 1996). High correlation between bark thickness and girth was also reported earlier in *Hevea* by Momoh and Alika (1987), Licy and Premakumari (1988) and Madhavan *et al*. (1996). NLVR and girth in the present study were also positively correlated (0.526). There was no correlation between bole height and girth in the seventh year, though a relatively weak correlation was observed with girth in the fifth year (0.457). Bole volume was more strongly correlated with girth (0.954) than with bole height (0.545).

In order to identify accessions with maximum number of desirable attributes, the performance of the accessions for each character was pooled using rank sum method (Table 5). Girth in the seventh year only was included for the calculation. RO 2629, AC 4149 and AC 626 were the top ranking accessions with maximum number of desirable traits. Since they have a different genetic background from the existing cultivated clones, their use in hybridization programmes is more likely to yield heterotic recombinants. AC 716, ranked fifth among the wild accessions for overall performance, had the third highest yield on par with two controls RRIM 600 and RRII 208, and very high NLVR. AC 626, which was ranked third for overall performance, had relatively low yield in spite of recording the highest growth rate, and high values for structural traits contributing to yield *viz*. girth and NLVR. Similarly, MT 999 which had the highest NLVR and moderate girth, had a relatively low yield. This accession could be used to increase the NLVR in elite clones for ultimately increasing productivity. MT 2233

Table 5. **Ranking of wild accessions and clones based on yield and growth parameters**

Accessions	Rank sum	Rank
RO 2629	168	1
AC 4149	149	2
AC 626	133	3
RRII 105	129	4
MT 2233	118	5
RRIM 600	118	5
AC 716	113	7
MT 1707	109	8
AC 163	102	9
MT 1012	100	10
RO 3624	97	11
MT 3930	96	12
RO 297	91	13
MT 999	90	14
MT 1057	78	15
MT 1002	72	16
MT 4435	69	17
RO 1739	67	18
RRII 208	66	19
MT 196	63	20
RO 3804	58	21
MT 1009	56	22
AC 605	56	22
RO 287	39	24
MT 4529	37	25
General mean	90.96	

stimulation (Table 2). The results indicate that if the clone RRII 105 is to be tapped under alternate daily frequency, it is ideal to go for S/3 d2 with three rounds of ethephon.

Experiment 3

In clone PB 235, the mean yield of five years tapping from d3, d4 and d6 frequencies with 3, 4 and 7 annual stimulations, respectively is presented in Table 3. Annual yield per hectare observed in d3 and d4 frequencies were at par. The low yield in d6 might be due to insufficient rounds of ethephon application per year. At least one application per month may be required for the clone PB 235 (as in traditional region for clone RRII 105). The highest yield per tree per tapping (g/t/t) was observed in T3 with seven annual stimulations in d6 system of tapping (80.5g). In the case of d3 frequency of tapping, mean yield per tapping was 60.6 g/t/t. Seasonal variation in yield was noticed for all the systems of tapping. Yield was seen to be low during the summer months and high during the early winter months (Fig. 1) with a declining trend during January as reported earlier (Dey, 2003).

Experiment 4

In this experiment, the treatment T2 with annual panel change, after two years of opening of the tree, showed higher yield over T1 without panel change (Table 4). Higher yield was observed in T2 for all the three clones, *viz*. RRIM 600, PB 235 and GT 1. Panel changing is generally considered useful reducing the physiological stress generated in the panel by tapping. There was also a reduction in TPD percentage in the treatment with panel change (Table 5). Lacote *et al.* (2004) reported that biennial panel change (three panel changes over nine years) resulted best level of cumulative yield.

