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Promising *Hevea brasiliensis* clones evolved by ortet selection with emphasis on latex – timber traits and response to stimulation

Kavitha K. Mydin, Alice John, M.A. Nazeer, E. Edwin Prem,
Vinoth Thomas and C.K. Saraswathyamma

Rubber Research Institute of India, Kottayam 686 009

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Abstract

An ortet selection programme was undertaken in a large estate in South India and the resultant 46 clones of rubber (*Hevea brasiliensis* Muell. Arg.) were evaluated in a small scale trial during the first five years of tapping. The parameters for evaluation were rubber yield and yield components, timber yield, response to stimulation and secondary traits like incidence of leaf and stem diseases. Significant clonal variation for the traits studied helped in the selection of 11 promising new primary clones. Promising rubber yielders, promising timber yielders , latex – timber clones and clones showing response to stimulation were identified. Five clones, MO 45, MO 7, MO 12, MO 28 and MO 48 were comparable in yield with the high yielding check clone RRII 105. Six clones, MO 15, MO 19, MO 45, MO 28, MO 12 and MO 50 had high bole volume and clones MO 49, MO 15 and MO 40 showed good response to stimulation. The superiority of the clones for specific traits is discussed.

Key words: Disease reaction, *Hevea brasiliensis*, latex- timber clones, ortet selection, response to stimulation

Ortet selection is one of the earliest methods of crop improvement in *Hevea brasiliensis* and has resulted in the release of a number of primary clones from Malaysia, Indonesia, Sri Lanka and India. Such primary clones have helped to achieve significant improvement in yield in the early years of rubber cultivation in the South East Asian countries (Khoo *et al.*, 1982). The term 'ortet' has been derived from the Latin word 'ortus' which means origin. Therefore, an ortet, is the original tree from which members of a clone have descended. This mass selection procedure, otherwise referred to as plus tree selection is participatory crop improvement as practised in rubber. It comprises the systematic screening of large heterogenous populations raised from seeds usually located in small and large growers' plantations, identification of superior trees, their cloning and subsequent evaluation in comparison to the popular clones. The first ortet selection programme in India has led to the release of clones of the RRII 1 to 10 series which have shown promising performance over the years (Nair and Jacob, 1968; Marattukalam *et al.*, 1990).

Conventionally, selection programmes for the genetic improvement of *Hevea brasiliensis* are undertaken with yield and related attributes as the sole criteria. In the present day scenario, modern exploitation techniques and yield stimulants are adopted for improving the economic viability of rubber plantations (Sivakumaran, 1994). Earlier reports have only dealt with the response of hybrid seedlings to yield stimulants in terms of test tap yield (Nazeer *et al.*, 1993) and of hybrid clones in terms of yield in the immature stage of four and a half years in the field (Licy *et al.*, 1992). The response of newly evolved clones to stimulation under regular tapping in the mature stage in the field, therefore needs to be explored. Rubber wood is fast gaining commercial significance with the concept of value addition through the manufacture of a variety of products. A phenomenal rise in the demand for rubber timber has been reported with the rapid growth of the rubber wood-based industry in Malaysia (Aziz, 2002). The value of new clones therefore needs to be assessed in terms of timber output also.

Address for correspondence: *Dr. Kavitha K. Mydin, Scientist S3, Rubber Research Institute of India, Kottayam 686 009*
E- mail: kavitha@rubberboard.org.in

The ortet selection programme reported here was undertaken in a large estate in South Kerala over a period of 15 years. This included evaluation of the newly developed primary clones along contemporary lines designed to meet the future requirements of the rubber plantation industry.

Materials and Methods

The base population for the ortet selection programme comprised of 88,688 trees raised from GG1 and GG2 polyclonal seedlings introduced from the Gough Gardens in Malaysia. These trees were planted in an area of 323.5 ha. during 1961 to 1965, in the Boyce estate of Harrisons Malayalam Ltd. at Mundakkayam, situated at a latitude of 9°38'N and a longitude of 76°55' E in South Kerala .

The selection programme was undertaken in 1987-1988 when the trees were tapped in panel BI-1. i.e. between 10 and 15 years of tapping. The tapping system followed was ½ S d/2. Based on preliminary observations on latex yield, 213 ortets were selected for detailed study on yield, growth and secondary attributes over a two year period. A batch of 56 ortets was finally selected out of which 43 were cloned and a nursery of source bushes was established. The experimental ortet clones were designated as the MO series after the location of the estate where this selection programme was undertaken. The clones were multiplied the following year for conducting a small scale evaluation at Mundakkayam estate of Harrisons Malayalam Ltd.

The small scale evaluation was done in two trials laid out in 1989 with two sets of clones, one set of 36 clones in a simple lattice design with four replications and another set of 13 clones in a randomized block design with three replications. The clones were planted in plots consisting of a linear row of five trees along contours adopting a spacing of 6.7 x 3.4m. and the check clones were RRII 105, RRIM 600 and GT 1 in both the cases. The simple lattice design facilitated the simultaneous comparison of a large number of ortet clones with the checks.

The trees were opened for tapping under the ½S d/3 system on attainment of seven years' growth. The clones were evaluated on the basis of growth and yield parameters in panel BO-1. The growth parameters included girth increment rate during the immature phase i.e. between the 3rd and 7th year after planting, girth at opening, girth increment rate under tapping estimated during the first four years of tapping, and height at forking. Timber yield was estimated at the age of 12 years in terms of clear bole volume following the Hoppus method (Chaturvedi and Khanna, 1982). Mean yield during the first four years of tapping was recorded by cup coagulation and weighing of smoke dried cup lumps at monthly intervals. Bark thickness and the number of latex vessel rows in the year of opening were determined microscopically following standard techniques. Yield components viz., volume of latex and dry rubber content (DRC) during the peak yielding season of October-November were recorded in the fourth year of tapping. Incidence of tapping panel dryness, pink disease and wind damage were recorded as percentage of affected trees. The intensity of abnormal leaf fall and powdery mildew in terms of PDI (percent disease intensity by visual scoring) were recorded during two consecutive years to identify clones with stable tolerance.

