

Potential New Primary Clones of Hevea Evolved by Ortet Selection in India

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An ortet selection programme for selection of elite mother trees of rubber (Hevea brasiliensis Muell. Arg) from among the seedlings of the Gough Garden (GG) series viz., GG1, GG 4 and GG 6 of the Prang Besar Isolation (PBIG) gardens in Malaysia was undertaken in a large estate in Central Kerala, South India. The resultant 47 preliminary selections of ortet clones were cloned and evaluated during the first five years of tapping in small scale trials in the same location. The parameters for evaluation were yield and yield components, growth attributes, timber yield, bark anatomical parameters and incidence of leaf diseases. Significant variation was observed for the traits studied. Based on the data on yield, growth and timber characteristics, 11 promising new primary clones were selected. Six clones, viz., KO 27, KO 25, KO 6, KO 9, KO 7 and KO 16 were identified as high rubber yielders. Four clones viz., KO 7, KO 13, KO 22 and KO 31 exhibited a high timber yield potential. Out of the eleven selections, four clones viz., KO 27, KO 7, KO 9 and KO 11 were promising in terms of rubber and timber yield. The superiority of the ortet clones with respect to yield and secondary characters are discussed.

Keywords : *Hevea brasiliensis*; ortet selection; rubber yield; timber yield; disease incidence

The primary goal of any plant breeding programme is to improve the genetic potential of a crop, particularly the productivity of the genotype. Ortet selection and hybridisation followed by clonal selection are the major strategies adopted for genetic improvement in rubber¹.

An ortet (derived from the Latin word 'ortus') is the original tree from which members of a clone have descended². *Hevea* being predominantly a cross pollinated species, considerable variability is observed in the seedling population, making it a

valuable genetic resource for ortet selection. Rapid progress in ortet selection programmes achieved in Indonesia and Malaysia resulted in release of a number of early primary clones which recorded up to 150% increase in yield over the original unselected seedling population³. Such early high yielding primary clones formed the bulk of the parents used in subsequent hand pollination programmes.

While research efforts were mainly concentrated on controlled hand pollination,

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seed gardens were also established with improved clones as parents to produce high yielding seeds as a supplementary planting material. The best known source of seedlings were Gough Garden (GG) series from the Prang Besar Isolation Garden (PBIG) in Malaysia. Large areas of advanced generation seedling stands were established in commercial planting with seedlings of GG, which offered a good scope of selection.

The first ortet selection programme in India led to the release of clones of the RRII 1-10 series which have shown good performance over the years^{4,5}. In the second phase of the ortet selection programme which was initiated in 1981, systematic screening was undertaken in large estates in Kerala for selection of outstanding individual seedlings from advanced generation seedlings.

Screening of 500 hectares of seedling population of GG1 and GG2 origins located in two large estates and subsequent small scale evaluation of 85 selected ortet clones, led to identification of 19 potential clones superior in latex yield, timber production and response to ethrel stimulation when compared with the popular class 1 clones of India^{2,6}.

In the present study, the results of the extension of the ortet selection programme covering seed garden seedlings of GG1, GG4 and GG6 origins undertaken in a large estate in central Kerala and subsequent small scale evaluation of the selections are reported. Such cooperative efforts will help achieve the major objective of generating improved planting material for enhancing the productivity and production in the rubber plantation sector.

MATERIALS AND METHODS

Initial Screening and Selection

The present study was carried out in the Koney Estate of Harrisons Malayalam Ltd. at

Konni, Pathanamthitta, situated at a latitude of 8° 64'N and longitude of 76° 64'N in central Kerala. The base population for the ortet selection programme comprised of 49,933 trees raised from seedlings introduced from the GG *viz.*, GG1, GG 4 and GG 6 of the PBIG in Malaysia. The trees were planted in an area of 136.62 ha from 1965 to 1976. The screening started in 1987, when the trees were under tapping for 12–15 years following the ½ S d/2 tapping system. Based on preliminary observations on latex yield and vigour, 192 high yielding trees were shortlisted. These selected trees were numbered and marked with paint. Subsequently, these trees were subjected to detailed evaluation for yield, growth and secondary attributes for a period of one year. Rubber yield was estimated based on latex volume on normal tapping days and dry rubber content (drc) together with information such as mean yield of the particular tapping block on the day of yield collection. Yield recording was repeated for four seasons. Growth vigour of the selected mother trees were monitored in terms of girth and secondary characters like branching habit and trunk characters (nature of bark and trunk). Incidence of diseases and tapping panel dryness were also recorded. Based on yield and secondary characters, a batch of 50 ortets were finally selected, cloned and a source bush nursery was established in Koney Estate in 1990. The experimental ortet clones were designated as the KO series after the name of the estate where the selection programme was undertaken. Ultimately, a total of 47 ortet clones were multiplied for establishing small scale clone trials for further evaluation at the same location.

