EVALUATION OF HALF-SIB PROGENIES UNDER TWO DIFFERENT AGRO-CLIMATIC REGIONS

Thomson Abraham, Ajithkumar E., and Kavitha K. Mydin

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

Abstract

Clonal nursery evaluation has emerged as a useful technique to reduce the time span of breeding in Hevea. This paper reports the performance of half-sib progenies from eight parental clones under clonal nursery trials in two different agro-climatic regions namely Padiyoor in North Kerala having dry sub humid conditions and Chethackal in Central Kerala with ideal conditions for rubber. Three important juvenile parameters viz., girth, yield on test incision and yield on test tap were employed for the study. Clones in general showed lower girth and yield in Padiyoor compared to Chethackal, indicative of the effect of climatic stress existing in Padiyoor. Out of the 15 top performing clones at Chethackal, 9 clones were among the top 15 at Padiyoor also. Hence, these clones can be considered stable and may have the potential for cultivation in varied agro-climatic conditions. Half-sib progenies from PB 255, PB 260, GT 1, RRII 203, PB 28/83 and PB 217 maintained superiority in the clonal population of progenies reconfirming the prepotency of the parent clones. Correlation analysis showed that girth from 12th month onwards is highly correlated with girth in subsequent years suggesting that clones with good growth potential can be identified from the very first year itself. Yield on test incision was highly correlated with test tap yield on 24 months at Chethackal and 24 and 48 months at Padiyoor. Girth recorded in plants from 18th month onwards showed significant correlation with yield at Chethackal and Padiyoor except in the final test tap yield at Padiyoor. Yield on test tapping in 24 months was highly correlated positively with final test tap yield (48 months) in both the locations suggesting that test tap yield in 24 months itself can be used for the identification of a potentially high yielding clone.

Keywords: Hevea, clonal nursery, half-sib progeny, test incision, test tapping

INTRODUCTION

In India, crop production potential of *Hevea brasiliensis* was improved from less than 300 kg (Panikker *et al*., 1980) to more than 3500 kg (Licy *et al*., 1998) per hectare per year by way of conventional breeding programmes. Owing to the perennial nature of the species, the development of improved clones is a time consuming job, even more laborious when targeting specific objectives and environments. The whole procedure for clonal selection, which includes preliminary evaluation for yield in small-scale trials (SST) followed by more elaborate large scale trials (LST) and on-farm evaluation trials (OFT) takes nearly 30 years

before a clone is released for commercial cultivation (Varghese and Mydin, 2000). In order to reduce the time span of the clonal selection procedure, a clonal nursery evaluation technique reported by Ho *et al*., (1973) was successfully used in different studies (Mydin *et al*., 2004). Significant positive correlation between juvenile yield in the clonal nursery and mature yield in the small scale trial was reported by Mydin *et al*., (2004). This paper reports the performance of half-sib progenies in clonal nurseries under two different agro-climatic regions viz., North Kerala and Central Kerala of India.

MATERIALS AND METHODS

Forty eight half-sib progenies, three parents and five checks were planted in clonal nursery trials in two locations, one at the Central Experiment Station (CES) of Rubber Research Institute of India (RRII) at Chethackal, Ranni, Pathanamthitta district at 09^{o} 22'N latitude and 76^{o} 50'E longitude at an altitude of 50m and the other at the Regional Research Station of RRII at Padiyoor, Iritty, Kannur district at 11^{o} 36'N latitude and 76^{o} 33'E longitude at an altitude of 80m. Although both the locations comes under the Kerala state in India, the former is considered as more ideal for rubber cultivation and the latter is not considered so because of the severe moisture and high temperature stress during summer (Lakshmanan *et al*., 2014; Meenakumari *et al*., 2015). Though the annual average rainfall ranges from 3000 to 4500 mm, distribution of rainfall is poor in Padiyoor compared to Chethackal. Padiyoor is characterized by high intensity rains during the months of June to September with relatively few showers during the North East monsoon season. Moreover, summer showers are scanty. The dry sub humid summer months extends from December to May. Soil moisture is a critical limiting factor for growth of plants in Padiyoor (Lakshmanan *et al*., 2014).