Response in yield of 16 selected clones to stimulation by panel application of 2.5 per cent Ethephon in oil was studied. Application of Ethephon was done in June and September during the fifth year of tapping. Yield was recorded by cup coagulation on all tapping days during the six month period from June to November. The percentage improvement over the pre treatment yields (mean yield during the corresponding period of the previous year and mean yield during the first four years of tapping) was then worked out to study the response to stimulation.

Data on yield, growth and secondary attributes were subjected to the analysis of variance to study the extent of clonal variation available for effective selection.

Results

Selection from the base population

Tables 1 and 2 show the block wise rubber yield, girth, and bark thickness of the ortets selected from Boyce estate. Yield of the preliminary selections numbering 213 ortets ranged from 6.5 to 167 g /tree/tap and their girth ranged from 63 to 160 cm. Ortets with mean yield ranging from 58.5 to 167 g./tree/tap were finally selected after evaluating their vigour, bark thickness and secondary attributes like disease reaction and wind fastness. Girth of the final selections ranged from 93 to 160 cm while virgin and renewed bark thickness of the selections ranged from 11 to 20 mm and 7 to 16 mm respectively.

The scatter diagram (Fig. 1) depicts the yield of the preliminary selections plotted against their girth. Out of the 56 ortets finally selected, all but two had above average yield and 41 ortets, *i.e.* 73.21 per cent of the selections had yield levels above the population mean + SD value. In terms of girth which was given a lower weightage in the selection process, 77 per cent of the selections had girth exceeding 110 cm, which was the population mean. Out of these, 13 ortets, *i.e.* 23.2 per cent of the selections, had girth exceeding the population

mean + SD value. Ortets with above average yield and girth were finally selected for disbudding and multiplication for the next stage of evaluation.

Table 1. Block wise yield of ortets

Block Number	Initial selections		Final selections	
	Number of ortets	Range in mean yield (g/tree/tap)	Number of ortets	Range in mean yield (g/tree/tap)
1	16	10.56 - 58.5	1	58.5
2	24	41.47 – 136.76	5	97.75 – 136.75
3	22	21.29 – 132.2	4	73.19 – 132.2
4	36	29.12 – 162.5	10	113.75 – 162.5
5	22	58.83 – 166.99	10	105.69 – 166.99
6	66	6.5 – 155.09	19	95.55 – 155.09
7	27	41.47 – 134.63	7	104.33 – 134.63

Table 2. Girth and bark thickness of final ortet selections

Block Number	Girth (cm)		Bark thickness (mm)			
	Range	Mean	Virgin		Renewed	
			Range	Mean	Range	Mean
1	-	121.0	-	15.0	-	9.0
2	125-160	142.2	13.0-17.0	15.2	8.0-16.0	11.2
3	100-142	119.75	14.0-18.0	15.5	10.0-15.0	12.25
4	119-147	130.89	13.0-17.5	15.11	8.0-14.5	12.33
5	93-136	118.5	12.0-16.0	14.11	7.0-13.0	10.2
6	105-147	125.58	11.0-20.0	14.21	7.0-14.0	9.74
7	111-142	133.29	11.0-15.0	13.57	8.0-11.0	10.0

Small scale evaluation

In the small scale trial, the 43 clones wer evaluated in terms of growth, rubber yield, timber yiel response to stimulation and tolerance to diseases. Table 3 to 9 show the extent of clonal variation for each of th traits studied.

Growth attributes

The 36 clones in trial 1 exhibited significan variation with respect to girth increment rate during the immaturity period and girth at opening in the seventh year after planting (Table 3). Girth increment at immaturity ranged from 4.9 to 8.5 cm per year with a general mean of 7.1 cm per year. Mean girth at opening ranged from 35.7 to 54 cm with a general mean of 46.7cm. GT 1 was the most vigorous of the check clones. Eight ortet clones viz., MO 50, 12, 19, 15, 45, 21, 7 and 40 were superior in terms of girth increment during the immature phase and seven clones, MO 15, 50, 45, 19, 12, 48 and 25 were superior for girth at the time of opening. There was significant clonal variation for girth increment under tapping in both the trials, with individual values ranging from 1.9 to 4.7 cm per year and a general mean of 3.2 cm per year. Fifteen clones viz., MO 15, 45,

Table 3. Growth characteristics of ortet clones

Clone	G I at immaturity (cm/year)	G I under tapping (cm/year)	Girth at opening (cm)	Clone	G I at immaturity (cm/year)	G I under tapping (cm/year)	Girth at opening (cm)
MO 1*	6.69	2.62	46.00	MO 40*	7.54	3.22	47.63
MO 3*	6.04	2.35	41.25	MO 41*	6.12	2.73	42.57
MO 5*	7.02	2.31	47.10	MO 42*	6.46	1.88	42.42
MO 7*	7.58	2.39	47.88	MO 44*	7.19	2.99	47.06
MO 9*	6.41	2.55	44.12	MO 45*	7.85	4.72	52.71
MO 12*	8.24	4.18	51.09	MO 48*	7.13	3.43	49.38
MO 13*	6.94	3.66	48.09	MO 50*	8.46	3.80	52.93
MO 15*	8.16	4.78	53.99	MO 51*	7.00	3.65	46.45
MO 16*	4.87	1.94	35.74	MO 6@	7.05	3.75	48.11
MO 17*	7.40	3.32	48.11	MO 8@	6.60	2.36	44.16
MO 19*	8.17	4.11	51.33	MO 10@	7.60	3.23	48.60
MO 20*	7.33	4.15	46.19	MO 18@	6.92	2.86	45.24
MO 21*	7.79	3.89	48.43	MO 32@	7.14	2.23	47.77
MO 24*	6.36	3.54	41.04	MO 34@	7.80	3.26	49.17
MO 25*	7.11	3.41	48.98	MO 43@	7.15	3.49	49.87
MO 26*	6.49	2.16	44.97	MO 46@	7.91	3.64	50.69
MO 27*	7.27	3.78	47.33	MO 49@	7.24	4.12	49.14
MO 28*	7.00	3.62	46.81	MO 53@	7.68	3.22	47.80
MO 29*	6.42	3.23	45.78	GT 1*@	7.52	2.89	48.93
MO 30*	6.85	3.26	43.80	RRIM 600*@	6.24	2.26	41.83
MO 31*	7.14	3.82	44.65	RRII 105*@	6.66	2.11	42.20
MO 35*	7.09	3.36	48.10	**G. Mean**	**7.09**	**3.22**	**46.71**
MO 37*	7.29	3.41	48.11	**V. R. Trial I**	**4.41****	**4.40****	**4.72****
MO 38*	6.33	2.50	40.50	**Trial II**	**NS**	**5.30****	**NS**
MO 39*	6.93	3.96	44.26	**C.D. Trial I**	**1.001**	**1.03**	**5.12**
				(0.05) Trial II	-	0.811	-

