POTENTIAL GROWTH AND YIELD IN SELECTED BRAZILIAN WILD *HEVEA* GERMPLASM IN INDIA

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Twenty-two potential wild *Hevea* accessions along with three modern clones *viz*. RRII 105, RRIM 600 and RRII 208 were evaluated in the seventh to eleventh years of growth in the traditional rubber growing region of Kerala, India. Highly significant clonal differences were observed for yield and growth traits, except bole height. RO 2629 had the highest yield of 29.4 g t^{-1} t^{-1} followed by AC 716 (24.9 g t^{-1} t^{-1}) and AC 4149 (23.6 g t^{-1} t^{-1}), respectively. RO 2629 also had the highest girth, girth increment per year over four years and bole volume. The girth in the seventh year ranged from 26.9 cm (RO 287) to 47.8 cm (RO 2629); girth increment from 3.6 cm (RO 3804) to 6.7 cm (RO 2629); branching height from 2.2 m (RO 3804) to 3.1 m (MT 2233); wood quantity from 0.03 m^3 (RO 3804) to 0.10 m^3 (RO 2629). PCV was higher than the GCV for all the characters and the highest PCV was recorded for mean yield over two years. Heritability was also high for mean yield. Girth was significantly correlated with girth increment and wood quantity. RO 2629, MT 2233, AC 4149 and AC 626 ranked top with the maximum number of desirable traits. Having a different genetic background from the traditional Wickham clones, these accessions will serve to broaden the genetic base of present-day cultivated *Hevea* by introgression into the elite cultivars.

Key words: Genetic variability, *Hevea brasiliensis*, Heritability, Potential genotypes, Wild germplasm

INTRODUCTION

The Para rubber tree (*Hevea brasiliensis*) belongs to the family Euphorbiaceae and indigenous to the Amazon rainforests of Brazil. This crop is domesticated in the Southeast Asian countries including India and the natural rubber obtained from this tree is in high demand due to its enormous industrial applications. Asia accounts for 92.7 per cent of the global natural rubber (NR) production, where as India is the fifth largest producer and second largest consumer of NR. The rubber tree is cultivated in over 7,95,135 ha in India during 2014-15, with a production of about 6,45,000 tonnes and an average productivity of 1,443 kg ha^{-1} (ANRPC, 2016).

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 4548 accessions are being conserved in source

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bush nurseries in India, and are under different stages of evaluation. Preliminary studies in some of these accessions showed promising yield and other yield contributing secondary traits, which has to be confirmed in further detailed evaluation trials. One such set of wild accessions, selected for juvenile yield, girth and number of latex vessel rows on the basis of preliminary nursery studies, was planted in a field trial for further evaluation. The present study was undertaken to evaluate their performance in the early mature growth phase, to ascertain the extent of genetic variability in this population, to understand the associations among different traits and identification of potential genotypes.

MATERIALS AND METHODS

Twenty two accessions selected based on juvenile yield, girth and number of latex vessel rows, from the preliminary nursery studies were planted in a field trial for further evaluation at the Central Experiment Station of the Rubber Research Institute of India, Chethackal, Kerala, India. The trial was laid out in simple lattice design, with four replications and three controls *viz*. RRII 105, RRII 208 and RRIM 600 during 2003. 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, 11 from Mato Grosso and six from Rondonia provenance.

Annual girth at 150 cm height from the seventh year onwards was used for this study. In the ninth year, trees were opened for regular tapping and tapping was carried out in S/2 d3 system at a height of 125 cm. Yield in the first two years of tapping was recorded once in a month in the form of cup lumps by cup coagulation method and expressed as g t^{-1} t^{-1}. In the eleventh 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 four years was calculated using the girth data of seventh and eleventh 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 the data on girth in the 11th year, girth increment per year over four years, bole volume and mean annual yield over two years.