The nurseries were established at the same time in both the locations with rectangular lattice design having three replications (Fig, 1). The list of clones under evaluation and their parentage is given in Table 1. The spacing adopted was 1.5 x 1.5m with a plot size of three plants. Evaluation of clones in both the locations was done based on three important juvenile parameters viz., girth, yield on test incision and yield on test tap. Girth was recorded at 6, 12, 18, 24 and 48 months after planting in the field. The first two observations were recorded by measuring the stem diameter at 5cm above bud union and thereafter by measuring the girth at 15cm above the bud union. The yield on test

incision was recorded from 12 month old plants by making a test incision 15cm above the bud union using a specially designed knife (Annamma *et al*., 1989). The latex that exuded from the cut was collected in pre-weighed strips of blotting paper and then weighed again after drying. Yield on test tapping was recorded in the 24 and 48 months after planting by tapping the plants only during the peak yield season (November-December) at a height of 30cm above the bud union under S/2d/3 system of tapping. After discarding the latex from the first five tappings, latex collected in the cup was coagulated from ten consecutive tappings. The coagulated cup lumps were dried and weighed to record the test tap yield.

Figure. 1 Plants under evaluation (A) Chethackal (B) Padiyoor

The rank-sum method (Huhn, 1979) was applied to data on girth (6, 12, 18, 24 and 48 months after planting) and yield (test incision on 12 month old, test tap on 24 and 48 months) in both the locations separately to identify the best performers having stability for yield and growth over the years in varied conditions. The correlation between girth, test incision and test tap yield were also estimated.

Table 1. Parentage of clones

Parent	Progeny clone
RRII 105	HS 89/205, HS 89/206, HS 96/26
PB 28/83	HS 89/207, HS 89/78, HS 89/79, HS 89/80, HS 89/81, HS 89/209, HS 89/138, HS 89/208, HS 89/186, HS 89/187, HS 89/188, HS 89/213
PB 217	HS 89/211, HS 89/210, HS 89/215, HS 89/212, HS 89/214
RRII 203	HS 96/73, HS 96/78, HS 96/186, HS 96/188, HS 96/306
PB 255	HS 96/260, HS 96/263, HS 96/266, HS 96/274, HS 96/98
PB 260	HS 96/117, HS 96/119, HS 96/145, HS 96/329, HS 96/360
GT 1	HS 96/112, HS 96/126, HS 96/132, HS 96/229, HS 96/246, HS 96/247, HS 96/250, HS 96/400, HS 96/406
RRIM 600	HS 96/32, HS 96/34, HS 96/37, HS 96/203
	Parents
Tjir 1 X Gl 1	RRII 105
Tjir 1 X PB 86	RRIM 600
PB 5/51 X PB 6/9	PB 217
	Check clones
RRII 105 X RRIC 100	RRII 414
RRII 105 X RRIC 100	RRII 417
RRII 105 X RRIC 100	RRII 422
RRII 105 X RRIC 100	RRII 429
RRII 105 X RRIC 100	RRII 430

RESULTS AND DISCUSSION

Clones HS 96/263 with 84.88g/t/10tap and HS 89/138 with 66.9g/t/10tap were the highest yielders at Chethackal (Table 2) and Padiyoor (Table 3) respectively. In Chethackal, clones HS 96/263, HS 96/274, HS 96/266, HS 96/145, HS 96/32, HS 96/260, HS 96/186, HS 96/73, HS 89/214, HS 96/329, HS 96/246, HS 96/360, HS 89/78, HS 96/306, HS 96/98, HS 89/80, HS 96/37, HS 96/250, HS 96/400, HS 96/119, HS 89/215, HS 96/203, HS 89/206, HS 89/138, HS 89/186 and HS 96/34 recorded comparable yield with top yielding check clones (Table 2).

