IDENTIFICATION OF PREPOTENT FEMALE PARENT CLONES FROM HALF-SIB PROGENY ANALYSIS OF *HEVEA BRASILIENSIS* AT EARLY STAGE-AN ALTERNATE APPROACH TO HYBRIDIZATION UNDER SUB-HIMALAYAN WEST BENGAL

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Seven promising clones, screened on the basis of their performance over 12 to 15 years under the cold prone agro-climate of sub-Himalayan West Bengal, were evaluated as parents in polycross breeding by evaluation of their open pollinated half-sib progenies. Weight of seeds of RRII 429 was significantly higher than that of RRIM 600 while that of SCATC 88/13 was at par with RRIM 600. Viability of seeds from RRIM 600 and RRII 429 was above 95 per cent, while viability of SCATC 88/13 seeds was low. Among the half-sib progenies of the seven promising clones, performance of progenies of SCATC 88/13 was the best in terms of mean juvenile yield and yield efficiency, despite its low seed weight and viability. Moreover, supremacy of this clone was also evident while selecting half-sib progenies showing above average yield as well in the final screening process. Out of the 28 progenies from different mother clones showing yield efficiency >0.3 g t^{-1} t^{-1} cm^{-1} girth, 21 progenies belonged to SCATC 88/13 indicating prepotency of this parent clone of Chinese origin. This was the first time a wild Amazonian accession (RO 5363) was used in polycross breeding and the half-sibs produced by this clone had the second largest number of juvenile high yielders after SCATC 88/13. These clones generated more number of superior progenies than the Class 1 clones RRIM 600 and RRII 208. For further cloning and evaluation of potential genotypes for the agro-climate of sub-Himalayan India, 34 selected progenies (40% of the top yielders) would be conserved in source-bush nursery. The results also suggest that clones SCATC 88/13 and RO 5363 may be good female parents for further hybridization programs in cold prone regions.

Key words: Half-sibs, Juvenile yield, North-East India, Polycross breeding, Prepotency, Wild Amazonian accession

INTRODUCTION

Success of breeding by hybridization in *Hevea* depends to a large extent on the weather conditions prevailing during the hybridization programme. *Hevea* breeding programme in cold prone North Eastern regions of India suffer from fluctuations in weather parameters during the breeding

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season. High speed wind during the time of seed set and invasion of powdery mildew disease affects flowering and fruit set. Based on earlier reports (Mydin *et al.*, 1992), attention was given to selection from open pollinated half-sib progenies, from known female parents. Due to diversity of the unknown male parents, the behaviour of the progeny is expected to vary. Screening of half-sib progenies derived from desirable high yielding clones selected as female parents that are open pollinated by surrounding male parents can provide a large number of progenies thereby improving the efficiency of selection. Half sib progeny selection has been earlier attempted in different agro-climatic conditions *viz*. Kerala (Mydin, 1990; Chandrasekhar and Gireesh, 2009), Karnataka (Narayanan and Mydin, 2016), Tripura (Antony *et al.*, 2014) and Meghalaya (Chandra *et al.*, 2016). Performance of *Hevea* seedlings from diverse regions in the agro-climate of sub-Himalayan West Bengal has been reported by Das *et al*. (2016).

In the present study, screening of half-sib progeny of *Hevea* was attempted under the agro-climate of sub-Himalayan West Bengal, predominated by severe low winter temperature (chilling cold), high speed wind and high rainfall. Seeds of known female parents which performed well in North eastern India were collected from mature clonal mother trees grown at Nagrakata. The objectives in northern West Bengal were to evaluate half-sib families derived from promising *Hevea* mother clones to identify superior progenies that can be used for evolving locally adapted clones. Such an attempt would help generate more region-specific *Hevea* clones for North-East India (Mydin, 2014).

MATERIALS AND METHODS

The experiment was conducted under the agro-climate of Nagrakata, Jalpaiguri - the sub-Himalayan region of West Bengal where average annual rainfall is as high as 3667 mm (Table 1) and the winter is very cold (mean T_{min} 18.5°C) with temperature going below 8°C every year, long sunshine duration (4.7 hr) and high wind speed.