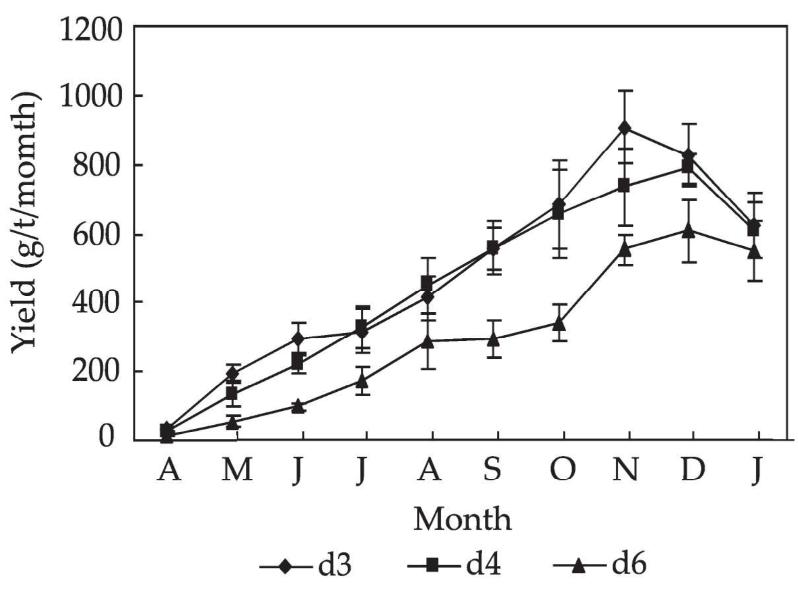

Fig. 1. Mean (four years) monthly yield per tree under different tapping and stimulation frequenceies in Clone PB 235

Table 3. **Average (five years) yield (BO-I panel), TPD and girth increment of clone PB 235 under LFT**

Treatment	Tapping days	Yield g/t/t	Yield kg/ha	TPD (%)	Annual girth increment (cm)
T1- S/2 d3 6d/7.ET 2.5% Pa 3/y	77	60.6	1309	3	4.53
T2- S/2 d4 6d/7.ET 2.5% Pa 4/y	52	79.2	1257	1.6	4.49
T3– S/2 d6 6d/7.ET 2.5% Pa 7/y	34	80.5	844	1.6	5.33
CD (P=0.05)		9.6	130		

It was observed that S/3 DCA (T3) had higher yield over S/4 DCA (T4) system in all the clones. Among the clones, PB 235 showed the highest yield compared to RRIM 600 and GT 1. The highest TPD was observed in PB 235 under S/2 d2 system of tapping followed by S/3 DCA (Table 5). Chantuma and Gohet (2005) reported that DCA system has increased production (25-30%) in Thailand and this system is suitable in newly opened plantation during initial three years of tapping. But, in the present experiment, during the first five years, production is at par under DCA and conventional systems. In general there is not much reduction in TPD and no growth advantage. After the initial five years panel management was very difficult due to exhaustion of virgin bark and immaturity of

Table 4. **Average (five years) yield (BO-1 and BO-2 panel) of three clones under different system of tapping with stimulation**

Clone	Treatment		Yield g/t/t	Yield kg/ha
RRIM 600	T1 - S/2 d2 6d/7		33.8	1265
	T2 - S/2 d2 6d/7	S/2 d2 (y,y) 6d/7	35.1	1310
	T3 - S/2 d2 6d/7	S/3 d2 (t,t) 6d/7	34.3	1283
	T4 - S/2 d2 6d/7	S/4 d2 (t,t) 6d/7	33.6	1257
	CD (P=0.05)		NS	NS
PB 235	T1- S/2 d2 6d/7		44.7	1668
	T2 - S/2 d2 6d/7	S/2 d2 (y,y) 6d/7	45.4	1695
	T3 - S/2 d2 6d/7	S/3 d2 (t,t) 6d/7	46.9	1752
	T4 - S/2 d2 6d/7	S/4 d2 (t,t) 6d/7	42.9	1605
	CD (P=0.05)		NS	NS
GT 1	T1- S/2 d2 6d/7		33.0	1233
	T2 - S/2 d2 6d/7	S/2 d2 (y,y) 6d/7	37.1	1388
	T3 - S/2 d2 6d/7	S/3 d2 (t,t) 6d/7	31.0	1159
	T4 - S/2 d2 6d/7	S/4 d2 (t,t) 6d/7	28.7	1073
	CD (P=0.05)		7.5	282

renewed bark for further tapping and hence the experiment was discontinued.

Experiment 5

Yield in CUT was higher (2163 kg/ha) than S/2 d2 system (1091 kg/ha) of downward tapping in BI-1 panel (Table 6). Difference in DRC was not observed. Downward tapping on first renewed bark was less productive than upward tapping on virgin bark of high panel. Bark consumption was slightly higher under CUT which is influenced by tapping skill. Obouayeba *et al.* (2008) reported that upward tapping on virgin bark has increased the productivity of rubber tree compared to downward tapping on renewed bark.

Tree growth under different systems of tapping

Girth increments among the different systems in the experiments were comparable. The degree of this relationship varied with the clones.

Tapping panel dryness

In all experiments, high percentage of TPD was observed in high yielding clones, with high frequency of tapping. In general, complete TPD was four per cent in BO-1 panel in this region, and the dryness increased in the subsequent panels (Dey, 2006). Resting or changing the panel to the opposite side is only a temporary way to manage TPD-affected trees. However, adoption of frequencies like d3 from opening onwards can restrict TPD to a very low level.