Table 2. Girth (48 months) and yield (mean of 2 years) of clones in Chethackal

Clone	Girth (cm)	Yield (g/t/10t) #
HS 96/263	35.08	84.88 a
HS 96/274	30.67	84.10 ab
HS 96/266	31.17	75.97 ab
HS 96/145	31.11	73.36 ab
HS 96/32	29.72	71.86 ab
HS 96/260	25.33	66.40 ab
RRII 417	28.03	65.99 ab

Clone	Girth (cm)	Yield (g/t/10t) #
HS 96/186	30.11	64.57 ab
RRII 414	28.33	63.48 ab
HS 96/73	29.00	61.63 ab
HS 89/ 214	28.56	61.23 ab
HS 96/329	33.78	60.58 ab
HS 96/246	28.11	59.52 ab
HS 96/360	34.83	59.07 ab
HS 89/ 78	29.47	58.21 ab
HS 96/306	24.03	57.83 ab
HS 96/98	30.69	57.12 ab
HS 89/ 80	31.11	56.86 ab
HS 96/37	27.08	55.82 ab
HS 96/250	28.67	54.75 ab
PB 217	29.56	53.51 ab
HS 96/400	31.17	52.80 ab
HS 96/119	28.78	51.10 ab
RRII 430	25.22	51.04 ab
RRII 105	22.00	49.77 ab
HS 89/ 215	31.00	49.70 ab
HS 96/203	29.00	48.72 ab
HS 89/ 206	30.17	48.32 ab
HS 89/ 138	27.22	48.31 ab
HS 89/ 186	23.39	48.30 ab
HS 96/34	28.44	48.24 ab
RRII 422	28.67	47.20 bc
HS 96/188	28.33	46.44 cd
HS 89/ 212	28.33	46.40 cd
HS 96/26	28.22	43.69 cd
RRIM 600	23.22	43.55 cd
HS 89/ 188	25.47	42.41 cd
HS 96/117	26.33	42.02 cd
HS 96/406	28.09	41.90 cd
HS 96/229	29.94	37.06 de
HS 89/ 208	26.17	37.00 de
HS 89/ 81	19.56	32.66 ef
HS 96/112	25.25	32.24 ef
HS 96/78	26.28	32.07 ef
HS 89/ 210	22.67	31.58 ef
HS 89/ 205	20.50	30.20 ef
HS 89/ 213	19.33	30.17 ef
RRII 429	22.11	29.54 ef
HS 89/ 211	25.06	29.31 ef
HS 89/ 207	22.39	23.44 fg
HS 89/ 187	25.11	22.51 gh
HS 96/247	22.83	21.82 hi
HS 96/132	19.83	19.36 ij
HS 89/ 79	19.06	19.13 ij
HS 89/ 209	18.83	14.57 j
HS 96/126	20.28	14.10 j

Clone	Girth (cm)	Yield (g/t/10t) #
Mean	26.83	47.3
CD (0.05)	5.99**	

** Significant at $p < 0.01$

Duncan's Multiple Range Test (DMRT). Averages followed by the same letter do not differ statistically between themselves at 5% level of probability.

Table 3. Girth (48 months) and yield (mean of 2 years) of clones in Padiyoor

Clone	Girth (cm)	Yield (g/t/10t) #
HS 89/138	22.03	66.90 a
RRII 430	20.67	65.62 ab
HS 96/329	19.87	65.22 ab
HS 89/80	20.90	60.45 ab
HS 96/263	20.60	57.74 ab
PB 217	17.43	57.70 ab
HS 89/186	20.30	47.94 ab
HS 96/145	18.33	47.17 ab
RRII 422	19.73	47.04 ab
HS 96/34	20.17	46.32 ab
HS 96/266	20.97	44.83 ab
HS 96/26	22.80	42.97 bc
HS 89/206	20.63	41.14 cd
HS 89/81	19.07	39.73 cd
HS 96/360	19.07	38.57 cd
HS 89/208	13.30	38.53 cd
HS 96/119	22.77	38.03 cd
HS 96/98	19.30	36.96 cd
RRII 417	20.63	35.56 de
HS 96/246	21.13	35.50 de
HS 96/117	20.83	34.42 de
HS 89/79	19.77	32.80 ef
HS 96/400	21.17	31.88 ef
HS 89/78	22.30	31.32 ef
RRII 414	21.37	30.80 ef
HS 96/186	19.47	30.43 ef
HS 96/406	18.47	29.85 ef
HS 89/215	20.60	29.68 ef
HS 96/306	21.73	29.48 ef
HS 96/229	20.90	26.66 ef
HS 89/187	19.07	25.89 ef
HS 96/203	21.47	25.49 ef
HS 96/73	21.00	25.48 ef
HS 96/37	21.43	25.10 ef
HS 96/274	23.60	25.01 ef
HS 89/188	14.75	24.53 ef
RRII 429	18.83	24.36 ef
HS 89/209	18.25	24.33 ef
HS 89/210	15.67	23.03 fg
HS 96/32	16.60	23.01 fg

