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Variability and character associations in different sets of the 1981 IRRDB wild *Hevea* germplasm in India

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Abstract

India has received a large share of the *Hevea* germplasm collection of the 1981 IRRDB expedition. A total of 4548 wild accessions belonging to three states of Brazil *viz.*, Acre (AC), Rondonia (RO) and Mato Grosso (MT) are being conserved. Systematic efforts are underway for conservation, characterization, evaluation and documentation of these valuable genetic resources. Different sets of wild accessions are being evaluated parallelly in a phased manner from 1990 onwards and these on going trials are at various stages of evaluation. Here we report the salient findings of different sets of accessions from the preliminary and further evaluation stages. The present investigation revealed the existence of wide genetic variability in this collection and also significant correlations among various agronomical, morphological and yield traits.

Promising accessions were selected from the preliminary studies *viz.*, nursery/preliminary evaluation trials planted in close spacing. based on early growth and test tap yield. These potential selections were put in large scale trials in normal spacing for selection of superior accessions. Accessions showing potential for girth, bark thickness and number of latex vessel rows have also been identified for incorporation in breeding programmes. These will help in broadening the narrow genetic base of cultivated rubber.

Key words: Characterization, Conservation, Evaluation, Variation, *Hevea brasiliensis,* Wild germplasm.

Introduction

In para rubber (*Hevea brasiliensis*), yield improvement in the recent phases of breeding slowed down due to the extremely narrow genetic base of cultivated rubber. To mitigate this problem and also to collect and conserve the fast disappearing wild germplasm of *Hevea*, the IRRDB had conducted an expedition jointly with EMBRAPA of Brazil in 1981, in the Amazon forests of Brazil which resulted in collection of huge germplasm (IRRDB, 1982). India has received a share of it between 1984 and 1990 in batches, and is being conserved in the conservation-cum-source bush nurseries (SBNs) at two locations – one in traditional region in Kerala state and the other in the nontraditional region of the Northeast. Once the accessions were established in conservation nurseries, the next priority was to characterize and evaluate the germplasm, so that they could be used in crop improvement programmes. Considering the perennial nature of the crop, evaluation was taken up in a phased manner, planting one set of accessions every year based on the availability of land. All the wild accessions are to be subjected to a preliminary agronomic evaluation and then detailed evaluation in large scale trials, and are being evaluated parallel in a phased manner. The present study was under taken to assess the extent of variability present in the wild population and character associations for identifying desirable accessions.

Materials and Methods

Preliminary evaluation

During the first two decades after import of the accessions (up to 2002), the strategy had been to evaluate all the wild germplasm in a phased manner by taking random samples of accessions into preliminary evaluation trials (PETs) for studying their field performance. A preliminary evaluation trial (PET1994A), comprising a set of 24 wild accessions and control clone (RRII 105) was established in 2.5 x 2.5 m spacing at Central Experiment Station employing simple lattice design. Early yield was recorded through test tapping in the fourth year in ½ S d 3 system at a height of 30 cm for 2 months. Girth was recorded in the first five years of growth and girth increment per year was estimated over four years period. The characters assessed in the third year were plant height and crotch height and the data were subjected to statistical analysis.

Instead of direct evaluation of the accessions in field trials up to the mature stage, the preliminary evaluation is now being done in the newly re-established conservation nurseries in the first few years. Accessions that consistently perform well in comparison with the controls are then laid out in full-fledged field trials: those accessions showing 80% or more yield than the controls were planted in further evaluation trials. Two nurseries (SBN 2001 and SBN 2003) were laid out during 2001 and 2003 in augmented RBD at Central Experiment Station (CES), Chethackal, the traditional rubber growing region of Kerala state, India using two and four popular clones respectively, as controls with a plot size of five and a spacing of 1m x 1m. Juvenile growth data were collected in the first 6 and 3 years of growth respectively. One round of testtapping was done in all accessions in the 3rd and 2nd year of growth respectively and a second round of test tapping for selected accessions in the 5th and 3rd year in the SBNs 2001 and 2003 respectively, to identify potential high yielders. Data were recorded from 55 accessions from SBN 2001 comprising Acre (11), Mato Grosso (33) and Rondonia (11), along with RRII 105 and RRIM 600 as controls. At the age of 5 years, test tapping and bark anatomical studies were conducted. In another nursery study (SBN 2003), a total of 545 wild accessions *viz.*, Acre (223), Mato Grosso (86) and Rondonia (229) provenances and 7 other types along with four popular clones *viz.*, RRII 105, RRII 208, RRIM 600, PB 235 were included. The data were subjected to analysis of variance for augmented RBD (Petersen, 1994) and simple correlations were computed following the method of Panse and Sukhatme (1978).

