Rubber Science, **27**(2): 234-242, 2014

IDENTIFICATION OF SUPERIOR GENOTYPES AND PREPOTENT PARENT CLONES OF *HEVEA* IN NORTH EAST INDIA BY HALF-SIB PROGENY ANALYSIS

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Received: 12 March 2014 Accepted: 19 July 2014

Antony, P. D., Dey, S. K. and Mydin, K. K. (2014). Identification of superior genotypes and prepotent parent clones of *Hevea* in north east India by half-sib progeny analysis. *Rubber Science*, **27**(2): 234-242.

Half-sib progeny analysis from selected clones has been successfully utilised for the identification of superior genotypes as well as prepotent parents for future breeding programmes in *Hevea*. The present study was conducted in Tripura in North East India utilising the half-sib progenies collected from nine *Hevea* clones and planted family-wise for seedling nursery evaluation. Girth, yield per unit girth and test tap yield were recorded two and a half year after field planting and analysed in comparison with reference clones for identification of superior genotypes and prepotent parents. Progenies of SCATC 93/114, PB 86 and Haiken 1 were superior in terms of vegetative vigour. Among the progeny families evaluated, RRIM 600 had the highest mean test tap yield (13.9 g $t^{-1}10t^{-1}$) as well as yield per unit girth (0.78 g $t^{-1}10t^{-1}cm^{-1}$). Test tap yield of the half-sib progenies ranged from 0.52 g $t^{-1}10t^{-1}$ to 79.62 g $t^{-1}10t^{-1}$, with an overall mean yield of 12.23 g $t^{-1}10t^{-1}$. Selection of top 20 per cent genotypes based on rank summation index revealed that mean yield of selections from family of PB 86 and SCATC 88/13 were better than the check clone, RRIM 600. Based on the study, 110 selections were made for further evaluation and an improvement of 32.9 per cent and 136 per cent were attained in girth and yield, respectively when compared to unselected population. Based on the superior performance of progenies and higher proportion of superior progenies, PB 86, RRIM 600 and Tjir 1 were identified as prepotent clones which can be utilised in future breeding programmes.

Keywords: Genotypes, Half-sib progeny, Prepotency, Selection

INTRODUCTION

Scientific breeding programmes coupled with vegetative propagation in *Hevea* have resulted in the development of high yielding clones compared to low yielding unselected seedling plants. This was achieved through various breeding strategies like hybridisation, polycross progeny selection, ortet selection *etc*. Two major considerations in *Hevea* breeding programmes are high yield and attainment of early tappability.

Genetic improvement through selection of promising hybrids or half-sib progenies has been employed successfully in the past. But development of hybrids involves the laborious programme of hybridisation and success is often affected by low fruit-set, non-synchronous flowering *etc*. The advantage of collecting seeds from high

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yielding trees for improving the yield of *Hevea* was identified by Cramer when he selected 33 outstanding yielders from the Wickham collection planted in 1883 in Biutenzorg (Djikman, 1951). He assumed that the chances of obtaining better yielding plants from such "mother tree seed" would be far better than from seeds picked up at random. The evaluation of half-sib polycross seedlings and selection by conventional clonal selection offers superior clones circumventing the bottleneck of low fruit set in rubber and ensuring a wider genetic base (Mydin, 2011; Mydin and Saraswathyamma, 2005). Chandrashekhar and Gireesh (2009) observed that half-sibs can contribute substantially to the genetic improvement of *Hevea* based on the distribution of high yielding selections among full and half-sib progenies. Half-sib progeny analysis serves two purposes *viz*., identification of promising selections and identification of prepotent parents for future breeding programmes. These factors make half-sib polycross progeny selection and evaluation a more promising option for the improvement of *Hevea.*

Several workers have used various selection parameters like rubber yield and girth (Sebastian and Sarawathyamma, 2005), latex yield (Chandrashekhar and Gireesh, 2008) oil content (Fernando and deSilva, 1971), physiological and stomatal characteristics (Ahmad *et al.*, 2009) *etc.* for early identification of superior genotypes in *Hevea.* Mydin *et al.* (1996) advocated simultaneous emphasis on juvenile yield, girth, number of latex vessel rows and number of leaf flushes as traits for determining the relative merit of progenies for recovery of superior seedlings. Goncalves *et al.* (2005) suggested that for early evaluation of clones, immature girth should be used in preference to secondary characters such as height and number of laticiferous vessel rings. Tan (1998) established that nursery yield alone could be adopted as the early selection criterion. He also reported that the degree of association of the nursery yield per girth appeared to be stronger than nursery yield in relation with mature yield. Hence nursery yield per girth was a better parameter predict to the yield potential of individual trees compared to nursery yield alone. In spite of several parameters being identified for early detection of high yielders, many investigators have suggested the use of yield and girth as the criteria for early selection of superior genotypes.