Clone	Girth (cm)	Yield (g/t/10t) #
RRIM 600	16.07	22.71 fg
HS 96/112	22.13	21.70 gh
RRII 105	18.77	21.67 gh
HS 89/207	21.43	20.81 hi
HS 96/188	21.93	20.68 hi
HS 89/211	20.23	20.59 hi
HS 89/214	17.57	20.06 hi
HS 89/205	15.27	18.63 ij
HS 89/212	18.60	18.36 ij
HS 96/250	17.63	17.80 jl
HS 96/78	18.83	17.77 jl
HS 89/213	20.20	16.34 jl
HS 96/247	20.07	16.22 jl
HS 96/132	19.77	14.22 lm
HS 96/260	19.13	12.53 mn
HS 96/126	16.13	9.63 n
Mean	19.66	32.10
CD (0.05)	NS	

Duncan's Multiple Range Test (DMRT). Averages followed by the same letter do not differ statistically between themselves at 5% level of probability.

When the parentage of the promising progenies were analyzed, it was observed that all the half-sib progenies of parent clone PB 255 under evaluation at Chethackal (HS 96/260, HS 96/263, HS 96/266, HS 96/274, & HS 96/98) and two progenies at Padiyoor (HS 96/263 and HS 96/266) were found to be promising having comparable yield with top yielding check clones (Table 4). It has been reported based on seedling progeny evaluation that PB 255 is a prepotent parent clone (Mydin *et al*., 2002). The present study showed that half-sib progenies from PB 255 maintained its superiority in yield even in the clonal nursery stage, which reconfirms the prepotent ability of the clone to produce superior progeny. Four progenies from PB 260 (HS 96/119, HS 96/145, HS 96/329 & HS 96/360) and three progenies each from RRII 203 (HS 96/73, HS 96/186 & HS 96/306) as well as GT 1 (HS 96/246, HS 96/250 & HS 96/400) were also found to be promising at Chethackal (Table 4) confirming the earlier report that those clones are also prepotent (Mydin *et al*., 2002). Among these, clones HS 96/329 and HS 96/145 (progenies of PB 260) were found to be promising at Padiyoor also (Table 4). It was reported that PB 28/83 and PB 217 are prepotent clones in the seedling progeny analysis (Mydin *et al*., 1996) as well as in the mature progeny analysis (Mydin *et al*., 2010). In the present study four progenies at Chethackal (HS 89/78, HS 89/80, HS 89/138 and HS 89/186) and three progenies at Padiyoor (HS 89/80, HS 89/138 and HS 89/186) from the parent clone PB 28/83 were found to be promising (Table 4) showing the prepotency of the

clone. Four progenies from RRIM 600 (HS 96/32, HS 96/34, HS 96/37 and HS 96/203), two progenies from PB 217 (HS 89/215 and HS 89/214) and one progeny from RRII 105 (HS 89/206) were also found to be promising at Chethackal (Table 4). One progeny from RRIM 600 (HS 96/34) was promising at Padiyoor also (Table 4).