RESULTS AND DISCUSSION

Table 1 represents the mean and range values of the population in comparison with the three control clones for each of the eight traits in the early mature growth phase. The genotypes exhibited significant clonal differences (P=0.05) for all the quantitative traits studied except bole height. The mean yield per tree per tap in the 1st year of tapping ranged from 5.4 g t^{-1} t^{-1} (AC 605) to 34.6 g t^{-1} t^{-1} (RO 2629) with a general mean of 14.3 g t^{-1} t^{-1}. Among the wild accessions, RO 2629 was the highest yielder followed by AC 716 (30.5 g t^{-1} t^{-1}) and AC 4149 (29.4 g t^{-1} t^{-1}) whereas the control clones RRII 105, RRII 208 and RRIM 600 recorded 36.0, 25.4 and 30.4 g t^{-1} t^{-1}, respectively. Similar trend was observed in the 2nd year of tapping. Mean annual yield over two years was the highest in RO 2629 (29.8 g t^{-1} t^{-1}) followed by AC 716 (24.9 g t^{-1} t^{-1}), AC 4149 (23.6 g t^{-1} t^{-1}) and RO 3804 (21.6 g t^{-1} t^{-1}), whereas the control clones RRII 105, RRII 208 and RRIM 600 recorded 31.9, 21.6 and 27.6 g t^{-1} t^{-1}, respectively. High yield and growth performance of these

Table 1. **Variability for yield and growth related characters in wild *Hevea* germplasm**

Characters	Wild accessions			Control clones		
	Minimum	Maximum	General mean	RRII 105	RRII 208	RRIM 600
Yield ($gt^{-1}t^{-1}$)-1st year	5.3 (AC 605)	34.6 (RO 2629)	14.3	36.0	25.4	30.4
Yield ($gt^{-1}t^{-1}$ -2nd year	5.7 (MT 1057)	24.2 (RO 2629)	12.4	27.8	17.7	24.8
Mean yield ($gt^{-1}t^{-1}$) over 2 years	5.8 (AC 605)	29.4 (RO 2629)	13.6	31.9	21.6	27.6
Girth (cm) - 7th year	26.2 (MT 4529)	47.8 (RO 2629)	34.8	36.2	32.7	34.3
Girth (cm) - 11th year	42.4 (MT 4529)	73.2 (RO 2629)	53.5	54.8	44.7	50.9
Girth increment (cm $year^{-1}$) over 4 years	3.6 (RO 3804)	6.4 (RO 2629)	4.7	4.6	3.0	4.2
Bole height (m)	2.2 (RO 3804)	3.1 (MT 2233)	2.5	2.5	2.2	2.9
Bole volume (m^3)	0.03 (RO 3804, MT 4529, MT1009, RO 287)	0.10 (RO 2629)	0.05	0.05	0.03	0.05

Note: Figures in parenthesis denotes the name of accession

accessions in the immature phase (Rao *et al*., 2011) and also in the nursery stage (Rao *et al*., 1999) was reported.

In general, yield and vigour in *Hevea brasiliensis* are hardly separable (Simmonds, 1989). Apart from the role of girth in increasing yield, a vigorous habit in the early mature growth phase of the plant reduces the immaturity period. Girth of the trees at the age of seven years ranged from 26.2 cm to 47.8 cm. RO 2629 had the highest girth (47.8 cm) followed by AC 4149 (43.3 cm) and AC 626 (42.8 cm). The girth of the control clones ranged from 32.7 cm (RRII 208) to 36.2 cm (RRII 105). A similar growth trend was observed for the successive years. Girth and number of latex vessel rows (NLVR) are two important structural traits contributing to yield (Gomez, 1982; Hu *et al*., 2005; Zeng *et al*., 2005). Varghese *et al*. (1989), Rao *et al*. (1999), Rao and Reghu (2000, 2012) Abraham *et al*. (2002), Rao and Varghese (2011) and Rao *et al*. (2011, 2013), have also reported wide variation in the wild germplasm for growth and yield traits in traditional rubber growing region in India. Girth increment per year, which indicates the rate of growth of a clone, was assessed over the next four years. Highly significant clonal differences were observed for this trait, with RO 2629 recording the highest growth rate (6.4 cm $year^{-1}$), which was higher than that of check clone RRII 105 (4.6 cm $year^{-1}$).