Obtaining higher proportion of high yielding genotypes from a progeny test is crucial to identify the suitable parents in a breeding programme. The prepotent ability of *Hevea* clones to produce high quality seedlings could be determined by systematic and planned experiments like seedling progeny analysis (Mydin *et al.*, 1990). Several studies have resulted in the selection of promising half-sib polycross progenies and identification of prepotent clones in traditional rubber growing areas of India (Sebastian and Saraswathyamma, 2005; Mydin *et al.*, 1990). But unlike the traditional rubber growing area of India, the climate of Tripura in the North East India is characterised by a conspicuous winter season and strong wind, limiting the growth and yield of rubber. No scientific information is available on the evaluation and selection of half-sib polycross progenies in this region. The objective of the study was to identify superior progenies in relation to a reference clone from the half-sib population raised from selected clones as well as to identify prepotent clones for future breeding programmes in Tripura.

MATERIALS AND METHODS

The seeds for evaluation of half-sib polycross progenies were collected from trees of nine *Hevea* clones (GT 1, Haiken 1, PB 5/51, PB 86, RRIM 600, RRIM 703, SCATC 88/13, SCATC 93/114 and Tjir 1) planted in two clone trials in 1987 in the research farm of Rubber Research Institute of India, Taranagar, Agartala (23°53′ N; 91°15′E; 30m above MSL). The clone trials (1987) were planted in completely randomised design (CRD) with single tree plots thus increasing the chances of cross pollination among the component clones. Female parents for seed collection were chosen based on their characteristics like prepotency in the case of GT 1 and PB 5/51, (Sebastian and Saraswathyamma, 2005; Mydin *et al.*, 2002), cold tolerance in clones like SCATC 88/13, SCATC 93/114 and Haiken 1 (Priyadarshan and Clement-Demange, 2004), wind tolerance in PB 5/51 (Vinod *et al.*, 1996) and high yield of RRIM 600 and RRIM 703 (Vinod *et al.*, 1996). Tjir 1 and PB 86 are the parents of RRIM 600, the most stable and high yielding clone in this region and hence were selected for seed collection. The seeds were collected during July –August, 2009 and were planted in polybags. The 10 month old seedling progenies were planted in the seedling nursery in June 2010 at a spacing of 1m x 1m. Progeny families of six clones (PB 86, RRIM 703, Tjir 1, SCATC 93/114, Haiken 1 and RRIM 600) were larger and were planted in RBD with three replications with 25 seedlings per replication along with the budded stumps of reference clones (RRIM 600, RRII 105 and RRII 429) for comparison. The remaining half-sib seedling progenies were planted family-wise in the adjacent plot at a spacing of 1m x 1m.

For identification of superior progeny families as well as individual genotypes, girth, yield per unit girth and mean test tap yield were taken as the criteria for selection. Girth of the seedlings was recorded at 20 cm height from the ground in June, September and February for calculating seasonal and annual girth increments (GI). Girth at the time of test tapping was recorded just before opening the trees for test tapping. Juvenile yield was recorded from the plants having more than 10 cm girth by test tapping following the modified Hammaker Morris Mann method under the S/2 d3 6d/7 system. First five tappings were discarded and latex from ten consecutive tappings thereafter was collected in cups, dried and weighed to record the yield expressed as grams per tree per ten tappings (g $t^{-1}10t^{-1}$). Juvenile yield was recorded in two seasons *viz.*, November 2012 (corresponding to peak yielding period in the region) and May 2013 (stress period). Yield per unit girth was calculated based on the test tap yield obtained from ten tappings in November and girth recorded just before opening for test tapping. Superior families were identified by ANOVA for the parameters studied. Percentage of available seedlings in each family two years after planting was calculated for assessing the survival ability of progenies. Variability in each progeny family was assessed based on co-efficient of variation for girth, yield and yield per unit girth. The data collected from the six progeny families planted in RBD were utilised for statistical analysis for identification of superior families, while the entire population of nine progeny families was utilised for selection of superior genotypes and for the assessment of survival.