A total of 1750 seeds were collected from trees of seven clones of different parentage (Table 2) from four clone trials planted in RBD under the agro-climate of sub-Himalayan West Bengal at Nagrakata. Mother trees were chosen on the basis of their overall yield potential over 12 to 15 years, winter yield contribution, tolerance to powdery mildew disease, wind tolerance and growth potential. Mature fruits were collected from individual trees from different plots of each clone in September 2012. Recorded the weight of 50 random seeds collected from each clone. Seeds were then germinated and per cent germination was noted. Seedlings with high vigour from each family were chosen for planting in the field for further evaluation. Seedlings were raised in polybags. Simultaneously, bud grafted polybag plants of each mother clone were also raised for

Table 1. **Climatological parameters of Nagrakata, West Bengal**

Geographical Position	Climatological Means				
	T_{max} (°C)	T_{min} (°C)	SS (hr)	Rainfall (mm)	WS (kmhr^{-})
Latitude 26°512 N	29.9	18.5	4.7	3667	1.30
Longitude 88°572 E	±	±	±	±	±
Altitude 69 m MSL	0.29	0.56	4.85	34.62	0.11

SE of means – on monthly basis

comparison (check). Polybag plants (seedlings as well as bud grafted mother clones) were planted in the field next year in July/August in replicated plots in a randomized block design (3 replications; 36 plants per replication, thus 108 seedlings per clone) with a spacing of 2 mx2 m. Bud grafted clones were planted as border plants around the replication of each progeny. All cultural practices were followed as per the recommendation for maintaining the nursery. Survival percentage in the field was noted.

Girth of all the plants was measured at 30 cm height after one year of field planting at six monthly intervals. Girth at 50 cm height was taken on 5th year of growth also. Test tapping was conducted in the third and fourth year of planting by the modified method of Hammaker-Morris-Mann during monsoon (July/August) and winter (November/ December) period. Rain guarding was fixed for conducting tapping during rainy season. At 30 cm height, fifteen consecutive tapping were conducted in S/2 d3 6d/7 system and the first-five crop harvest was discarded for yield stabilization. Latex from the 6th to 15th tapping was cup-coagulated and cup lumps from 10 tappings on each plant were pooled. Fresh cup lumps were smoke dried and weighed for recording the mean of dry cup lump yield from 10 tappings following Mydin *et al*. (2005). Coefficient of variation over individual data scored was calculated between plants of each progeny seedling / check plants. Yield efficiency was calculated in terms of yield per unit girth (g t^{-1} t^{-1} cm^{-1} girth at 30cm height). Analysis of variance was done as per standard statistical procedure.

RESULTS AND DISCUSSION

Open pollinated seeds of half-sib progeny were collected from seven promising clones which were cultivated under the agro-climate of sub-Himalayan West Bengal at Nagrakata. Wide variations were observed in seed weight. Mean weight of fifty seeds from RRII 429 was significantly higher than that of RRIM 600 while the weight of seeds collected from other clones was at par with RRIM 600 indicating that weight of seeds of RRII 429 was superior to all the other clones (Table 3). Viability of seeds (germination percentage) was similar for RRIM 600, RRII 429 (above 95%) and it was the lowest in SCATC 88/13. Survival of plants in the field after two years was comparable for all clones.

Most breeding programmes involve tree selection at the juvenile age. Immature vigour of seedlings in terms of girth was found to be important in progeny analysis in *Hevea* (Gireesh and Pravitha, 2009). In *Abies alba*, stem diameter and height was found to be important 6 - 10 years after field

Table 2. **Details of parentage of mother clone from which progenies were raised**

Mother Clone	Country of origin	Parentage	Annual yield over 12 to 15 years (g t^{-1} t^{-1})
RRII 208	India	Mil 3/2 x AVROS 255	42.22
RRII 417	India	RRII 105 x RRIC 100	57.38
RRII 422	India	RRII 105 x RRIC 100	54.57
RRII 429	India	RRII 105 x RRIC 100	63.72
SCATC 88/13	China	RRIM 600 x Pil B 84	47.66
RO 5363	Wild Amazonian Accession		41.56
RRIM 600	Malaysia	Tjir 1 x PB 86	40.95