Further evaluation

Selected accessions from various PETs are subjected to a detailed evaluation in further evaluation trials (FETs). FET 2003 was planted during 2003 in simple lattice design at CES with RRII 105, RRII 208 and RRIM 600 as controls. The trial consists of 22 wild accessions in four replications with a plot size of four. They belonged to Acre (5), Rondonia (6) and Mato Grosso (11) provenances. These accessions had originally been selected on the basis of preliminary information from various nursery studies on yield, girth or number of latex vessel rows in the initial years of germplasm evaluation. The performances of these genotypes in terms of growth and yield were evaluated at the age of 2 to 7 years for early

growth and anatomical traits. Test tapping was carried out during the 5th year at a height of 30 cm for two months. The data were subjected to analysis of variance for lattice design (Gomez and Gomez, 1984).

Results and Discussion

Preliminary evaluation

In a preliminary evaluation trial 1994A, highly significant difference was observed for juvenile yield and growth characters (Table 1). MT 1012 had the highest test tap yield of 2.53 g/t/t followed by RO 895 (1.79 g/t/t) and MT 940 (1.50 g/t/t), whereas the control clone RRII 105 recorded 6.33 g/t/t. In the first year after planting girth ranged from 4.81 cm (MT 932) to 7.81 cm (AC 757) and in the 5th year after planting it was 21.78 cm (AC 736) to 30.10 cm (MT 940). Girth increment per year ranged from 3.74 cm (AC 736) to 5.79 cm (MT 940), crotch height ranged from 2.49 m (MT 939) to 4.72 m (AC 757) and plant height from 4.74 m (MT 932) to 7.31 m (AC 757). The findings are in accordance with the earlier studies (Rao *et al*, 2006). The plant height was positively correlated with girth, girth increment and crotch height (Table 2). Vigorous accessions with promising test tap yield and good vigour (AC 757, MT 1012, RO 895, MT 940, RO 867 and AC 666), and other accessions showing superiority for individual traits (RO 263, MT 938, AC 664 and MT 930) were identified, which could be of use in future crop improvement programmes. Top accessions that have been identified so far as potential high yielders and also for individual secondary traits in comparison to the control clone RRII 105 will be evaluated in detail in statistically laid out further evaluation trials to confirm their yield potential.

The preliminary evaluation carried out in a set of 55 accessions in SBN 2001 showed significant variability for test tap yield, growth and structural traits (Table 3). Highest test tap yield was recorded in RO 5018 followed by RO 2841 and RO 5432. RO 5432 ranked top for girth and girth increment. MT 4771 recorded highest bark thickness and RO 2841 had the highest number of latex vessels. Diameter of latex vessels ranged from 10.69 µm (AC 5487) to 21.66 µm (MT4762). MT 4690 (5.14 m) recorded highest crotch height followed by RO 5442 (5.05 m) and MT 4772 (4.36 m). The yield was significantly correlated with bark