** Significant at P < 0.01 ; GI: Girth increment ; * Clones in Trial I; @ Clones in Trial II.

12, 20, 19, 39, 21, 50, 31, 27, 51, 49, 6, 46 and 43 showed high girth increment under tapping.

Timber traits

Table 4 shows the performance of the clones with respect to forking height, girth and clear bole volume at the age of 12 years. Clones in both the trials exhibited significant variation for forking height which ranged from 3.4 to 5.4m with a mean of 4.2 m. A total of 20 clones in both the trials showed a high branching nature (MO 15, 28, 12, 13, 50, 29, 40, 17, 51, 44, 27, 37, 3, 7, 9, 43, 18, 49, 32 and 46).

Girth in the 12th year after planting ranged from 48.1 to 74.3 cm with a general mean of 61cm. There was significant variation for girth among both sets of clones. Among the check clones, GT 1 with a mean girth of 61.8 cm was the most vigorous, while RRII 105 with 50.3 cm was poor in vigour. Clones MO 15, 45, 19, 50, 12, 25, 49, 43 and 46 showed the highest vigour in the 12th year.

There was significant clonal variation for clear bole volume which ranged from 0.05 to 0.18 m^3 among clones in trial 1 and from 0.06 to 0.13 m^3 In trial 2 Clone MO 15 exhibited a significantly high clear bole volume of 0.18 m^3 followed by clones MO 12, 50, 45, 19, 13, 28 and 43 with bole volumes exceeding 0.12 m^3.

Yield and yield attributes

Tables 5 and 6 show the clonal variation for dry rubber yield, volume of latex, dry rubber content and bark anatomical parameters.

The mean yield over four years of tapping ranged from 18.8 to 45.3 g/tree/tap with a general mean of 30.7 g/tree/tap. Nine ortet clones gave higher yield than the check clone GT 1, while five ortet clones were better than RRIM 600. Five clones viz., MO 45, MO 7, MO 12, MO 28 and MO 48 were comparable with the high yielding check clone RRII 105, out of which clone MO 45 showed a higher yield. These five ortet clones with mean yield exceeding 37 g/ tree/ tap could be selected as high yielders. The clones with yield ranging from 28 to 36 g/tree/tap which were comparable with the check clones RRIM 600 and GT 1 could be classified as medium yielders. These include clones MO 43, 40, 6, 44, 10, 49, 26, 34, 35, 31, 41, 39, 25, 21, 53, 17, 1, 46, 32, 18 and 15.

Table 4. Timber traits of ortet clones at the age of 12 years

Clone	Clear bole volume (m^3)	Branching height (m)	Girth 12th year (cm)	Clone	Clear bole volume (m^3)	Branching height (m)	Girth 12th year (cm)
MO 1*	0.078	3.91	58.11	MO 41*	0.061	3.40	56.26
MO 3*	0.071	4.46	52.30	MO 42*	0.059	3.62	51.25
MO 5*	0.068	3.43	57.20	MO 44*	0.102	4.65	59.86
MO 7*	0.092	4.46	58.32	MO 45*	0.128	3.90	72.88
MO 9*	0.074	3.94	56.20	MO 48*	0.093	3.77	62.80
MO 12*	0.145	5.02	67.79	MO 50*	0.142	4.90	70.30
MO 13*	0.121	4.94	63.99	MO 51*	0.109	4.70	62.58
MO 15*	0.180	5.39	74.40	MO 6@	0.096	3.75	63.57
MO 16*	0.046	3.89	51.30	MO 8@	0.062	3.47	51.75
MO 17*	0.112	4.73	63.03	MO 10@	0.097	4.07	61.80
MO 19*	0.127	4.45	71.90	MO 18@	0.102	5.00	57.50
MO 20*	0.094	3.83	63.95	MO 32@	0.084	4.16	59.47
MO 21*	0.097	3.61	63.30	MO 34@	0.106	4.42	63.13
MO 24*	0.084	4.28	57.39	MO 43@	0.127	5.03	66.60
MO 25*	0.108	4.37	67.53	MO 46@	0.111	4.16	66.45
MO 26*	0.065	3.51	53.83	MO 49@	0.118	4.30	68.18
MO 27*	0.109	4.47	65.39	MO 53@	0.082	3.57	63.07
MO 28*	0.121	5.10	62.21	GT 1*@	0.087	3.76	61.79
MO 29*	0.103	4.80	59.51	RRIM 600*@	0.063	3.77	51.57
MO 30*	0.082	4.12	60.79	RRII 105*@	0.063	3.80	50.26
MO 31*	0.094	4.16	61.70	General Mean	0.097	4.24	61.00
MO 35*	0.101	4.33	63.82	V. R. Trial I	6.42**	2.31**	4.04**
MO 37*	0.107	4.47	62.17	Trial II	5.37**	2.75*	4.43**
MO 38*	0.068	4.31	50.25	C.D. Trial I	0.032	0.95	8.96
MO 39*	0.093	3.92	57.19	(0.05) Trial II	0.027	0.894	8.38
MO 40*	0.109	4.75	61.45				