Tapping intensity and stimulation

Increasing productivity by proper latex harvesting methods is one of the approaches for reducing the cost of production in natural rubber. Ethephon is widely used as the effective yield stimulant in rubber

Table 5. **TPD, girth and girth increment of three clones under different system of tapping**

Clone	Treatment		TPD (%)	Girth (April 2009) (cm)	Girth increment/ year (cm)
RRIM 600	T1 - S/2 d2 6d/7		6.6	68.9	3.30
	T2 - S/2 d2 6d/7	S/2 d2 (y,y) 6d/7	3.3	67.9	3.56
	T3 - S/2 d2 6d/7	S/3 d2 (t,t) 6d/7	10.0	67.8	3.25
	T4 - S/2 d2 6d/7	S/4 d2 (t,t) 6d/7	6.6	70.0	3.54
PB 235	T1 - S/2 d2 6d/7		14.2	73.2	3.62
	T2 - S/2 d2 6d/7	S/2 d2 (y,y) 6d/7	7.1	74.4	4.04
	T3 - S/2 d2 6d/7	S/3 d2 (t,t) 6d/7	7.1	67.5	3.26
	T4 - S/2 d2 6d/7	S/4 d2 (t,t) 6d/7	7.1	70.6	3.52
GT 1	T1 - S/2 d2 6d/7		0	69.0	4.30
	T2 - S/2 d2 6d/7	S/2 d2 (y,y) 6d/7	0	72.2	4.11
	T3 - S/2 d2 6d/7	S/3 d2 (t,t) 6d/7	10	65.2	3.91
	T4 - S/2 d2 6d/7	S/4 d2 (t,t) 6d/7	0	66.2	4.06

Table 6. **Average yield (two years), average annual DRC and girth (2009) of clone RRIM 600 under controlled upward tapping**

Treatment	Tapping days	Yield		DRC	Girth
		g/t/t	kg/ha	(%)	(cm)
CUT (HO-1)	140	43.7	2163	34.5	87.1
Control (BI-1)	140	24.2	1091	35.6	86.7

plantations. Yield stimulation offers opportunities for reducing number of tappings and length of tapping cut resulting in labour savings and improved land productivity. Fewer number of stimulations is recommended at higher tapping intensities. Results in the traditional region have shown favourable response of rubber clones to less labour input tapping systems with different frequencies of ethephon stimulation (Rajagopal *et al*., 2000). In general, when lesser number of latex vessels are severed during tapping, a higher level (round) of ethephon application and *vice versa* is required without changing the tapping frequency. Similarly, low frequency of tapping requires higher number of stimulation of same concentration and *vice versa*.

Low frequency tapping

Non-availability of skilled tappers and attempts to reduce cost of production have led to the introduction of low frequency tapping (LFT) systems such as four-day interval of tapping (d4) and weekly (d6) with appropriate yield stimulation. Stimulation schedules for d4 frequency of tapping have been reported for high yielding clones (Gohet *et al.,* 1991; Vijayakumar *et al.,* 2001). However, yield reduction was reported under d6 frequency of tapping (Gohet *et al.,* 1991; Sivakumaran *et al.,* 1993). High yields from d4 and d6 frequencies of tapping with stimulation from long-term experiments have been reported in clone RRII 105 in traditional region. Initial two years yield reduction under d6 can be overcome by higher frequency (fortnightly) of stimulation in clone RRII 105 (Karunaichamy *et al.,* 2001). Lower yield in the present study under weekly tapping in clone PB 235 may be due to insufficient number of stimulation per year.

Low intensity tapping systems are not sustainable without yield stimulation (Lee, 1989). For the clones RRIM 600 and RRII 105, Chaudhuri *et al.* (2005) and Dey *et al.* (2005) advocated five stimulations (ET 2.5% Pa) per year and two months rest for obtaining reasonable yield in half-spiral under d3 system of tapping compared to that of the d2 system of tapping in NE region. Higher yield in shorter cuts of the d2 system with stimulation is due to the easy flow of latex and efficient regeneration mechanism induced by it. There is a need for stimulation for improving flow by breaking the flow restricting mechanisms and activating the metabolism of the tree (Nair *et al*., 2004). The production potential of RRII 105, with its high metabolic activity (Dey *et al*., 1995) and low sugar reserve, limits its ability to respond to hormonal stimulation (Nair *et al*., 2004) under d3 frequency tapping. Therefore, judicious selection of stimulation frequency depending on the clone and tapping frequency is very important for obtaining sustainable yield.