The rank sum method (Mydin *et al.*, 2004) was utilised to identify the best performers based on yield and girth of clones. Individual genotypes were ranked for girth at the time of test tapping, yield per unit girth and mean yield over two seasons by assigning lowest rank for the best performer. The rank sum for each individual was calculated as,

$\sum R_i = R_{gi} + R_{ygi} + R_{yi}$, where R_{gi} , R_{ygi} and R_{yi}, corresponds to the rank assigned to the i^{th} individual for girth, yield per unit girth and mean yield respectively.

Best genotypes were ranked based on the rank sum and selections were restricted to the top 20 per cent of the total seedling population (572 genotypes) as recommended by Simmonds (1989). The selections were grouped into four classes based on combination of girth (high girth (>20 cm) or average girth (15-20 cm) and yield (high yield (>25 g $t^{-1}10t^{-1}$) or average yield (10-25 g $t^{-1}10t^{-1}$).

RESULTS AND DISCUSSION

Identification of superior progeny families was done based on girth, girth increment (GI), mean yield and yield per unit girth. Analysis of girth at the time of tapping revealed that there was no significant difference between progenies and reference clones (Table 1). Progeny of SCATC 93/114 had the highest mean girth at tapping (16 cm), significantly higher monsoon GI (5.3 cm), summer GI (1.8 cm) as well as annual GI (8.2 cm) compared to check clones indicating vigorous growth and stability of the progenies of SCATC 93 /114 over different seasons. The progenies of PB 86 and Haiken 1 were also on par with SCATC 93/114 in seasonal as well as annual GI. All the progeny families except that of RRIM 600 showed significantly higher monsoon girth increment compared to reference clones. Families of RRIM 703 (1.2 cm), SCATC 93/114 (1.1 cm), PB 86 (1.1 cm) and Haiken 1 (1.1 cm) showed significantly higher winter GI than the reference clone RRII 429 (0.5 cm). All the families tested had significantly higher annual girth increment compared to reference clones. Sasikumar *et al.* (2001) also reported comparatively higher girth and girth increment in seedlings compared to the multiclonal population in Tripura. Among the families tested, progenies of RRIM 600 had the lowest mean annual GI.

Yield and yield per unit girth was significantly higher for the check clone RRIM 600 compared to the half-sib seedling progenies (Table 2). All the progenies tested were on par with each other as well as with clones RRII 429 and RRII 105 for the peak season test tap yield. Test tap yield in May was the highest for the progeny of RRIM 600 (14.53 g $t^{-1}10t^{-1}$). Higher test tap yield

Table 1. **Mean girth and girth increment (GI) of progeny families**

Progeny	Girth at test tapping (cm)	Monsoon GI (cm)	Winter GI (cm)	Summer GI (cm)	Annual GI (cm)
SCATC 93/114	16.0	5.3 ^{a}	1.1 ^{a}	1.8 ^{a}	8.2 ^{a}
Haiken 1	15.4	4.9 ^{a}	1.1 ^{a}	1.4 ^{ab}	7.4 ^{abc}
Tjir 1	15.3	4.9 ^{a}	0.9 ^{ab}	1.4 ^{ab}	7.3 ^{bc}
RRIM 703	15.2	4.8 ^{a}	1.2 ^{a}	1.4 ^{ab}	7.3 ^{bc}
PB 86	14.9	4.9 ^{a}	1.1 ^{a}	1.6 ^{ab}	7.5 ^{ab}
RRIM 600	14.2	4.3 ^{ab}	0.9 ^{ab}	1.4 ^{b}	6.6 ^{c}
RRII 429 (Check clone)	15.1	3.8 b^{c}	0.5 ^{bc}	1.2 ^{bc}	5.4 ^{d}
RRIM 600 (Check clone)	14.3	3.2 ^{c}	0.8 ^{ab}	0.8 ^{c}	4.6 ^{d}
RRII 105 (Check clone)	14.1	3.3 ^{c}	0.2 ^{c}	0.9 ^{c}	4.4 ^{d}
CD (P=0.05)	NS	0.64	0.48	0.44	0.85

*Values followed by the same alphabet do not differ significantly

Table 2. **Test tap yield and yield per unit girth of half-sib progeny families in the nursery**