** Significant at P < 0.05 ** Significant at P < 0.01 ; * Clones in Trial I; @ Clones in Trial II.*

Table 5. Yield and yield components of ortet clones

Clone	Mean yield over first 4 years (g/tree/tap)	Volume of latex (ml/tree/tap)	DRC (%)	Clone	Mean yield over first 4 years (g/tree/tap)	Volume of latex (ml/tree/tap)	DRC (%)
MO 1*	28.74	86.25	43.56	MO 40*	36.20	206.25	44.83
MO 3*	19.64	50.86	33.38	MO 41*	30.82	158.75	42.74
MO 5*	28.00	113.75	44.45	MO 42*	24.55	101.25	41.62
MO 7*	40.38	155.63	38.92	MO 44*	34.32	208.13	43.41
MO 9*	24.96	95.00	42.09	MO 45*	45.27	292.50	45.79
MO 12*	39.67	153.75	38.71	MO 48*	37.17	161.25	46.99
MO 13*	26.48	125.00	44.14	MO 50*	25.15	60.00	45.76
MO 15*	28.41	123.75	41.81	MO 51*	25.22	88.13	40.07
MO 16*	18.76	47.50	33.19	MO 6@	35.53	58.75	35.97
MO 17*	29.60	108.75	39.03	MO 8@	24.55	171.67	42.39
MO 19*	28.19	113.13	48.11	MO 10@	33.99	85.00	44.08
MO 20*	26.88	151.88	43.62	MO 18@	28.79	116.67	47.34
MO 21*	29.72	121.25	40.29	MO 32@	29.57	152.50	46.01
MO 24*	21.92	91.25	41.51	MO 34@	33.16	115.83	47.98
MO 25*	30.11	118.75	42.10	MO 43@	36.49	109.17	40.34
MO 26*	33.59	167.50	37.10	MO 46@	29.46	94.17	47.39
MO 27*	28.08	143.13	39.72	MO 49@	33.65	125.00	48.34
MO 28*	39.17	184.38	43.47	MO 53@	29.46	79.17	48.14
MO 29*	25.08	108.13	45.11	GT 1*@	34.53	118.65	37.02
MO 30*	28.38	71.25	36.28	RRIM 600*@	38.01	125.53	36.01
MO 31*	31.43	148.75	46.04	RRII 105*@	45.05	171.04	38.63
MO 35*	31.88	166.25	44.66	**G. Mean**	**30.67**	**127.29**	**42.30**
MO 37*	25.79	109.38	44.22	**V. R. Trial I**	**3.74****	**2.70****	**2.25***
MO 38*	24.84	124.38	41.45	**Trial II**	**NS**	**NS**	**4.49****
MO 39*	30.36	176.25	41.98	**C.D. Trial I**	**9.62**	**81.49**	**7.59**
				(0.05) Trial II	-	-	**6.65**

** Significant at P < 0.05 ; ** Significant at P < 0.01 ; * Clones in Trial I; @ Clones in Trial II.*

The clones evaluated gave a mean yield of 127.3 ml/tree/tap in terms of the volume of latex which ranged from 43.1 to 292.5 ml/tree/tap. Clone MO 45 gave the highest volume yield of latex which was significantly superior to the rest. Thirteen clones were comparable with clone RRII 105 for volume of latex.

The DRC ranged from 30.4 to 48.3 per cent with a general mean of 42.3 per cent. A high DRC of more than 40 per cent was exhibited by 33 clones, while clone RRII 105 had a DRC of 38.6 per cent. Among the ortet clones evaluated, MO 19, 48, 31, 45, 50, 29, 43, 46, 6, 18, 10 and 49 could be selected for their high dry rubber content.

The number of latex vessel rows (Table 6) ranged from 7 to 13 and bark thickness ranged from 4.2 to 6.5 mm. Clones in trial 1 showed significant variation for both the traits. Nineteen clones showed a high number of latex vessel rows ranging from 10 to 13 which was comparable with that of clone RRII 105. These included 17 ortet clones viz., MO 19, 35, 1, 12, 51, 21, 44, 7, 26, 31, 30, 10, 32, 34, 43, 53 and 28. Twelve ortet clones had significantly thick bark on par with clone GT 1. These include clones MO 1, 28, 26, 19, 12, 35, 7, 20, 31, 50, 43 and 45.

Response to stimulation

The 16 clones studied for response to stimulation included 13 of the ortet clones which were relatively promising in yield and the three check clones as shown in Table 9. The mean yield on stimulant application during the peak yielding period of June to November ranged from 49.8 ± 9.94 to 66.0 ± 18.78 g/tree/tap with a general mean of 56.23 g/tree/tap. The unstimulated yield during the corresponding period in the previous year ranged from 24.9 ± 6.64 to 64.5 ± 17.82 g/tree/tap with a mean of 43.1 g/tree/tap. The mean yield during the pre treatment period i.e. the first four years of tapping ranged from 28.4 to 45.3 g/tree/tap with a general mean of 36.8 g/tree/tap. In general, the clones registered an yield increase of 35.3 per cent over unstimulated yield in the previous peak season and 56.81 per cent over mean yield during the first four years of tapping. The enhancement in yield ranged from 1.1 to 107.2 per cent over the