Table 3. **Seed weight and germination potential of half-sib progenies**

Progenies of clone	Number of seeds tested	Average wt. of fifty seeds (gm)	Viability of seeds (%)	Number of progeny seedlings in the field	Survival after two years of field planting (%)
RRII 208	150	219	93	108	100
RRII 417	150	193	90	108	98
RRII 422	150	236	84	108	99
RRII 429	150	337	95	108	100
SCATC 88/13	150	207	72	108	94
RO 5363	150	197	83	108	95
RRIM 600	150	196	97	108	98
CD (P≥0.05)		125			

planting (Mihia and Mirancea, 2016). In half-sib progeny analysis of *Hevea* under the agroclimate of Kerala, growth potential could be identified only after one year of field establishment (Abraham *et al.,* 2017). Growth performance of half-sib progenies was found to be comparable and variability in girth increased from 1st to 3rd year of age (Chandrasekhar and Gireesh, 2009). Girth at 5th year in the present study showed that at 30 cm height (Table 4), mean girth of progenies from RRII 429, RRII 422 and RRII 208 was significantly higher than that of RRIM 600. Girth of bud grafted plants of the check clones in comparison to that of the progenies of the corresponding clones showed that in most of the cases, plants raised from half-sib progeny was superior/ similar to that of the check clones except in RO 5363 and RRIM 600 where girth of check clone was superior to that of the progenies. In a study on early selection of bud grafted *Hevea* clones in field under the agro-climate of Sao Paulo, Brazil, girth especially vigour at 2nd year (Goncalves *et al*., 2005) was found as one of the traits having high accuracy (Souza *et al.*,2017). Girth increment over five years after planting in RRII 422 and RRII 429 was significantly higher than RRIM 600 among progeny families followed by

Table 4. **Growth of different seedling progenies in field condition**

Clone	Mean girth of progeny* (cm)	Mean girth of budgrafted check clone* (cm)	Annual girth increment of progenies (cm year^{-1})
RRII 208	31.6	35.4	4.1
RRII 417	30.8	28.4	4.2
RRII 422	31.7	25.9	4.6
RRII 429	34.0	30.2	4.7
SCATC 88/13	28.6	23.0	3.6
RO 5363	29.3	31.9	3.8
RRIM 600	20.6	24.8	2.8
CD (P≥0.05)	10.51	7.8	1.6

*5th year of planting at 30cm height

Table 5. **Yield performance of half-sib progenies during pre-winter and winter period**

Progenies of clone	Juvenile yield (g t^{-1} $10t^{-1}$)				Juvenile yield efficiency (g $t^{-1}t^{-1}cm^{-1}$ girth)			
	Monsoon	Winter	Mean	CV (%)	Monsoon	Winter	Mean	CV (%)
RRII 208	19.8	42.9	31.4	54.1	0.06	0.13	0.10	50.3
RRII 417	19.1	52.5	37.0	70.3	0.06	0.17	0.12	62.1
RRII 422	16.1	37.9	27.1	82.0	0.05	0.12	0.08	74.2
RRII 429	19.5	46.9	32.4	72.1	0.06	0.16	0.10	64.4
SCATC 88/13	30.3	61.5	63.7	68.9	0.10	0.20	0.20	54.1
RO 5363	22.3	42.0	33.0	85.1	0.07	0.13	0.11	67.9
RRIM 600	13.4	31.6	22.9	75.7	0.06	0.13	0.10	55.9
CD (P≥0.05)	7.6	13.9	18.8		0.02	0.04	0.06	

families of RRII 417 and RRII 208. Significant high annual girth increment in progenies compared to the reference clones was also reported under the agro-climate of Tripura (Antony *et al.*, 2014).