Reduced spiral tapping cut

In general, an average of 10 to 11 years of tapping is possible on virgin basal panels (BO-1 and BO-2) under S/2 d2 system of tapping with two months rest in NE region. The number of tapping years could be increased under reduced spiral cut in d2 system of tapping, *i.e*. it can be increased up to 15 in S/3 and 20 years in S/4. Growth of trees under short spiral cut was also higher compared to control. Relative tapping intensity, which denotes the percentage of intensity (100%) of standard system (S/2 d2) was also low with 50 and 67% for the S/4 and S/3 respectively under the same frequency of tapping. Adoption of reduced spiral cuts had been advocated by Thomas *et al.* (2003) for the traditional region. Shorter tapping cuts of S/4 and S/3 under d2 frequency with stimulation is recommended for marginal farmers in Indonesia (Kuswanhadi and Junaidi, 1986). This approach could reduce the cost of tapping through increasing tapping task. Sustainable yield could be obtained for longer years due to increase of economic life of the tree. Tapping of shorter lengths could maximize physiological efficiency with minimum injury to the laticiferous system without affecting the health of the tree.

In smallholdings, only downward tapping is practised during the first 10 to 11 years on virgin panel followed by tapping on the renewed bark. The bark consumption is high due to poor tapping skill. The numbers of tappable trees are also reduced in subsequent years due to wind damage and TPD. As a result, in smallholdings productive period of rubber trees is shorter.

There is no one single exploitation system that will give the best result on all cultivars and under all conditions (RRIM, 1980). The studies showed that different system of tapping can be implemented in NE region depending on age of tree and availability of tapper *etc*. as per management plan. TPD incidence is high in alternate daily tapping compared to other systems. The study showed that comparable yield can be obtained by third daily tapping with three to five stimulations per year (depending on clones) as that under d2 frequency of tapping.

Since labour shortage is not experienced at present in this region, the high intensive tapping like S/2 d2 system is being practised though with adverse effects. In this system, the annual bark consumption is very high and quality of tapping is poor. Drastic change in the frequency may not be very easy due to socio-economic reasons. Hence, adopting S/3 d2 with appropriate stimulant application as evidenced from the experiment may be an option. Since S/2 d3 system with ethephon application (at five times per year) and two months rest can result in better yield and higher tapper productivity at lesser cost, it appears to be another reasonable option for this region. Since indiscriminate application of stimulation may lead to high TPD, before adoption of system with stimulation, awareness among the growers need to be created on necessity of judicious application of yield stimulant. CUT system needs to be popularized in this region to enhance production and productivity of old plantations.

REFERENCES

Alam, B., Das, G., Raj, S., Roy, S., Pal, T. K. and Dey, S. K. (2003). Studies on yield and biochemical sub-components of latex of rubber trees (*Hevea brasiliensis*) with a special reference to the impact of low temperature in non-optional environment. *Journal of Rubber Research*, **6** (4): 241-257.

Chaudhuri, D., Singh, R.P., Gohain, T., Mandal, D., Thomas, K.U. and Vijayakumar, K.R. (2005). Response of clone RRIM 600 to different exploitation systems with stimulation and tapping rest in agro climatic conditions of Assam. *Preprints of Papers. International Natural Rubber Conference*, 6-8 November 2005, Cochin, India, pp. 333-337.

Chantuma, P. and Gohet, E. (2005). New tapping system: An optimal rubber farmers plantation in Thailand. *Preprints, International Natural Rubber Conference*, 6-8 November 2005, Kottayam, India, pp. 303-304.

Das, G., Raj, S., Dey, S.K. and Chaudhuri, D. (2008). Low winter temperature rest based tapping system for Tripura and North Bengal. *Natural Rubber Research*, **21**(1&2):84-91.

Dey, S. K. (2003). Sink source relationship in rubber (*Hevea brasiliensis*) in different months in the North East Indian climatic conditions. *Indian Journal of Plant Physiology,* (Special Issue) Part 1, 74-80.

Dey, S.K. (2006). Incidence of tapping panel dryness in *Hevea brasiliensis* trees in Tripura. In: *Tapping Panel Dryness of Rubber Trees* (Eds. James Jacob, R. Krishnakumar and N.M. Mathew), Rubber Research Institute of India, Kottayam, India, pp.74-78.

Dey, S. K., Singh, R. S., Satisha, G. C. and Pal, T. K. (2004). Performance of *Hevea brasiliensis* clones in Mizoram. *Natural Rubber Research*, **17**(1): 41-46.