are two important structural traits contributing to yield (Gomez, 1982; Hu, 2005; Zeng, 2005). In the 7th year, girth ranged from 26.23 cm (MT 4529) to 47.75 cm (RO 2629). RO 2629 recorded highest girth followed by AC 4149 (43.25 cm) and AC 626 (42.79 cm) as compared to the control clone RRII 105 (36.19 cm), RRIM 600 (34.25 cm) and RRII 208 (32.69 cm). Highest number of latex vessels was observed in MT 999 (12.90) followed by AC 4149 (8.83), RO 2629 (8.81) and AC 716 (8.42) while control clone RRII 105, RRII 208 and RRIM 600 recorded 10.10, 7.56 and 8.56 respectively. These findings are in line with the earlier reports (Abraham *et al* 1992, 2000; Madhavan *et al* 1993; Mercy *et al* 1993, Rao *et al* 1996, 1999). The bole height ranged from 2.19 m (RO 3804) to 3.07 m (MT 2233), though the difference was not statistically significant. Azwar *et al.*, (1995) and Rao *et al.*, (1999 and 2006) have reported the branching tendency of wild *Hevea* germplasm at a higher level than that of Wickham clones. However, significant clonal differences were observed for clear bole volume, which ranged from 0.011 m^3 (MT 4529 & RO 287) to 0.041 m^3 (RO 2629). The accessions RO 2629 (0.041 m^3), AC 4149 (0.029 m^3), AC 626 (0.029 m^3), MT 2233 (0.028 m^3) and MT 1707 (0.023 m^3) recorded the highest timber volume while control clones RRII 105, RRII 208 and RRIM 600 recorded values of 0.021 m^3, 0.015 m^3 and 0.022 m^3 respectively.

Simple correlation coefficients between pairs of different characters are presented in Table 8. Yield was significantly positively correlated with girth of the same year (5th year) (0.604), bark thickness (0.533) and NLVR (0.504). It did not show any significant relationship with crotch height. Earlier studies by Narayanan *et al.* (1973), Ho (1976), Hamzah and Gomez (1982), Madhavan *et al.*, (1996), Rao and Reghu (2000) and Zeng *et al.* (2005) have also reported positive correlations between yield and girth, NLVR and bark thickness. The correlation observed here between yield and bole volume (0.549) was probably due to the correlation of both traits with girth. Bark thickness was also positively correlated with girth (0.613) but did not show any relationship with the number of NLVR. Rao and Reghu (2000) also did not find any correlation between bark thickness and number of laticifer rows, though other studies have found these traits to be positively correlated (Hamzah and Gomez, 1982; Madhavan *et al.*, 1996). High correlation between bark thickness and girth has also been reported earlier in wild *Hevea* germplasm by Momoh and Alika (1987), Licy and Premakumari (1988) and Madhavan *et al.*, (1996). NLVR and girth in the

thickness (0.361), number of latex vessels rows (0.510), latex vessel diameter (0.382), girth (0.352) and girth increment (0.368) (Table 4).

All accessions of SBN 2003 were evaluated at immature phase in the first three years for their early juvenile yield and growth characters such as girth, girth increment, plant height, crotch height and single leaf area. Highly significant clonal variability was observed for juvenile yield and all the growth characters *viz.*, girth, girth increment, plant height and crotch height except single leaf area (Table 5). The yield ranged from 0.3 g/t/t. (RO 2153) to 4.8 g/t/t. (AC 4394); girth ranged from 8 cm (AC 3559) to 19.4 cm (MT 200); girth increment from 1.1 cm (MT 2229, RO 5430) to 7.4 cm (RO 2846); single leaf area from 33.7 cm^2 (RO 2790) to 232.5 cm^2 (AC 3755); plant height from 2.4 m (AC 3559) to 7.5 m (7/118) and crotch height ranged from 1.7 m (AC 3559) to 5.5 m (AC 4114). Correlations worked out among the six quantitative traits revealed that yield was significantly correlated with all the growth characters except single leaf area (Table 6). Based on this study, the top 10% of the potential accessions showing early growth vigour and yield were identified. AC 1822, AC 4238, AC 4394, RO 3778, RO 3483, AC 2206, MT 187, RO 90, RO 2846, AC 176 were identified as vigorous genotypes with high yield and girth. The high yielders with good growth identified from this study also have high timber potential. The testapping of 600 accessions planted in 2001 and 2003 resulted in the identification of identification of 28 accessions with 80% and 38 accessions with above 50% of the yield of RRII 105. These accessions are now under evaluation in FETs, and the first set comprising 26 accessions has already been planted.