Progeny	Test tap yield (November) (g $t^{-1}10t^{-1}$)	Test tap yield (May) (g $t^{-1}10t^{-1}$)	Mean test tap yield (g $t^{-1}10t^{-1}$)	Test tap yield/girth (November) (g $t^{-1}10t^{-1}cm^{-1}$)
RRIM 600	13.31 ^{b}	14.53 ^{b}	13.9 ^{b}	0.78 ^{bc}
Tjir 1	10.97 ^{b}	12.71 ^{bc}	11.8 ^{b}	0.64 ^{c}
RRIM 703	10.48 ^{b}	12.98 ^{bc}	11.7 ^{b}	0.59 ^{c}
Haiken 1	9.94 ^{b}	11.98 ^{bc}	11.0 ^{b}	0.57 ^{c}
PB 86	10.72 ^{b}	11.31 ^{bc}	11.0 ^{b}	0.55 ^{c}
SCATC 93/114	8.00 ^{b}	8.00 ^{bc}	8.0 ^{b}	0.48 ^{c}
RRIM 600 (Check clone)	26.89 ^{a}	30.48 ^{a}	28.7 ^{a}	1.58 ^{a}
RRII 105 (Check clone)	18.44 ^{ab}	5.12 ^{c}	11.8 ^{b}	1.16 ^{ab}
RRII 429 (Check clone)	15.49 ^{b}	16.72 ^{b}	16.1 ^{b}	0.87 ^{bc}
CD (P=0.05)	10.64	8.98	9.13	0.46

Values followed by the same alphabet do not differ significantly

observed in May compared to November in all the families (except SCATC 93/114) may be due to higher girth attained by the plants. Progenies of RRIM 600 (13.9 g $t^{-1}10t^{-1}$) and SCATC 93/114 (8.0 g $t^{-1}10t^{-1}$) recorded the highest and lowest mean yield respectively. Yield per unit girth was highest for the reference clones followed by the progeny of RRIM 600. Among the half-sib seedling progenies, that of RRIM 600 (0.78 g $t^{-1}10t^{-1}cm^{-1}$) had the highest mean yield per unit girth though there was no significant difference among the different progenies. Mean yield among the half-sib progenies ranged from 0.52 g $t^{-1}10t^{-1}$ to 79.62 g $t^{-1}10t^{-1}$ and overall mean yield was 12.23 g $t^{-1}10t^{-1}$. Chandrasekhar and Gireesh (2009) reported an overall yield range of 7 to 41 g $t^{-1}10t^{-1}$ in seedling progeny analysis when test tapped at three years after planting. Mean progeny juvenile yield (2 years after planting) of 4.14 g $t^{-1}10t^{-1}$ was reported in the half sib progeny analysis from 12 clones from Malaysia and Thailand (Sebastian and Saraswathyamma, 2005). The higher yield obtained in the present study may be due to wider spacing compared to the earlier studies (0.6 m x 0.6 m) or the higher yield potential of the progeny.

Co-efficient of variation (CV) for girth at opening as well as annual GI were lowest

Table 3. **Co- efficient of variation for growth and yield in different progeny families**

Progeny	Girth at test tapping (%)	Monsoon GI (%)	Winter GI (%)	Summer GI (%)	Annual GI (%)	Mean test tap yield (%)	Yield/ girth (%)
PB 86	33.0	30.6	40.0	54.2	29.0	99.1	65.6
RRIM 703	27.2	29.4	31.8	46.8	25.4	67.5	46.0
Tjir 1	26.5	42.9	125.4	55.4	24.6	72.5	60.4
SCATC 93/114	17.1	14.4	34.3	36.3	14.3	70.2	44.0
Haiken 1	27.1	29.7	48.3	62.4	27.2	81.2	69.4
RRIM 600	35.3	32.6	54.4	56.0	31.3	72.8	70.7

for progeny of SCATC 93/114, indicating more uniform growth for SCATC 93/114 progenies in terms of vegetative vigour (Table 3). The high mean girth combined with low CV percentage observed in this study and the established cold tolerance of this clone (Priyadarshan and Clement-Demange, 2004) indicates the potential for utilising SCATC 93/114 progenies for raising uniform root stock populations especially in North East India. Earlier studies have established the fact that growth relations exists between stock and scion, and that the use of vigorous root stock for budding will improve the growth of scion (Djikman, 1951). Progenies of RRIM 600 recorded the highest CV (35.3%) for girth. Progeny family of PB 86 recorded the highest CV for yield (99.1%) indicating more variability for exercising selection in terms of yield. The CV for yield and girth observed in the present study are comparable with the reported mean values of 43 per cent and 112 per cent for girth and yield respectively for half-sib progenies (Chandrasekhar and Gireesh, 2009). Comparison of survival of individuals among the different progenies (Table 4) revealed that PB 86 had the highest survival of 95 percentage with sufficient number of seedlings followed by Tjir 1 and SCATC 93/114. RRIM 600 recorded the lowest survival (76%) indicating poor establishment.