Table 4. Parentage wise list of promising clones based on yield

Parent	Total no. under study	Clones comparable with top yielding check	
		Chethackal	Padiyoor
PB 255	5	HS 96/260, HS 96/263, HS 96/266, HS 96/274, HS 96/98	HS 96/263, HS 96/266
PB 260	5	HS 96/119, HS 96/145, HS 96/329, HS 96/360	HS 96/329, HS 96/145
RRII 203	5	HS 96/73, HS 96/186, HS 96/306	-
GT 1	9	HS 96/246, HS 96/250, HS 96/400	-
PB 28/83	12	HS 89/78, HS 89/80, HS 89/138, HS 89/186	HS 89/80, HS 89/138, HS 89/186
RRIM 600	4	HS 96/32, HS 96/34, HS 96/37, HS 96/203	HS 96/34
PB 217	5	HS 89/215, HS 89/214	-
RRII 105	3	HS 89/206	-
Check/parents	8	RRII 417, RRII 414, PB 217, RRII 430, RRII 105	RRII 430, PB 217, RRII 422

When the general mean of all the clones was used to compare the difference in girth, 26.7% less girth was recorded in Padiyoor. This is due to the specific agro-climatic condition in Padiyoor reported earlier (Lakshmanan *et al*., 2014; Meenakumari *et al*., 2015). Clone HS 96/263 with 35.08cm and clone HS 96/274 with 23.6cm recorded the highest girth at Chethackal and Padiyoor respectively in the 4th year after planting (Table 2 & 3). Clones HS 96/263 and HS 96/360 recorded significantly higher girth compared to the top most check RRII 400 series clone at Chethackal (Table 2). But, in Padiyoor there was no significant variation in girth between clones.

Clone-Wise Performance

The rank assigned for each clone at Chethackal and Padiyoor based on Rank-sums for growth and yield is given in Table 5. Out of the 15 top performing clones at Chethackal, nine clones were in top 15 at Padiyoor also (HS 96/263, HS 96/34, RRII 430, HS 96/145, HS 96/329, HS 89/80, HS 96/274, HS 89/215 & HS 89/78). Hence, these clones possess the potential for cultivation in varied agro-climatic conditions. This is evident from the performance of check clone RRII 430 in which it came in 4th rank in both the locations. Several studies from the field have reported that clone RRII 430 is suitable for cultivation in both moisture

stress prone (Meenakumari *et al*., 2015) as well as ideal agro-climatic conditions (Mydin *et al*., 2011). Ajithkumar *et al*., (2007) based on growth up to six months after field planting identified four clones viz., HS 96/145, HS 89/78, HS 96/34 and HS 96/274 that showed stability in growth in both the locations. It is important to note that these clones were among the top 15 in the present study also at both the locations showing its stability over the years.

Table 5. Ranking of clones

Sl. No.	Clone	Chethackal		Padiyoor		Overall	
		Rank-sum	Rank	Rank-sum	Rank	Rank-sum	Rank
1	HS 96/263	398	1	352	4	750	1
2	HS 96/34	334	8	375	1	709	2
3	RRII 430	345	4	352	4	697	3
4	HS 96/145	343	5	351	6	694	4
5	HS 96/329	300	14	373	2	673	5
6	HS 89/80	314	12	353	3	667	6
7	HS 96/274	343	5	306	15	649	7
8	HS 89/215	318	11	321	11	639	8
9	HS 96/360	335	7	288	17	623	9
10	HS 89/78	305	13	309	13	614	10
11	HS 96/119	261	21	333	9	594	11
12	HS 96/98	249	23	343	7	592	12
13	HS 96/246	360	3	231	28	591	13
14	HS 89/206	279	16	272	20	551	14
15	HS 89/187	273	17	275	19	548	15
16	HS 96/400	327	9	219	32	546	16
17	HS 89/138	216	33	328	10	544	17
18	HS 96/32	378	2	156	42	534	18
19	HS 96/266	280	15	247	24	527	19
20	HS 96/73	321	10	206	36	527	19
21	RRII 422	227	27	288	17	515	21
22	HS 96/203	236	24	272	20	508	22
23	HS 96/406	270	18	224	31	494	23
24	HS 89/81	166	43	313	12	479	24
25	RRII 417	260	22	216	33	476	25
26	HS 96/186	264	20	210	34	474	26
27	HS 96/247	220	30	253	22	473	27
28	RRII 414	219	31	232	27	451	28
29	HS 96/229	158	44	290	16	448	29
30	HS 89/186	209	36	235	26	444	30
31	HS 96/306	209	36	229	29	438	31
32	HS 96/26	84	54	341	8	425	32
33	HS 89/212	234	25	183	39	417	33
34	HS 96/188	230	26	185	38	415	34
35	HS 96/117	175	40	237	25	412	35
36	PB 217	178	39	226	30	404	36