Juvenile yield was recorded at 3rd and 4th year during monsoon and winter seasons. The progenies from SCATC 88/13 showed extraordinary performance in both the seasons in terms of yield from 10 tappings as well as in yield efficiency (Table 5). The annual mean yield in the progeny of RRIM 600 was poor compared to progenies from SCATC 88/13 and RO 5363. Progenies of RO 5363 gave significantly high yield during monsoon. Similarly, during cold season, progenies of SCATC 88/13, RRII 417 and RRII 429 showed significantly higher juvenile yield. In terms of mean yield of these two seasons, only progenies of SCATC 88/13 showed significantly higher yield than that of RRIM 600 which had lowest yield. Variation in yield (CV %) among the individual plants within progenies of RO 5363 was very high followed by RRII 422 while in RRII 208, it was low. Juvenile yield efficiency of progenies from RRII 422 showed poor performance whereas, - yield efficiency of progenies from SCATC 88/13 and RO 5363 was significantly higher in monsoon. Yield efficiency of progenies of SCATC 88/13 was significantly higher during winter period as well. In SCATC 88/13, mean yield efficiency of both the periods was

Table 6. **Men juvenile yield of bud grafted plants of female parent clones**

Bud grafted check clone	Juvenile yield (g t^{-1} $10t^{-1}$)			
	Monsoon	Winter	Mean yield	CV (%)
RRII 208	26.3	40.0	36.0	68.4
RRII 417	24.0	67.4	45.6	38.7
RRII 422	26.0	50.0	39.1	64.6
RRII 429	32.3	57.8	37.5	39.2
SCATC 88/13	40.2	63.5	50.0	39.5
RO 5363	19.3	39.2	21.0	91.4
RRIM 600	15.7	51.9	32.6	40.0
CD (P≥0.05)	11.5	15.4	13.2	

higher than that of RRII 422 which showed the lowest yield. High variations in mean yield were observed in progenies of RRII 422 compared to that of SCATC 88/13 indicating better and more uniformity in performance of the progeny of the latter. Better juvenile yield performance of progenies from SCATC 88/13 was also observed under the agro-climate of Mohanpur, Tripura (Antony *et al.*, 2014).

Among the bud grafted mother clones also, the juvenile yield performance of SCATC 88/13 was superior to that of RRIM 600 during both monsoon and winter seasons (Table 6). During winter period, clones RRII 417 and RRII 429 also showed better yield than RRIM 600. Juvenile yield variation within plots in check mother clone of RO 5363 was the highest followed by RRII 208 and RRII 422 whereas, it was low in RRII 417, RRII 429 and SCATC 88/13. The juvenile yield performance of RRII 429 was found to be a mid-performer compared to that of RRII 414 which showed better performance under the agro-climate of Kottayam, Kerala (Chandrasekhar and Gireesh, 2009).

The first and foremost step undertaken for selection was identification of the progenies showing above average population mean (mean of monsoon and winter yields) in terms of juvenile yield (g t^{-1} $10t^{-1}$) as well as juvenile yield efficiency (g t^{-1} t^{-1} cm^{-1} girth). The percentage of plants showing above average yield and yield efficiency from the population mean was 31.4 and 22.5, respectively (Table 7). This indicates the fairly good success rate of obtaining desirable selections from the half sib progenies. Therefore polycross breeding can be considered as a viable alternative to conventional bi-parental breeding by hybridization with the process being less cumbersome as also reported earlier (Mydin *et al.*, 1996; Mydin, 2011). Contribution of SCATC 88/13 in respect of superior seedlings was the highest while that of RRIM 600 and RRII 422 was the lowest. When the performance of the two Class I clones of North - East India (RRIM 600 and RRII 208) were taken as the reference point, recovery of plants in the whole population showing yield above the mean of RRIM 600 and RRII 208 was 49.6 and 36.7 per cent, respectively. Performance of progenies showing above average yield of the two check clones was the best in SCATC 88/13 followed by RRII 417. Half sibs of RRII 422 showed poor performance compared to that of the other progenies.

For a further refinement of selection, out of the selected population of superior

Table 7. **Recovery of superior genotypes within progenies**

Progeny of clone	Progenies showing above population mean yield (%)	Progenies showing above population mean yield efficiency (%)	Progenies showing above mean yield of RRIM 600 (%)	Progenies showing above mean yield of RRII 208 (%)
Total plants	31.4	22.5	49.6	36.7
RRII 208	5.4	5.3	-	-
RRII 417	5.2	5.8	54.6	41.7
RRII 422	2.5	2.9	36.1	23.2
RRII 429	4.9	4.3	53.7	38.9
SCATC 88/13	7.3	8.2	63.0	51.9
RO 5363	3.7	3.6	40.7	27.8
RRIM 600	2.4	3.4		