Further evaluation

Table 7 depicted the general mean and range for various traits in the further evaluation trial 2003. The genotypes exhibited highly significant differences ($P<0.01$) for all the quantitative traits studied except crotch height (NS) and bark thickness ($P=0.05$). The test tap yield ranged from 0.18 g/t/t (AC 605) to 7.68 g/t/t (RO 2629) with a general mean of 2.30 g/t/t. Among the wild accessions, RO 2629 was the highest yielder followed by AC 4149 (7.47 g/t/t), and AC 716 (5.02 g/t/t), whereas the control clones RRII 105, RRII 208 and RRIM 600 recorded 7.47, 4.01 and 4.36 g/t/t respectively. Girth and number of latex vessels

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present study were also positively correlated (0.526). There was no correlation between branching height and girth in the seventh year, though a relatively weak correlation was observed with girth in the fifth year (0.457). Bole volume was more strongly correlated with girth (0.954) than with bole height (0.545). The present study confirmed the presence of wide variability in the germplasm for most growth and yield contributing traits.

Conclusion

Wild germplasm is known to be a reservoir of variability and desirable genes. Analysis of data from the various field trials (nurseries, preliminary and further evaluation trials), on different sets of accessions has revealed wide variability and significant differences among the genotypes for most of the agro-morphologic traits, bark structural characters. Vigorous accessions with promising yield potential and good vigour (AC 2629, AC 4149 and AC 716), and other accessions showing superiority for individual traits (MT 999, AC 626, MT 2233, and MT 1707), were identified, which could be of use in future crop improvement programmes after assessment of their mature performance. AC 2629 and AC 4149 had been originally selected on the basis of their girth and yield performance in the nursery, and continued to perform well in this trial too. Since they are genetically diverse from the cultivated clones, transgressive segregation and heterosis can be expected on crossing these accessions with elite Wickham cultivars. In general yield and growth vigour in *Hevea brasiliensis* are hardly separable (Simmonds, 1989). High correlation observed between yield, growth and structural traits. Association of juvenile yield with other growth traits indicates the scope for selection of potential accessions. As expected, most of the wild accessions were low yielders compared to the popular Wickham clones. However, a few individual accessions with comparable or even higher yield than the popular clone RRII 105 have been identified in the early growth phase. Even if these accessions fall slightly below par in terms of yield, they may be highly desirable since their hybridization with cultivars is most likely to result in transgressives as the parents come from two entirely different gene pools. Incorporation of wild genes into the cultivated clones will improve the yield and simultaneously broaden the genetic base of the crop.

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Table 2. Correlation coefficients among six quantitative characters.

Characters	Characters				
	Girth (1st year)	Girth (5th year)	Girth increment	Crotch height	Plant height
Test tap yield	-0.169	0.312	0.388	-0.117	-0.042
Girth – 1st year after planting		0.415*	0.155	0.654**	0.713**
Girth - 5th year after planting			0.963**	0.282	0.631**
Girth increment (cm/year) over 4 years				0.113	0.474*
Crotch height					0.552**

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

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

Characters	Wild accessions			RRII 105	CV (%)
	Minimum	Maximum	General mean		
Test tap yield (g/t/t)	0.27 (AC 442, RO871)	2.53 (MT 1012)	1.00	6.33	47.00
Girth (cm) – 1st year after planting	4.81 (MT 932)	7.81 (AC 757)	6.41	5.81	10.25
Girth (cm) - 5th year after planting	21.78 (AC 736)	30.1 (MT 940)	25.86	27.13	8.72
Girth increment (cm/year) over 4 years	3.74 (AC 736)	5.79 (MT 940)	4.86	5.33	10.77
Crotch height (m)	2.49 (MT 939)	4.72 (AC 757)	3.05	2.84	14.73
Plant height (m)	4.74 (MT 932)	7.31 (AC 757)	6.16	5.63	7.77

Note: Figures in parenthesis denotes the name of accession.

Table 4. Correlation coefficients among eight quantitative characters.

Characters	Characters						
	Bark thickness	Total no of laticifer rows	Latex vessel diameter	Girth	Girth increment	Crotch Height	Single leaf area
Test tap yield	0.361**	0.510**	0.382**	0.352**	0.368**	-0.197	-0.311
Bark thickness		0.518**	0.220	0.737**	0.734**	0.054	-0.047
Total no. of laticifer rows			0.325**	0.311*	0.348**	-0.176	-0.302
Diameter of latex vessels				0.083	0.270*	-0.329	-0.249
Girth					0.815**	0.217	-0.052
Girth increment						-0.107	-0.072
Crotch height							-0.031

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

Table 3. Variability for yield, yield components and growth related characters in wild *Hevea* germplasm.