Table 4. **Percentage of survival in half-sib progenies two years after planting**

Progeny	Population size	Survival (%)
PB 86	101	95.0
RRIM 703	75	88.0
Tjir 1	140	93.6
SCATC 93/114	77	93.5
Haiken 1	103	90.3
RRIM 600	75	76.0
GT 1	40	75.0
PB 5/51	21	100.0
SCATC 88/13	9	66.7

Selection of top 20 per cent seedlings was worked out based on rank summation index. It was observed that the mean girth of selections in all half-sib progenies were superior to that of budded reference clones (Table 5). Mean yield/girth of selections were highest for the progeny of PB 86 (1.2 g $t^{-1}10t^{-1}cm^{-1}$). Sasikumar *et al.* (2001) have reported a high yield per unit length of tapping cut in high yielding selections in rubber. Significant positive correlation for nursery seedling yield and nursery yield per cm girth with mature yield of corresponding clones over five years has been reported by Tan (1998). Mean yield of selections from half-sib progenies of PB 86 (29.72 g $t^{-1}10t^{-1}$) and SCATC 88/13 (31.2 g $t^{-1}10t^{-1}$) were better than that of reference clone RRIM 600 (28.7 g $t^{-1}10t^{-1}$). Mean test tap yield of selections from all progeny families were superior to the mean test tap yield of check clones, RRII 105 and RRII 429. Among the progenies with sufficient number of seedlings, highest proportion of selections were obtained from PB 86 (27.1 %). Highest yielding genotypes identified in the study with more than 50 g $t^{-1}10t^{-1}$ were the progeny of PB 86 and they also had very high girth (above 23 cm). Chandrasekhar and Gireesh (2008) had also reported that in the top selections (5%) in a seedling population, the majority of high yielding seedlings were of high girth. Among the 110 selections, 41.8 per cent seedlings belonged to the high yield category (above 25 g $t^{-1}10t^{-1}$) and 58.2 per cent belonged to the average yield category (11-25 g $t^{-1}10t^{-1}$). Highest number of selections in high yield with high girth class and high yield with average girth class was obtained from PB 86 (9 selections) and Tjir 1 (9 selections) progenies

Table 5. **Growth and yield of top 20% selections from half-sib population**

Progeny	No. of seedlings	No. of selections	Mean girth (cm)	Mean test tap yield (g $t^{-1}10t^{-1}$)	Mean test tap yield/ girth (g $t^{-1}10t^{-1}cm^{-1}$)	Proportion of selection (%)
PB 86	96	26	20.88	29.72	1.20	27.1
Tjir 1	131	29	19.45	24.14	1.19	22.1
RRIM 600	57	12	19.63	23.14	1.15	21.1
Haiken 1	93	16	20.96	24.85	1.04	17.2
RRIM 703	66	10	20.02	22.83	0.97	15.2
SCATC 93/114	72	5	20.52	23.58	1.04	6.9
PB 5/51	21	7	20.24	26.36	1.10	33.3
SCATC 88/13	6	3	20.77	31.20	1.32	50.0
GT 1	30	2	18.00	17.28	1.12	6.7
RRIM 600 (Check clone)			14.3	28.7	1.58	
RRII 105 (Check clone)			14.1	11.8	1.16	
RRII 429 (Check clone)			15.1	16.1	0.87	

respectively (Fig. 1). Whether the high productivity of the high yielding selections can be realised even after budding onto heterogenous root stock needs further investigation. A deviation in yield of budgraft with respect to mother tree yield due to the effect of budgrafting was reported by Pathiratna *et al.* (2007). They reported that the yield of clones of high yielding mother trees were significantly reduced on budding while the yield of clones from moderate yielding mother trees did not show any significant difference, and they attributed it to the combined effect of budgrafting and stock scion interactions. But a significant correlation was reported between yield and girth in early clonal phase as well as in juvenile phase in rubber (Licy *et al.*, 1990). Mean girth of the selected genotypes (20.2 cm) was 32.9 per cent higher compared to the unselected population, while mean test tap yield of selections (25.52 g $t^{-1}10t^{-1}$) was 136 per cent higher compared to the original population (10.81 g $t^{-1}10t^{-1}$).