Sl. No.	Clone	Chethackal		Padiyoor		Overall	
		Rank-sum	Rank	Rank-sum	Rank	Rank-sum	Rank
37	RRIM 600	215	35	189	37	404	36
38	HS 89/207	226	28	171	40	397	38
39	HS 96/112	175	40	210	34	385	39
40	HS 89/79	61	55	307	14	368	40
41	HS 89/209	97	52	253	22	350	41
42	HS 96/37	216	33	126	47	342	42
43	HS 89/208	201	38	136	45	337	43
44	HS 89/214	267	19	51	56	318	44
45	HS 89/188	172	42	144	44	316	45
46	HS 96/78	139	47	154	43	293	46
47	HS 89/210	123	48	163	41	286	47
48	HS 96/250	222	29	60	54	282	48
49	HS 96/260	219	31	58	55	277	49
50	HS 96/126	118	49	136	45	254	50
51	RRII 105	145	45	108	50	253	51
52	HS 89/211	144	46	89	53	233	52
53	RRII 429	101	51	120	48	221	53
54	HS 89/213	116	50	95	52	211	54
55	HS 96/132	87	53	117	49	204	55
56	HS 89/205	41	56	105	51	146	56

The top performing clones at Chethackal viz., HS 96/32 and HS 96/246 which came in the 2nd and 3rd positions respectively in Chethackal were in the 42nd and 28th rank respectively at Padiyoor and hence, can be considered as vulnerable to moisture stress. Hence, these clones may be suitable for planting only in places were agro-climatic conditions are ideal for rubber cultivation. The clones HS 96/400 and HS 96/73 also performing well in Chethackal showed poor performance at Padiyoor.

When clones were sorted considering their performance in both the locations together, only one check clone (RRII 430), figured among the top 20 (Table 5). Four out of five progenies of PB 255 (clones HS 96/98, HS 96/263, HS 96/266 and HS 96/274) and PB 260 (clones HS 96/119, HS 96/145, HS 96/329 and HS 96/360) figured among the top 20. Two out of four progenies of RRIM 600 (clone HS 96/32 and HS 96/34), one out of three of RRII 105 (clone HS 89/206) and RRII 203 (HS 96/73), four out of 12 of PB 28/83 (clone HS 89/78, HS 89/80, HS 89/138 and HS 89/187), one out of five of PB 217 (clone HS 89/215) and two out of nine of GT 1 (clone HS 96/246 and HS 96/400) featured in the top 20. It has already been reported that PB 255 and PB 260 are prepotent parent clones as proven by seedling progeny analysis (Mydin *et al*., 2002). The present study showed that half-sib progenies from PB 255 and PB 260 maintained its superiority even after clonal multiplication through bud

grafting on to assorted root-stocks, which reconfirms the prepotency of the parents as well as the superiority of the genotypes.

Correlation in Growth and Yield at Different Stages

The correlation for growth (six months, one year, one and half year, two years and four years after planting) and yield (test incision in one year old, test tap in second and fourth year) at Chethackal and Padiyoor is given in Table 6.

Table 6. Correlation in growth and yield. Upper diagonal – Padiyoor, Lower diagonal - Chethackal

Variables #	Stem Diameter (6)	Stem Diameter (12)	Girth (18)	Girth (24)	Girth (48)	Test incision yield	Test tap yield (24)	Test tap yield (48)
Stem Diameter (6)	-	.839**	.652**	.579**	0.221	0.026	0.199	0.173
Stem Diameter (12)	.670**	-	.743**	.732**	.285*	0.117	.347**	.294*
Girth (18)	.468**	.629**	-	.924**	.353**	0.038	.554**	.516**
Girth (24)	.448**	.629**	.939**	-	.382**	0.085	.579**	.592**
Girth (48)	0.155	.277*	.625**	.657**	-	0.069	0.076	0.242
Test incision yield	-0.126	0.107	0.085	0.112	0.045	-	.366**	.524**
Test tap yield (24)	0.261	0.223	.486**	.465**	.517**	.350**	-	.702**
Test tap yield (48)	0.117	0.093	.400**	.443**	.774**	0.073	.616**	-