Dey, S. K., Thomas, M., Sathik, M. B. M., Vijayakumar, K.R., Jacob, J. and Sethuraj, M.R. (1995). Physiological and biochemical regulation of yield in clones of *Hevea brasiliensis. Proceedings of IRRDB Symposium on Physiological and Molecular Aspects of the Breeding of* Hevea brasiliensis. 6–7 November 1995, Penang, Malaysia, IRRDB Rickendonbury, Hertford, England. pp 168-174.

Dey. S.K., Vijayakumar, K.R. and Thomas, K. U. (2005). Response of rubber tree (*Hevea brasiliensis*, Clone RRII 105) to different exploitation systems with stimulation and tapping rest in climatic conditions of Tripura. *Preprints, International Natural Rubber Conference*, 6-8 November 2005, Rubber Research Institute of India, Kottayam, India, pp. 323-326.

Gohet, E., Lacrotte, R., Obuayba,. S. and Commere, J. (1991). Tapping systems recommended in West Africa. *Proceedings of the Rubber Research Institute of Malaysia Rubber Growers' Conference*, 1991, Kuala Lumpur, Malaysia, pp. 235-254.

Karunaichamy, K., Vijayakumar, K.R., Thomas, K.U., Rajagopal, R. and Anilkumar, D. (2001). Response of rubber trees (*Hevea brasiliensis* Muell. Arg., clone RRII 105) to low frequency tapping (LFT) systems. *Indian Journal of Natural Rubber Research,* **14**(2): 79-87.

Kuswanhadi, T. and Junaidi, U. (1986). Low intensity tapping systems to lengthen rubber production period. *Laporan Penelitian*, **2**(3): 15-20.

Lacote, R., Obouayeba, S., Clement-Demange, A. Dian, K. Gnagne, M. and Gohet, E. (2004). Panel management in rubber (*Hevea brasiliensis)* tapping and impact on yield, growth and latex diagnosis. *Journal of Rubber Research,* **7**(3): 199-217.

Lee, C. K. (1989). Low intensity tapping system. In: *Training Manual on Tapping, Tapping Systems and Yield Stimulation of* Hevea (Ed. A.H. Yusoff). Rubber Research Institute of Malaysia, Kuala Lumpur, Malaysia, pp. 178-195.

Nair, N.U., Nair, R., Thomas, M. and Gopalakrishnan, J. (2004). Latex diagnosis in relation to exploitation systems in clone RRII 105. *Journal of Rubber Research,* **7**(2): 127-137.

Obouayeba, S., Soumahin, E.F., Boko, A.M.C., Dea, G.B., Dian, K. and Gnagne, Y.M. (2008). Improvement of productivity of rubber trees in smallholding by introduction of upward tapping in the South-East of Cote d' Ivoire. *Journal of Rubber Research*, **11**(3): 163-170.

Rajagopal, R., Vijayakumar, K.R., Thomas, K.U. and Karunaichamy, K. (2004). Effect of judicious ethephon application on yield response of *Hevea brasiliensis* (clone RRII 105) under 1/2 S d/3 6d/7 tapping system. *Journal of Rubber Research*, **7**(2): 138-147.

Rajagopal, R., Vijayakumar, K.R. and Thomas, K.U. (2000). Comparative effectiveness of different stimulation methods on yield performance of *Hevea brasiliensis*. In: *Plantation Crops Research and Development in the New Millennium.* (*PLACROSYM XIV*), (Eds. P. Rethinam, N.H. Khan, V.M. Reddy, P.K. Mandal and K. Suresh). Coconut Development Board, Cochin, India, pp. 420-423.

RRIM (1980). *Training Manual on Tapping. Tapping Systems and Yield Stimulation of* Hevea. Rubber Research Institute of Malaysia. p.130.

Sivakumaran, S., Nayagam, J., Chong, K. and Yong, H. W. (1993). Economics of tapping rubber trees once a week. *Planters' Bulletin*, **224:**17-25.

Thomas, K.U., Vijayakumar, K. R., Rajagopal, R. and Karunaichamy, K. (2003). Crop harvesting through mini and reduced spiral tapping cuts in *Hevea brasiliensis. Proceedings of the International Workshop on Exploitation Technology,* 15-18 December 2004, Kottayam, India, pp. 72-82.

Vijayakumar, K.R., Thomas, K.U., Rajagopal, R. and Karunaichamy, K. (2001). Low frequency tapping systems for reduction in cost of production of natural rubber. *Planters' Chronicle*, **97**(11): 451-454.