le 6. Bark anatomical parameters in the year of opening

ne	Bark thickness (mm)	No. of latex vessel rows	Clone	Bark thickness (mm)	No. of latex vessel rows
1*	6.52	12.56	MO 41*	5.47	7.66
3*	5.65	9.81	MO 42*	5.50	8.93
5*	5.56	10.06	MO 44*	5.41	11.17
7*	6.03	10.78	MO 45*	5.95	9.69
9*	5.51	8.96	MO 48*	5.41	7.75
12*	6.06	12.52	MO 50*	5.97	8.06
13*	5.84	8.21	MO 51*	5.22	12.50
15*	5.13	9.75	MO 6@	5.24	9.80
16*	5.25	8.31	MO 8@	5.63	7.53
17*	5.74	8.31	MO 10@	5.80	13.33
19*	6.10	12.75	MO 18@	5.60	9.50
20*	6.02	9.94	MO 32@	5.74	11.33
21*	5.36	11.88	MO 34@	5.80	10.58
24*	5.39	6.60	MO 43@	6.14	10.83
25*	5.75	9.69	MO 46@	5.91	9.08
26*	6.13	10.46	MO 49@	5.59	8.50
27*	4.76	8.30	MO 53@	4.64	10.33
28*	6.14	10.15	GT 1*@	5.84	10.27
29*	5.80	8.00	RRIM 600*@	4.66	8.90
30*	5.34	10.41	RRII 105*@	5.45	10.03
31*	5.97	10.44	**G Mean**	**5.62**	**9.78**
35*	6.04	12.75	**V.R Trial I**	**4.74****	**3.51****
17*	5.79	9.63	**Trial II**	**1.83**	**1.81**
18*	5.09	7.75	**C.D. Trial I**	**0.57**	**2.60**
19*	5.42	6.94	**(0.05) Trial II**	**NS**	**NS**
0*	5.27	9.04			

*ificant at P < 0.01; * Clones in Trial I; @ Clones in Trial II.*

imulated yield during the peak season in the previous —. The yield increase achieved over the mean yield ng the first four years of tapping was to the tune of 1.3 to 95.7 per cent. The highest yielding clones, viz., I 105 and the ortet clone MO 45 showed little onse to stimulant application. The rest of the clones wed varying levels of yield enhancement. Eight es (MO 53, 10, 31, 49, 40 and 15, along with GT 1 RRIM 600) registered a good response of more than er cent enhancement in yield when compared to the ious peak season. Of these, the six ortet clones g with MO 48 showed more than 56 per cent ncement in yield when compared to the mean yield the first four years.

dence of diseases, tapping panel dryness and wind age

The incidence of tapping panel dryness, wind age, pink disease, abnormal leaf fall and powdery ew are shown in Tables 7 and 8.

In general, 6.7 per cent of the trees expressed ng panel dryness and the incidence among the s ranged from 0 to 25 per cent. Eleven clones viz., 7, 12, 15, 16, 17,20, 24, 35, 10, 18 and 32 were free from tapping panel dryness after five years of tapping.

Wind damage among the clones ranged from 0 to 15 per cent with 26 clones remaining unaffected. Only 3 per cent of the trees under observation were affected by wind. Clones GT 1 and RRII 105 were free from wind damage.

Incidence of pink disease ranged from 5 to 40 per cent with a general mean value of 19.4 per cent. Clone RRII 105 showed the highest incidence of 40 per cent disease affected trees while clones MO 3 and MO 28 had the lowest incidence of 5 per cent.

The intensity of powdery mildew caused by *Oidium heveae* (Table 8) ranged from 57.5 to 81.5 per cent when pooled over the two years of observation. There was significant clonal variation in trial 1 and the mean PDI of the clones evaluated was 66.4 per cent. Six clones showed less than 60 per cent intensity of the disease, of which the lowest PDI was registered by clone MO 26. The co-efficient of variation of PDI between years ranged from 5 to 48.3 with a mean of 24.5 for clones in trial 1. Thirteen clones showed consistency of disease reaction with less than 20 per cent CV between years. These include clones MO 1, 37, 15, 29, RRIM 600, MO

Table 7. Incidence of tapping panel dryness, pink disease and wind damage

Clone	Tapping panel dryness (% affected trees)	Pink disease (% affected trees)	Wind damage (% affected trees)	Clone	Tapping panel dryness (% affected trees)	Pink Disease (% affected trees)	Wind damage (% affected trees)
MO 1[#]	5.0	10.0	0.0	MO 39[#]	5.0	35.0	5.0
MO 3[#]	20.0	5.0	0.0	MO 40[#]	5.0	20.0	0.0
MO 5[#]	5.0	35.0	0.0	MO 41[#]	5.0	25.0	5.0
MO 7[#]	0.0	30.0	0.0	MO 42[#]	5.0	40.0	15.0
MO 9[#]	5.0	25.0	0.0	MO 44[#]	15.0	20.0	5.0
MO 12[#]	0.0	15.0	5.0	MO 45[#]	5.0	20.0	5.0
MO 13[#]	5.0	10.0	5.0	MO 48[#]	5.0	20.0	0.0
MO 15[#]	0.0	30.0	5.0	MO 50[#]	15.0	5.0	0.0
MO 16[#]	0.0	10.0	15.0	MO 51[#]	10.0	30.0	0.0
MO 17[#]	0.0	10.0	5.0	MO 6[@]	6.66	0.0	0.0
MO 19[#]	5.0	15.0	0.0	MO 8[@]	20.00	20.0	13.33
MO 20[#]	0.0	35.0	10.0	MO 10[@]	0.0	6.66	6.66
MO 21[#]	25.0	30.0	5.0	MO 18[@]	0.0	13.33	0.0
MO 24[#]	0.0	20.0	5.0	MO 32[@]	0.0	6.66	0.0
MO 25[#]	15.0	25.0	0.0	MO 34[@]	13.33	0.0	0.0
MO 26[#]	5.0	25.0	0.0	MO 43[@]	6.66	13.33	6.66
MO 27[#]	5.0	20.0	0.0	MO 46[@]	6.66	6.66	0.0
MO 28[#]	15.0	5.0	5.0	MO 49[@]	0.0	20.0	0.0
MO 29[#]	5.0	35.0	5.0	MO 53[@]	6.66	6.66	0.0
MO 30[#]	10.0	25.0	0.0	GT 1[#@]	8.57	20.0	0.0
MO 31[#]	15.0	25.0	10.0	RRIM 600[#@]	8.57	28.57	2.86
MO 35[#]	0.0	30.0	0.0	RRII 105[#@]	2.86	40.00	0.0
MO 37[#]	10.0	15.0	0.0	**G. Mean**	**6.74**	**19.39**	**3.03**
MO 38[#]	10.0	10.0	0.0				

[#] *Clones in Trial I;* [@] *Clones in Trial II.*

27, 13, 26, 19, 51, RRII 105, MO 16 and MO 51. The CV was not estimated from trial 2 since all the clones were susceptible and on par in disease reaction during both the years of study. However, since the disease intensity of all the clones was more than 50 per cent, none of them could be classified as tolerant to powdery mildew.