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). A higher bole height is desirable as it increases the clear bole volume, and hence the timber potential of a tree. Bole height showed a range from 2.2 m (RO 3804) to 3.1 m (MT 2233), though clonal differences were not statistically significant. Azwar *et al*. (1995) and Rao *et al*. (1999, 2006 and 2011) have reported the tendency of wild *Hevea* germplasm to branch at a higher level than the Wickham clones. Significant clonal differences were observed for clear bole volume, which ranged from 0.03 m^3 (RO 3804, MT 4529, MT 1009 & RO 287) to 0.10 m^3 (RO 2629). The accessions RO 2629 (0.10 m^3),

MT 2233 (0.08 m^3), AC 4149 (0.06 m^3), MT 1707 (0.06 m^3) and AC 163 (0.06 m^3) recorded the highest timber volume while control clones RRII 105, RRII 208 and RRIM 600 recorded values of 0.05 m^3, 0.03 m^3 and 0.05 m^3, respectively.

Components of variation and heritability in the broad sense were estimated in the population. Very high phenotypic coefficient of variation (PCV) was observed for mean yield over two years (82.1) and bole volume (40), whereas it ranged from medium to low for the remaining traits (Table 2). Very high PCV (163.3%) for yield was also reported by Rao *et al*. (1999) in another set of wild *Hevea* germplasm. The genotypic coefficient of variation (GCV) was also high for mean yield over two years (60.0) followed by bole volume (28.3). The wide difference between PCV and GCV estimates for traits like mean yield over two years, 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. Mean yield over two years showed the highest heritability (53%), followed by girth and bole volume (50%) each. Heritability (H^2) of bole height was very low (8%). Earlier studies have also reported that broad sense heritability for yield in rubber is high (Simmonds, 1989). Rao *et al*. (1999, 2012, and 2013) 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.

Table 2. **Phenotypic and genotypic coefficients of variation and heritability for six quantitative characters in *Hevea* germplasm**

Characters	PCV	GCV	Heritability (%)
Mean yield over 2 years	82.1	60.0	53
Girth in 7th year	17.6	12.2	47
Girth in 11th year	16.8	11.5	47
Girth increment/ year over 4 years	26.1	14.5	31
Bole height	16.5	4.6	8
Bole volume	40.0	28.3	50

Simple correlation coefficients between pairs of different characters are presented in Table 3. Girth in the 7th year was significantly positively correlated with the girth of 11th

Table 3. **Correlation coefficients among eight quantitative characters**

Characters	Characters							
	Girth in 7th year	Girth in 11th year	Girth increment	Bole height	Bole volume	Yield in 1st year	Yield in 2nd year	Yield over 2 years
Girth in 7th year	1.00							
Girth in 11th year	0.91 **	1.00						
Girth increment over 4 years	0.51 *	0.82 **	1.00					
Bole height	0.32	0.45 *	0.49 *	1.00				
Bole volume	0.83 **	0.92 **	0.77 **	0.65 **	1.00			
Yield in 1st year	0.35	0.12	-0.23	0.14	0.23	1.00		
Yield in 2nd year	0.23	0.06	-0.20	0.18	0.21	0.95 **	1.00	
Yield over 2 years	0.31	0.10	-0.22	0.16	0.16	0.99 **	0.98 **	1.00

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

Table 4. **Ranking of wild accessions and control clones based on yield and growth parameters**