* significant at $p < 0.05$; ** significant at $p < 0.01$
# Figures in parenthesis indicate months

Growth Over the Years

It was observed that stem diameter recorded in six months old plants did not show any correlation with final girth (48 months) in both the locations (Table 6). This shows that initial growth up to six months is not correlated with final growth. This could be due to the fact that the initial growth is highly influenced by the stock. Clearwater *et al.,* (2006) reported that in Kiwifruits, scions on low-vigor rootstocks had 50% or less leaf area than scions on the most vigorous rootstocks and the most important effect of rootstocks on scion development occurred during the initial period of shoot growth immediately after bud burst.

Girth recorded in the 12 month old plants showed significant correlation with final growth (Table 7). This shows that a clone starts to show its real growth potential once it attains one year growth. This is more evident from the fact that girth from first year onwards was highly

correlated with that in subsequent years (Table 6). Hence, clones with good growth potential can be identified from the very first year itself.

Girth, Test Incision, and Test Tap Yield

The yield on test incision was not correlated with girth at any stage in both the locations (Table 6). But it was highly correlated with test tap yield in 24 months after planting at Chethackal and 24 and 48 months test tap yield at Padiyoor. The yield on test incision was not correlated with final test tap yield at Chethackal. This shows that yield on test incision alone cannot be used for identifying a potentially high yielding clone.

Girth and Yield

When the correlation between girth and yield was studied, the initial girth (6 months) did not show any correlation with the yield at any stage in both the locations (Table 6). Girth recorded in 12 month old plants also did not show any correlation with yield at Chethackal, but it showed significant positive correlation with test tap yield in the 24 and 48 months old plants at Padiyoor. Girth recorded after 18 months of planting onwards showed significant positive correlation with yield at Chethackal and Padiyoor except in the final test tap yield at Padiyoor. Significant positive correlations were already reported between the yield of rubber and growth vigor (Gonçalves *et al*., 2004; Mydin *et al*., 2004).

Test Tap Yield Over the Years

Yield on test tapping in the 24 months showed highly significant correlation with final test tap yield (48 months) in both the locations (Table 6). Hence, test tap yield in the second year itself can be used for the identification of a potentially high yielding clone.

CONCLUSION

The present study was able to identify 10 clones with good yield potential, specific to each of the two locations as well as three clones HS 96/246, HS 96/360 and HS 96/119 with wide adaptability (to both locations) among the half-sib progenies. Clones in general showed lower girth as well as yield in Padiyoor compared to Chethackal. Out of the 15 top performing clones at Chethackal, nine clones were among the top performers at Padiyoor also and hence, these clones may have the potential for cultivation in varied agro-climatic conditions. Half-sib

progenies from prepotent clones maintained superiority even in the clonal population reconfirming the prepotency of the parents and the genetic potential of the clones. Correlation analysis showed that girth from first year onwards is highly correlated with that in subsequent years and hence, clones with good growth potential can be identified from the first year of planting itself. Girth of plants from 18 months onwards showed significant positive correlation with yield at Chethackal and Padiyoor except in the final test tap yield at Padiyoor. Since yield on test tapping over the years is highly positively correlated; the test tap yield in the second year itself can be used for the identification of a potentially high yielding clone.

ACKNOWLEDGEMENT

The authors are thankful to Director, Rubber Research Institute of India, Deputy Director, CES Chethackal and Dr. Radha Lakshmanan, Senior Scientist, Regional Research Station, Padiyoor for kindly providing facilities for conducting the experiment. The authors would also like to acknowledge Mr. Aneesh, P., Assistant Statistician for statistical analysis. The CSIR research fellowship granted to the second author is also hereby acknowledged.

REFERENCES

Ajithkumar, E., Radha Lakshman and Kavitha K. Mydin (2007). Juvenile evaluation of half-sib progenies of rubber (*Hevea brasiliensis*) in North Malabar. *19th Kerala Science Congress*, Kannur, 29-31 January, 2007.