The intensity of abnormal leaf fall due to infection by *Phytophthora* spp. varied significantly among clones in both the trials with PDI values ranging from 21.9 to 69.1 per cent and a general mean of 40.4 per cent . Clone RRII 105 and three ortet clones were found highly tolerant with less than 25 per cent leaf fall. The tolerance of clone RRII 105 to abnormal leaf fall in terms of high leaf retention has been reported by Pillay *et al.*, 1980 and Mushrif *et al.*, 2004. Clone MO 35 showed the lowest disease intensity followed by MO 19, RRII 105 and MO 40. Thirteen clones with PDI values less than 35 per cent were comparable with these and could be classified as moderately tolerant. These include clones MO 15, 12, 45, 31, 21, 26, 39, 1, 48, 25, 17, 50 and 5. The variation in intensity of leaf fall between the two years of observation ranged from 10.3 to 100.9 with a mean CV of 41.7 per cent. Fourteen clones showed stability of disease reaction with less than 40 per cent CV between years. Ortet clones identified as possessing stable tolerance to abnormal leaf fall are MO 15, 12, 48, 17 and 25, while clones MO 35, 19 and 40 though not stable, were highly tolerant to abnormal leaf fall.

Discussion

Tree breeding often involves multiple objectives depending upon the economic produce obtained from the species of interest. Until recent years latex was considered the sole economic produce from the rubber tree. Socio-economic factors influencing the exploitation process and the recent price fluctuations of rubber coupled with the upgradation of rubber wood into a major timber species has led to a shift in the breeding objectives (Aziz, 2002). Though the rubber tree is valued for its yield of latex, tree girth, one of the major determinants of timber yield has also been employed as an important selection parameter in *Hevea* breeding programmes. Yield and vigour in rubber are hardly separable (Simmonds, 1989). Improvement programmes over the years have thus taken care of the present bi-directional selection objective to a certain extent. The present study, besides identifying promising latex yielders, also attempts quantification of the timber yield of the clones

Table 8. Reaction of clones to *Oidium* and *Phytophthora* infection

Clone	Powdery mildew		Abnormal leaf fall		Clone	Powdery mildew		Abnormal leaf fall	
	P.D.I	C.V.	P.D.I	C.V.		P.D.I	C.V.	P.D.I	C.V.
MO 1#	58.08	4.99	32.53	94.68	MO 41#	67.11	20.62	39.66	42.46
MO 3#	58.70	38.09	46.67	14.14	MO 42#	64.40	26.33	51.37	27.17
MO 5#	70.81	21.45	34.80	68.26	MO 44#	74.12	34.57	41.23	58.24
MO 7#	73.50	35.19	36.73	58.64	MO 45#	79.29	29.37	29.14	64.98
MO 9#	80.97	24.74	36.22	61.37	MO 48#	77.19	36.98	32.89	10.26
MO 12#	67.63	29.30	27.13	24.11	MO 50#	65.18	38.33	34.53	51.30
MO 13#	63.91	15.72	49.00	16.58	MO 51#	62.29	17.80	43.03	13.24
MO 15#	65.53	11.26	26.63	29.90	MO 6@	70.00	-	42.67	28.73
MO 16#	65.39	19.77	69.14	16.13	MO 8@	64.00	-	45.17	38.09
MO 17#	64.44	20.10	34.10	24.26	MO 10@	64.17	-	42.00	65.09
MO 19#	68.28	17.42	23.71	48.97	MO 18@	63.67	-	51.83	36.84
MO 20#	63.95	33.75	47.99	32.39	MO 32@	68.67	-	62.00	50.18
MO 21#	61.25	19.88	30.37	62.25	MO 34@	68.67	-	42.33	23.39
MO 24#	72.72	48.31	37.25	45.56	MO 43@	66.67	-	40.50	43.65
MO 25#	74.09	32.00	33.26	32.98	MO 46@	61167	-	42.84	6.06
MO 26#	56.60	17.37	31.97	58.47	MO 49@	69.00	—	44.00	35.36
MO 27#	65.57	11.70	53.70	13.69	MO 53@	68.67	-	43.84	34.96
MO 28#	69.74	23.88	53.49	5.91	GT 1#@	63.78	41.34	50.09	82.41
MO 29#	59.76	11.52	36.36	43.20	RRIM 600#@	58.72	11.67	61.11	27.59
MO 30#	62.51	26.26	40.87	4.74	RRII 105#@	56.88	19.15	26.54	94.83
MO 31#	60.25	20.90	29.87	52.65	**G. Mean**	**66.40**	**24.53**	**40.40**	**41.65**
MO 35#	70.46	33.48	21.87	86.46	**V. R. Trial I**	**2.79****	-	**6.08****	-
MO 37#	60.68	9.45	48.61	50.50	**Trial II**	**NS**	-	**2.98***	-
MO 38#	64.23	23.73	52.02	10.83	**C.D. Trial I**	**10.53**	-	**12.96**	-
MO 39#	68.88	22.06	32.39	81.38	**(0.05) Trial II**	-	-	**15.72**	-
MO 40#	72.75	34.71	25.00	43.02					

** Significant at P < 0.05 ** Significant at P < 0.01; # Clones in Trial I; @ Clones in Trial II.*

developed under the ortet selection programme. Exploitation of the production potential of the virgin bark with judicious use of yield stimulants is the technique adopted for maximising productivity (Vijayakumar *et. al.*, 2002). The present results of ortet selection are therefore examined in the perspective of the development of latex- timber clones amenable to modern methods of exploitation.