Table 8. **Top 40 per cent potential performers at fifth year within the above average population**

Progeny	Girth at 30 cm height (cm)	Juvenile yield ($g\ t^{-1}\ 10t^{-1}$)	Juvenile yield efficiency ($g\ t^{-1}t^{-1}cm^{-1}$ girth)	Proportion of selection among above average population yield (%)	
				Juvenile yield	Juvenile yield efficiency
RO 5363 P 20/3	42.5	138.6	0.4		
RO 5363 P 20/7	45.2	122.5	0.3		
RO 5363 P 20/24	43.6	108.7	0.3		
RO 5363 P 20/30	42.5	99.7	0.3		
RO 5363 P 7/32	45.6	96.8	0.2		
Population mean	43.9	113.2	0.3	2.1	2.0
RRII 417 P 3/5	39.0	95.6	0.3		
RRII 417 P 9/2	43.5	100.6	0.2		
RRII 417 P 9/4	40.5	126.4	0.3		
RRII 417 P 9/10	32.0	132.8	0.4		
Population mean	38.8	113.8	0.3	1.7	1.6
RRII 422 P 8/7	47.5	94.6	0.2		
RRII 422 P 8/16	47.5	116.4	0.2		
Population mean	47.5	105.5	0.2	0.8	0.8
RRII 429 P 15/4	45.1	114.4	0.3		
RRII 429 P 15/27	37.5	116.5	0.3		
RRII 429 P 5/4	39.7	97.7	0.3		
Population mean	40.8	109.5	0.3	1.3	1.2
SCATC 88/13 P 21/1	45.7	147.8	0.4		
SCATC 88/13 P 21/4	44.6	105.8	0.3		
SCATC 88/13 P 21/6	37.5	129.4	0.4		
SCATC 88/13 P 21/11	47.4	146.9	0.3		
SCATC 88/13 P 21/16	43.2	133.2	0.4		
SCATC 88/13 P 21/18	32.5	125.0	0.4		
SCATC 88/13 P 21/20	51.2	102.4	0.2		
SCATC 88/13 P 21/30	52.7	151.5	0.3		
SCATC 88/13 P 21/34	46.2	110.2	0.3		
SCATC 88/13 P 6/9	32.5	103.1	0.3		
SCATC 88/13 P 6/13	33.5	112.4	0.4		
SCATC 88/13 P 6/21	46.2	115.7	0.3		
SCATC88/13 P 14/7	46.6	139.4	0.3		
SCATC88/13 P 14/9	49.2	156.2	0.4		
SCATC88/13 P 14/15	38.7	116.1	0.3		
SCATC88/13 P 14/17	50.8	120.1	0.3		
SCATC88/13 P 14/18	34.3	99.4	0.3		
SCATC88/13 P 14/26	47.8	183.3	0.4		
SCATC88/13 P 14/27	46.4	137.6	0.3		
SCATC88/13 P 14/33	39.2	125.2	0.3		
Population mean	43.3	128.0	0.3	8.4	7.9

seedlings, the top 40 per cent high yielding seedlings with yield efficiency 0.2 g $t^{-1} t^{-1} cm^{-1}$ girth or above were considered (Table 8). A total of 34 seedling progenies were in this group out of which, the proportion of progenies from SCATC 88/13 was the highest followed by RO 5363. Not a single progeny from the mother clone RRIM 600 or RRII 208 figured in this elite group indicating their poor performance as female parents of half-sib progenies. Five seedling progenies showed yield efficiency above 0.4 g $t^{-1} t^{-1} cm^{-1}$. The best performer was SCATC 88/13 P14/26 where both girth and yield efficiency was promising. This was followed by SCATC 88/13 P21/18 of which yield efficiency was as high as 0.43 g $t^{-1} t^{-1} cm^{-1}$, but girth was low.