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

Clearwater, M.J., Seleznyova, A.N., Thorp, G., Blattmann, P., Barnett, M. A., Lowe, R.G. and Austin P. T. (2006). Vigor-controlling rootstocks affect early shoot growth and leaf area development of kiwifruit. *Tree Physiology*, 26:505–515

Gonçalves, P.S., Martins, A.L.M., Bortoletto, N. and Saes, L.A. (2004). Selection and genetic gains for juvenile traits in progenies of *Hevea* in São Paulo State, Brazil. *Genetics and Molecular Biology*. 2004, vol.27, n.2, pp. 207-214. ISSN 1678-468. http://dx.doi.org/10.1590/S1415-47572004000200014.

Ho C.Y., Narayanan, R. and Chen, K.T. (1973). Clonal nursery studies in *Hevea*: I. Nursery yields and associated structural characteristics and their variations. *Journal of Rubber Research Institute of Malaysia*, **23**(4):305-316

Huhn, M. (1979). Beittage zur Erfassung der Phanotypischen Stabilitat. I. Vorschlag einiger auf Ranginformationen Beruhenden Stabilitatparameter. *EDP in Medicine and Bioilogy*, **10**:112-117.

Lakshmanan, R., Meenakumari, T., Chandrasekhar, T. R. and Nazeer, M.A. (2014). Growth and yield performance of some exotic clones of *Hevea brasiliensis* in north Kerala region. *Journal of Plantation Crops*, 42(2):93-100.

Licy, J., Panikkar, A.O.N., Premakumari, D., Saraswathyamma, C.K., Nazeer, M.A. and Sethuraj, M.R. (1998). Genetic parameters and heterosis in rubber (*Hevea brasiliensis*) Muell. Arg. IV. Early versus mature performance of hybrid clones. In: *Developments in Plantation Crops Research* (Eds. N.M. Mathew and C. Kuruvilla Jacob), Rubber Research Institute of India, Kottayam, pp. 9-15.

Meenakumari, T., Lakshmanan, R., Meenattoor, J.R., Joseph, A., Gireesh, T. and Mydin, K.K. (2015). Performance of new generation clones of *Hevea brasiliensis* under the dry sub-humid climate of North Kerala. *Rubber Science*, **28** (1):40-51.

Mydin, K.K., Ammal, S.L., Thomas, V. and Saraswathyamma, CK. (2002). Prepotency in rubber: Half sib progeny evaluation. *Proceedings of PLACROSYM XV*, 10-13 December 2002, Mysore, India. pp.47-52.

Mydin, K.K., Licy, J., Varghese, Y. A., John, A., Nair, R.B. and Saraswathyamma, CK. (2004). Clonal nursery evaluation for shortening the breeding cycle in *Hevea brasiliensis. Natural Rubber Research*, 17(1):60-66.

Mydin, K.K., Nair, V.G., Sethuraj, M.R, Panikkar, A.O.N., Nazeer, M.A. and Saraswathy, P. (1996). Prepotency in rubber II. Seedling progeny analysis for yield and certain yield attributes. *Indian Journal of Natural Rubber Research* 9(1): 63-66.

Mydin, K.K., Thomas, V. and Mercykutty, V.C. (2010). Variability in performance among mature half-sib progenies of *Hevea brasiliensis* (Willd ex Adr. de Juss. Muell. Arg.). *Journal of Plantation Crops*, 38(2): 125-131

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.

Panikker, A.O.N., Nair, V.K.B., and Markose, V.C. (1980). Breeding and tree improvement. *In: Handbook of Natural Rubber Production in India.* (Ed. P.N. Radhakrishna Pillay). Rubber Research Institute of India, Kottayam, pp. 35-49.

Prabhakaran, V. T. and Jain, J. P. (1994). Statistical Techniques for Studying Genotype-Environment Interactions. South Asian Publishers Pvt. Ltd., New Delhi, pp.221, ISBN 81–7003–168–0.

Varghese, Y.A. and Mydin, K.K. (2000). Genetic improvement. *In: Natural Rubber: Agromanagement and Crop Processing*. (Eds. P.J. George and C. Kuruvilla Jacob). Rubber Research Institute of India, Kottayam, India, pp. 36-46.