Selection of ortets from the base population

As evident from the ortets labelled in the scatter diagram (Fig. 1), in the selection process, a greater weightage was given to yield. The ortets of the clones classified as high and medium yielders were among the high yielding group (yield exceeding Mean + SD) in the base population. This points to the efficiency of the ortet selection procedure adopted. Tree girth, besides being an important determinant of the area of the tapping panel, also determines the bole volume, which in turn contributes to timber yield. The high girthing ortets with above average girth also developed into high girthing clones with high bole volume as evident from the results of the small scale trials (Table 4).

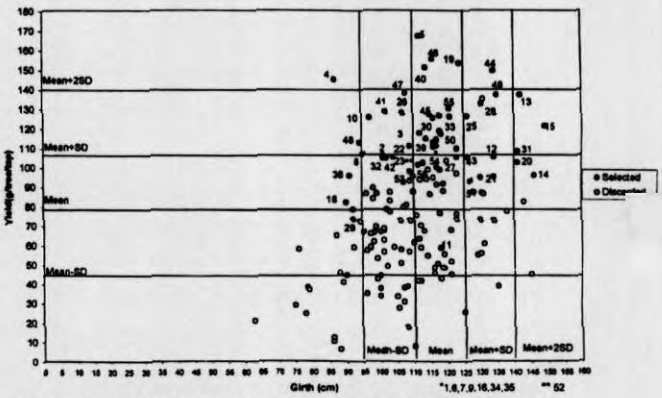

Fig. 1. Ortets selected from the base population at Boyce estate

Small scale evaluation

Rubber yield and related attributes

The present results (Table 5) reveal the superiority in dry rubber yield of clones MO 45, MO 7, MO 12, MO 28 and MO 48. These clones also gave more than 150 ml of latex /tree/tap with MO 45 being significantly superior to the rest of the clones. Clones MO 7 and MO 12 , though poor in dry rubber content, had significantly thick bark coupled with a high number of latex vessel rows.

Table 9. Response to stimulation

Clone	Peak season yield prior to stimulation (g/tree/tap)	Peak season yield after stimulation (g/tree/tap)	Yield increase over previous peak season (%)	Yield increase over mean of first 4 years (%)
MO 40	40.95 ± 8.13	58.76 ± 6.08	43.49	62.32
MO 31	38.63 ± 11.64	59.84 ± 12.4	54.91	90.42
MO 26	46.83 ± 22.87	51.42 ± 2.24	9.80	53.05
MO 28	51.72 ± 7.07	52.28 ± 9.16	1.08	33.44
MO 12	44.76 ± 8.34	51.84 ± 5.15	15.82	29.52
MO 45	55.92 ± 14.16	65.67 ± 3.78	17.44	45.06
MO 7	40.05 ± 17.44	53.60 ± 8.15	33.83	32.74
MO 48	51.06 ± 7.43	58.42 ± 6.66	14.41	56.90
MO 15	39.09 ± 9.57	55.60 ± 5.12	42.24	95.74
MO 10	34.27 ± 11.80	59.46 ± 5.41	73.50	74.93
MO 49	42.40 ± 9.85	62.83 ± 3.95	48.18	88.23
MO 53	24.86 ± 6.64	51.51 ± 9.09	107.20	74.85
MO 43	42.78 ± 5.04	49.79 ± 9.94	16.39	36.45
GT 1	37.24 ± 9.26	51.82 ± 5.90	39.15	50.28
RRIM 600	35.10 ± 17.87	50.84 ± 5.56	44.84	38.23
RRII 105	64.48 ± 17.82	65.96 ± 18.78	2.30	46.79
Mean	**43.13**	**56.23**	**35.29**	**56.81**

Dry rubber content and volume of latex are the most important components of rubber yield (Simmonds, 1989; Sethuraj,1992). Structural attributes like bark thickness and the number of latex vessel rows are clonal characters which influence rubber yield (Premakumari, 1992). Among the ortet clones evaluated, MO 19 could be selected for its high DRC, MO 45 for its high yield of latex, MO 1 for high bark thickness and MO 19, 35, 1, 12 and 51 for a high number of latex vessel rows.

Growth attributes

The clones in general suffered a setback in growth on tapping, which is to be expected since the tapping process imposes stress on the trees and the photosynthates are partitioned between two competing sinks, latex offtake and tree growth (Simmonds, 1989). However, the response of clones to tapping varies, as evident from the fall in growth rate of the ortet clones MO 7 and MO 40, under tapping, while they were among the most vigorous clones during the immature phase (Table 3). To obtain sustained yield for a number of years, it is necessary to maintain a satisfactory rate of growth of trees under tapping (Vijayakumar *et al.*, 2000). The *Hevea* breeder always aims at achieving a combination of high yield and steady growth rate in clones. This study identified stable and vigorous ortet clones like MO 15, 45, 12, 19 and 21 which were unaffected by the tapping stress and maintained a high growth rate. High girth coupled with high growth rate during the immature phase shown by clones MO 15, 50, 45, 19 and 12 indicate the early attainment of tappability of these clones. The inherent vigour of clones MO 45, 12, 15 and 19 is evidenced by their maintenance of high growth rates even under tapping.