Accession/ Clone	Rank sum	Rank
RO 2629	99	1
MT 2233	77	2
AC 4149	75	3
AC 626	75	3
MT 1707	74	5
RO 297	74	5
RRII 105	70	7
AC 163	66	8
RO 3624	64	9
MT 3930	63	10
MT 1012	57	11
RRIM 600	57	11
RO 1739	52	13
MT 999	48	14
MT 196	48	14
AC 605	46	16
MT 4435	36	17
AC 716	35	18
MT 1057	33	19
MT 4529	29	20
RO 3804	28	21
MT 1009	27	22
RO 287	25	23
RRII 208	23	24
MT 1002	19	25
General mean	52	

year (0.91), girth increment per year over four years (0.51), and bole volume (0.83). But a non-significant relationship was obtained for crotch height and yield. Crotch height showed significant relationship with girth in the 11th year (0.445) and girth increment (0.49). Bole volume was more strongly correlated with girth in the 7th year (0.83), and 11th year (0.92), girth increment (0.77) and with bole height (0.65) and this is in line with the earlier report of Rao *et al.* (2011). Earlier studies by Narayanan *et al*. (1973), Ho (1976), Hamzah and Gomez (1982), Madhavan *et al*. (1996), Rao and Reghu (2000, 2012) and Zeng *et al.* (2005) also reported positive correlations between girth, girth increment and yield. A high correlation was observed between annual mean yield over two years and mean yield of 1st year (0.99) and 2nd year (0.98).

In order to identify accessions with maximum number of desirable attributes, the performance of accessions for each of the four characters was pooled using rank sum method (Table 4). Rank sum values ranged from 19 to 99 with a general mean of 52. RO 2629, MT 2233, and AC 4149, AC 626 ranked first, second and third, respectively with the maximum number of desirable traits. RO 2629, AC 716, AC 4149 along with RO 3804, which was ranked 1st, 18th, 3rd and 21st among the wild accessions, showed very high yield, comparable to, that of the control clones. Mercy (2001), Rao *et al.* (2006 and 2011), Rao and Varghese (2011), Rao and

Table 5. **Superior wild germplasm accessions for various traits**

Accession	Traits for which superior
RO 2629	Yield, girth, growth rate, bole volume, bole height.
AC 716	Yield, bole height.
AC 4149	Yield, girth, bole volume, bole height.
RO 3804	Yield
MT 4529	Yield
MT 196	Yield, bole height.
RO 3624	Girth, growth rate, yield.
AC 163	Growth rate, bole volume, yield
RO 297	Yield, bole volume, bole height, growth rate, girth.
MT 2233	Bole height, bole volume, growth rate, girth.
MT 1707	Bole volume, growth rate, girth, bole height.
AC 626	Girth, growth rate, bole volume, bole height.

Reghu (2012) and Rao *et al.* (2013) also reported similar ranking in wild *Hevea* while evaluating the Brazilian germplasm in India. These accessions had been picked initially from the nursery study for their test tap yield, vigour and number of latex vessel rows (NLVR), and continued to perform well in the current long term evaluation also. If the performance is maintained up to the mature phase too, they can be used as selections for latex timber clones. Since they have a different genetic background from the existing cultivated clones, their use in hybridization programs is more likely to yield heterotic recombinants. Top rankers displayed high girth and timber related traits, with an average yield. Table 5 gives the list of accessions identified as potentially superior for various traits.

CONCLUSION

The present study confirmed the presence of wide variability in the germplasm for most growth and yield contributing traits. Accessions with highly promising yield potential (RO 2629, AC 716, AC 4149 and RO 3804), good growth vigour (RO 2629, AC 626, MT 2233, AC 4149, MT 1707, MT 3930, RO 297 and RO 3624), bole volume (RO 2629, MT 2233, AC 4149, MT 1707, AC 626, RO 297 and AC 163) and other accessions showing superiority for individual traits (MT 2233, MT 1707, MT 3930, RO 297, AC 605, MT 1012 and MT 196), were identified, which could be of use in future crop improvement programs after assessment of their performance in the full mature phase. RO 2629 and AC 4149 had been originally selected on the basis of their yield and girth performance in the nursery stage, and continued to perform well in this present evaluation trial also. Since they are genetically diverse from the cultivated clones, transgressive segregation and heterosis can be expected on crossing these accessions with elite Wickham cultivars. Having a completely different genetic background from the traditional Wickham clones, these accessions will serve to broaden the genetic base of present-day cultivated *Hevea*, either by direct use or by introgression into elite cultivars.

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