Characters	Wild accessions			Control clones		CV (%)
	Minimum	Maximum	General mean	RRII 105	RRIM 600	
Test tap yield (g/t/t)	0.04 (RO 5358)	11.19 (RO 5018)	1.17	2.88	5.82	41.97
Bark thickness (mm)	1.00 (AC 5896)	5.30 (MT4771)	2.76	3.17	3.08	15.14
Total number of laticifer rows	3.00 (MT 5824)	10.67 (RO2841)	6.39	9.74	8.41	21.98
Diameter (µm) of latex vessels	10.69 (AC 5487)	21.66 (MT4762)	16.74	17.19	18.42	25.23
Girth (cm) after 6th year of planting	10.75 (AC5896)	35.60 (RO5432)	20.62	21.56	20.54	20.91
Girth increment (cm/yr) over 3 years	0.50 (AC5466)	5.47 (RO 5432)	2.35	2.47	2.69	22.45
Crotch height (m)	1.88 (RO 5364)	5.14 (MT 4690)	3.04	2.65	2.46	14.09
Single leaf area (cm^2)	37.51(RO 5318)	150.40 (RO 5365)	69.34	52.68	56.46	22.93

Note: Figures in parenthesis denotes the name of accession

Table6. Correlation coefficients among six quantitative characters.

Characters	Characters				
	Girth	Girth increment	Single leaf area	Plant height	Crotch height
Juvenile yield	0.411**	0.408**	-0.088	0.242**	0.072
Girth		0.883**	0.274**	0.775**	0.454**
Girth increment			0.122*	0.624**	0.347**
Single leaf area				0.246**	0.194**
Plant height					0.605**

** Significant at P<0.01

Table 5. Variability for yield and growth related characters in wild *Hevea* germplasm.

Characters	Wild accessions			Control clones				CV (%)
	Minimum	Maximum	General mean	RRII 105	RRII 208	RRIM 600	PB 235	
Juvenile yield (g/t/t)	0.30 (RO 2153)	4.82 (AC 4394)	0.64	2.02	1.62	2.05	2.48	108.90
Girth (cm)	8.00 (AC 3559)	19.40 (MT200)	13.16	14.50	13.58	14.22	17.11	18.85
Girth increment (cm)	1.10 (MT 2229, RO5430)	7.37 (RO 2846)	3.97	4.82	4.30	4.28	5.73	26.12
Single leaf area (cm^2)	33.75 (RO 2790)	232.50 (AC 3755)	100.97	83.34	91.67	72.61	96.30	28.19
Plant height (m)	2.35 (AC 3559)	7.50 (7/118)	4.94	5.15	4.57	5.48	6.04	23.10
Crotch height(m)	1.75 (AC 3559)	5.48 (AC 4114)	2.63	2.41	2.22	2.72	3.18	24.39

Note: Figures in parenthesis denotes the name of accession.

Table 8. Correlation coefficients among eight quantitative characters.

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

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

Table 7. 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
Immature yield (g/t/t)	0.18 (AC 605)	7.68 (RO 2629)	2.30	7.49	4.01	4.36
Bark thickness (mm)	2.70 (MT 196)	5.16 (RO 2629)	3.84	4.19	3.38	3.77
No of laticifer rows	5.10 (RO 287)	12.94 (MT 999)	7.46	10.13	7.56	8.56
Girth (cm) - 5th year after planting	19.65 (RO 287)	36.50 (RO 2629)	26.88	29.31	27.81	28.38
Girth (cm) - 7th year after planting	26.23 (MT 4529)	47.75 (RO 2629)	34.80	36.19	32.69	34.25
Girth increment (cm/year)over 2 years	2.82 (MT 4435)	6.44 (AC 626)	3.96	3.44	2.44	2. 49
Crotch height (m)	2.19 (RO 3804)	3.07 (MT2233)	2.51	2.46	2.18	2.91
Bole volume (m ^{3})	0.011(MT 4529, RO287)	0.041 (RO 2629)	0.02	0.021	0.015	0.022

Note: Figures in parenthesis denotes the name of accession.