Timber yield

The yield of timber obtained from a rubber tree comprises mainly of the clear bole volume (Najib *et al.*, 1995) which is dependant on the height at first forking and the girth of the tree which in turn is dependant on its growth rate. The growth attributes, especially girth increment under tapping, thus have a bearing on the volume of timber. Among the clones with a high clear bole volume, MO 15, 12, 50, 45, 13, 28 and 43 showed a high branching nature, while clones MO 45 , 15 and 12 were significantly high girthing clones which maintained a high growth rate in the tapping phase also, an indication of their timber yield potential in future years . Girth has a bearing on the diameter of logs of wood and consequently the size of sawn planks. The clones with a high clear bole volume showed significantly superior girth at the age of 12 years, except clones MO 13 and MO 28. Clones with high girth along with a high branching nature are preferred for use as timber clones since the wastes generated while felling, logging and sawing would be less (Viswanathan *et. al.*, 2002). Clone MO 15 exhibited a higher clear bole volume compared to PB 235 reported to yield a high volume of timber in India (John *et al.*, 2003). Clone MO 45 has also emerged superior in terms of timber yield potential among the newly evolved primary clones followed by clones MO 12, 50, 19 and 43.

Secondary attributes

This ortet evaluation programme has also led to the identification of clones possessing tolerance to tapping panel dryness, wind, pink disease and abnormal leaf fall. Abnormal leaf fall is the most destructive disease of rubber in India (Edathil *et al.*, 2000), while pink disease, predominant in young rubber trees is the most serious among the stem diseases (Kothandaraman and Idiculla, 2000). Tapping panel dryness, generally considered to be a physiological disorder associated with excessive exploitation (Chrestin *et al.*, 1985), occurs in varying intensities among clones (Sivakumaran *et al.*,1986; Mydin *et al.*, 1999).

It would be worthwhile to examine the secondary attributes of the promising rubber yielders and timber yielders. Among the promising rubber yielding clones, MO 7 was unaffected by wind and showed no tapping panel dryness, clone MO 12 which was also free from TPD showed stable tolerance to abnormal leaf fall and clone MO 28 had the lowest incidence of pink disease. Among the promising timber yielders, clone MO 15 was free from TPD and showed stable tolerance to abnormal leaf fall. Clone MO 50 showed a low incidence of pink disease and was free from wind damage while clone MO 19 showed a wind fast character and was highly tolerant to abnormal leaf fall with leaf retention as high as RRII 105, reported to be a clone with a high level of tolerance to *Phytophthora* (Pillay *et al.*, 1980; Mushrif *et al.*, 2004).

Response to stimulation

The high yielding clones MO 45 and MO 48 showed better response to stimulation than RRII 105. Clone MO 49, a medium yielder showed substantial response bringing it on par in yield with the high yielding clones. Clones MO 53, 10, 31, 40 and 15 also responded well to stimulation and holds promise for increased yield. Another noteworthy aspect is the high branching nature of the high yielding clones, MO 28, 12 and 7 which render these clones amenable to longer exploitation of high panels.

Among the three stages of clonal selection in rubber (Varghese and Mydin 2000) it is in the small scale evaluation trials that the maximum number of entries are screened and only the best clones are carried forward to the subsequent stages which involve more land and resources. The present study on response to stimulation has revealed the high yield potential of clone MO 49, which would normally have been discarded after small scale evaluation, being only a medium yielder. This brings to light the need for investigating the response of clones to yield stimulants in the early stages of selection i.e., in the small scale trials, so as to prevent loss of valuable material, which amounts to gene erosion. Large scale trials incorporating such potential clones could then be designed to accommodate exploitation systems as well. Such an approach would generate more information which would serve to improve the efficacy of genetic improvement programmes.

Conclusions

The results of the ortet selection programme at Boyce estate and subsequent small scale evaluation of the 46 cloned ortets at Mundakkayam estate have led to the development of 11 new latex, timber and dual purpose clones. The promising traits of these clones are listed in Table 10. From a comprehensive study of various parameters of the ortet clones, it emerges that clones MO 45, MO 7, MO 12 , MO 28 and MO 48 could be termed the high latex yielders and clones MO 15, MO 50 and MO 19, the high timber yielders. Of these clones MO 50 and MO 19 were not affected by wind. The timbe quality parameters of these clones warrant further investigation. Clones MO 45, MO 15, MO 12 and MO 28 could be considered as latex timber clones which showed promise in terms of both rubber yield and timber yield potential. A medium yielding clone, MO 49, showed very good response to stimulation and gave yield comparable with the high yielding check clone. The 11 new primary clones evolved by the present ortet selection programme could be carried over to the next stages of clonal selection viz, large scale trials and on-farm trials.

Table 10. Features of the promising new primary clones

Clone	Promising features
MO 45	High rubber yield, high timber yield, high DRC, high volume of latex, high bark thickness, high girth increment at immaturity, high girth at opening, high girth increment under tapping, moderate tolerance to abnormal leaf fall.
MO 7	High rubber yield, high number of latex vessel rows, high bar thickness, high branching, high girth increment at immaturit, absence of TPD.
MO 12	High rubber yield, high timber yield, high girth increment at immaturity, high girth at opening, high girth increment under tapping, high branching, high number of latex vessel rows, high bark thickness, absence of TPD, stable and moderate tolerance to abnormal leaf fall.
MO 28	High rubber yield, high timber yield, high number of latex vessel rows, high bark thickness, high branching, low incidence of pink disease.
MO 48	High rubber yield, high DRC
MO 49	Moderately high rubber yield, high DRC, high response to stimulation, high girth increment under tapping, high branching.
MO 15	High timber yield, moderately high rubber yield, high branching, high girth increment at immaturity, high girth at opening, high girth increment under tapping, good response to stimulation.
MO 50	High timber yield, high girth increment at immaturity, high girth

	at opening, high girth increment under tapping, high branching, high DRC, moderate tolerance to abnormal leaf fall.
MO 19	High timber yield, high girth increment at immaturity, high girth at opening, high girth increment under tapping, high DRC, high number of latex vessel rows, high tolerance to abnormal leaf fall.
MO 40	Moderately high yield, high tolerance to abnormal leaf fall, good response to stimulation.
MO 43	Moderately high yield, high DRC, high number of latex vessel rows.

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