In the present study it was observed that PB 86 (27.1%), RRIM 600 (21.1%) and Tjir 1(22.1%), which gave more than 20 per cent selection from their respective half-sib progenies along with higher mean yield as well as yield per unit girth are likely to be prepotent (Table 5). Mydin *et al.* (1996) identified that high performance of progenies coupled with a high proportion of superior seedlings within the progeny was indicative of the ability of a parent to transmit superior traits to its offspring. RRIM 600 is the most popular clone in North East India, which is a non-traditional rubber growing area, and is the progeny of Tjir1 x PB 86. Hence, the prepotency of the said clones may be due to the existence of genetic factors favouring high yield as well as adaptability to the agro-climate of this region. Similarly, the popular clone of the traditional region RRII 105 has been reported to be prepotent when tested in traditional region (Saraswathyamma and Panikkar, 1989; Mydin *et al.*, 2002; Sebastian and Saraswathyamma, 2005). Apart from its advantage of being prepotent, utilisation of PB 86 as female parent in future breeding programmes for North East India will help

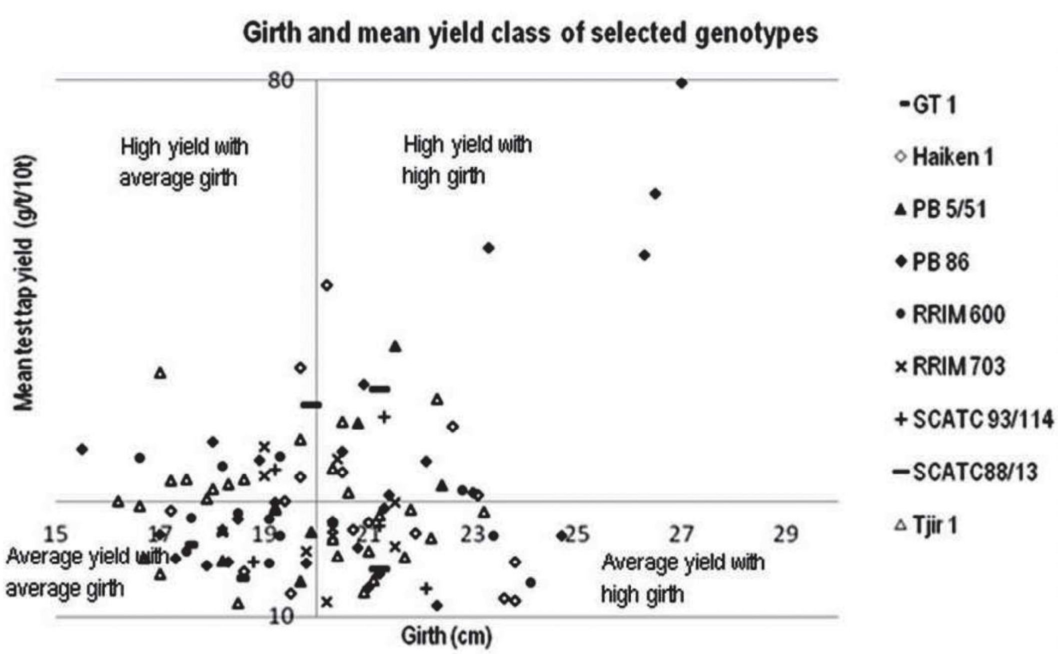

Fig. 1. Distribution of selected genotypes in different girth and yield categories

to introduce variability in cytoplasmic genes. Since most of the commercially cultivated rubber clones have cytoplasm from Tjir 1 or PB 56 (Priyadarshan and Goncalves, 2003), primary clones like PB 86 which are reported to be less similar to Tjir 1 (Antony , 2011) can improve the variability in the cytoplasmic gene pool of *Hevea.*

The findings of the present study indicates that half-sib progeny analysis can be successfully utilised for identification of high yielding genotypes through careful selection of clones as female parent. Identification of PB 86, RRIM 600 and Tjir 1 as prepotent clones based on superior performance of progenies and higher proportion of superior progenies in their families will aid in their utilisation in future breeding programmes in North East India. Information on the higher as well as more uniform girth attainment of seedlings in the SCATC 93/114 progeny family suggests the potential of utilising the clone for raising root stock population and needs further investigation. The selected genotypes in the study will be further evaluated after budgrafting for assessing their suitability, in terms of early tappability, high yield and biotic and abiotic stress tolerance, for commercial cultivation in North East India.

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