In open pollinated progenies obtained from parental clones selected phenotypically in *Hevea brasiliensis* population, it was reported that during initial period, location wise selection of growth and yield simultaneously is important (Gouvea *et al.*, 2013). While plotting the girth with yield of the top 40 per cent population (Fig. 1), it was noted that maximum distribution was on the side of low girth with low average yield efficiency and high girth with average yield efficiency. Out of 34 potential progenies, 16 progenies were under the category of high girth with high yield efficiency which is a very high proportion of plus plants. As the growers' interest has shifted from only high yield to, high yield with comparatively shorter juvenile phase, screening progenies with high vigour and high juvenile yield at immature phase would be of immense importance (Gireesh *et al.*, 2017).

The fact that among the half-sib progenies of the seven promising clones, performance of the progeny of SCATC 88/13 was the best merits special attention. In terms of mean juvenile yield and yield efficiency and in comparison to that of the two check clones

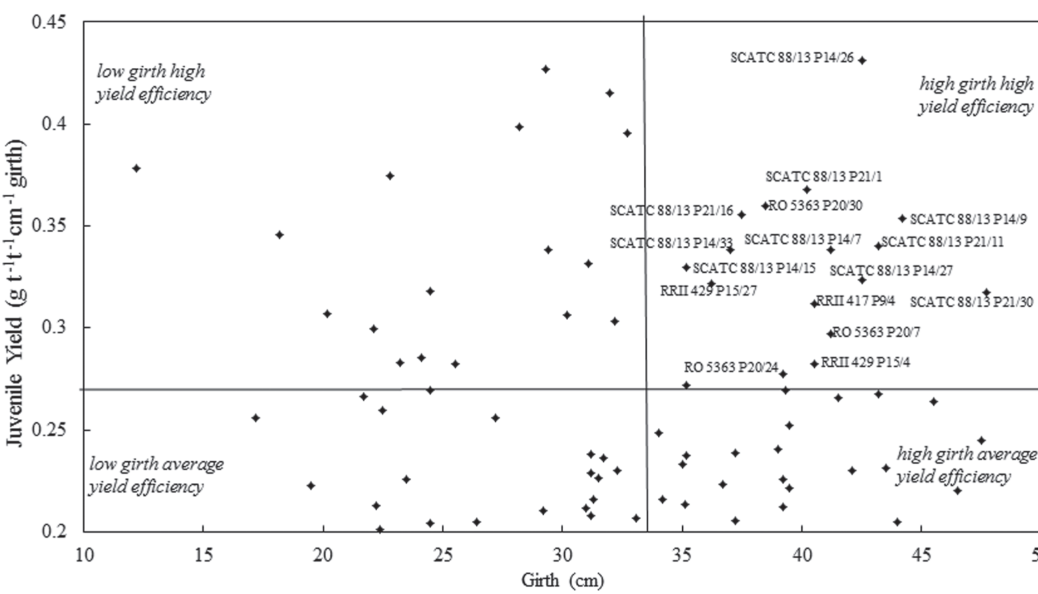

Fig. 1. Girth at 30 cm height vs juvenile yield efficiency of the top 81 progenies (median line based on mean of 81 selected progenies)

(Table 7) performance of progenies of this particular clone was the best under the agro-climate of sub-Himalayan West Bengal, though seed weight as well as viability of this progeny was low. It is reported that the Chinese clone SCATC 88/13 is cold acclimatized and showed remarkable potential in terms of yield under the cold agro-climate of sub-Himalayan West Bengal (Das *et al.*, 2010) as well as in Tripura (Priyadarshan *et al.*, 1998, 2000) though under the agro-climate of Kerala, this clone was reported to be unsuitable (Chandrasekhar, 2017). While selecting half-sib progenies showing above average yield as well as in the final screening process of 40 per cent of top yielders, dominance of SCATC 88/13 was noticed. This indicates the prepotent ability of the clone to transmit its characters to the offspring. Among the 28 progenies from different mother clones showing yield efficiency of 0.3 g t^{-1} t^{-1} cm^{-1} girth and above, 21 progenies belong to SCATC 88/13 ensuring better genetic gain under that agro-climate. The wild accession from Rondonia, RO 5363 was also introduced in the half-sib breeding programme with much success for the first time in India indicating its potential for use in breeding for North- East India. All the selected 34 progenies (Table 8) would be preserved in bud wood nursery for cloning and further field evaluations to develop suitable clones for the agro-climate of North - East India.

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