Small Scale Evaluation

The small scale evaluation of the 47 selected ortet clones was carried out in three statistically laid out trials established in 1991 at the same estate. The first and second trials comprised of 18 clones each and the

third one with 20 clones laid out in randomised 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 m × 3 m. In all the trials, RR1105, RRIM 600 and GT1 were included as control clones. The growth performance in the immature phase of the trees was monitored by recording girth measurements from the third year of planting. Trees were opened for tapping under the S/2 d3 system upon attainment of seven years growth. The clones were evaluated on the basis of growth and yield parameters in BO 1 panel. The growth parameters included girth increment rate during the immature growth phase, *i.e.* between the 3rd and 7th year after planting, girth at opening, girth increment rate under tapping estimated during the first five 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 method⁷. Mean latex yield during the first five 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 recorded following standard techniques. Yield components

viz., volume of latex and dry rubber content during the peak yielding season of October to November were recorded in the fifth year of tapping. Incidence of tapping panel dryness 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) were recorded by visual scoring during two consecutive years to identify tolerant clones. Data on yield and yield components, growth and secondary characters were subjected to analysis of variance to study the magnitude of clonal variation available for effective selection.

RESULTS

The results of the ortet selection programme conducted are presented in two stages, firstly, the details of the selection from the base population and secondly, data from the small scale trials.

Selection from the Base Population

Details of the seedling area screened for superior mother trees are given in *Table 1*.

TABLE 1. SEEDLING AREAS IN KONEY ESTATE, HARRISONS MALAYALAM LTD.

Field No.	Year of planting	Area (ha)	Plant material	No. of trees	Yield kg/ha	
					1984–85	1985–86
65 A	1965	17.15	GG 1	5871	1781	1563
66 A	1966	17.35	GG 1	5188	1430	1723
67 A	1967	27.3	GG 1	9025	1658	1513
NC 71	1971	6.96	GG 4	1652	950	1120
NC 76 A	1976	53.76	GG 6	22311	1358	1426
NC 76 B	1976	14.10	GG 6	5886	1252	1298
Total		136.62		49 933		

The block wise yield of seedling trees from the six fields ranged from 950 to 1781 kg⁻¹ ha⁻¹ yr⁻¹ in 1984–85 and 1120 to 1723 kg⁻¹ ha⁻¹ yr⁻¹ in 1985–86. From the population of 49,933 seedlings, 192 mother trees were initially shortlisted for yield recording and visual scoring of secondary characters. Yield of the preliminary selections ranged from 86 to 1225 mL tree⁻¹ tap⁻¹ and their girth ranged from 70.5 to 172 cm (*Table 2*).

Fifty six ortets were finally selected based on data on yield, vigour and secondary attributes like disease reaction and wind fastness. Yield of these final selections ranged from 281 to 1225 mL tree⁻¹ tap⁻¹ while girth ranged from 84 to 172 cm. These 56 ortets were finally selected for the next stage of evaluation by generation of young budwood by chopping the branches of the trees, establishment of a budwood nursery and further multiplication.

Small Scale Evaluation

Out of the the 56 final selections, 47 ortets were successfully multiplied and evaluated in three small scale trials (*Table 3*). The clones were evaluated in terms of growth,

rubber yield and yield components, timber yield and tolerance to diseases. Mean growth performance and range in variability of clones across three trials are presented in *Tables 4* and *5*. Analysis of variance revealed significant clonal variation for the traits studied indicating scope for selection of superior ortet clones.

Growth Attributes

Mean girth at opening in trial 1 ranged from 45.53 to 64.98 cm with a general mean of 53.7 cm (*Tables 4* and *5*). Clone KO 7 showed the highest girth at opening of 64.98 cm followed by KO 13 (60.43 cm). GT 1 was most vigorous among the check clones. Girth increment at immaturity ranged from 6.48 to 9.20 cm year⁻¹ with a general mean of 7.54 cm year⁻¹. The girth increment under tapping ranged from 1.72 to 5.13 cm year⁻¹ with a general mean of 3.31 cm year⁻¹. Four clones KO 7, KO 13, KO 11 and KO 9 were superior in terms of girth increment before tapping and four clones KO 7, KO 9, KO 3 and KO 13 were superior in terms of girth increment under tapping. Eleven clones exhibited more than 70% tappability with a range of 27.27 to 100 percent. Two clones *viz.*, KO 7 and KO 11 showed 100% tappability.

TABLE 2. MEAN GIRTH AND MEAN YIELD OF THE SELECTED MOTHER TREES

Field No.	Initial selection			Final selection		
	No. of ortets	Range in mean girth (cm)	Range in mean yield (mL tree ⁻¹ tap ⁻¹)	No. of ortets	Range in mean girth (cm)	Range in mean yield (mL tree ⁻¹ tap ⁻¹)
65 A	15	107 – 164	330 – 1157.5	12	115 – 164	410 – 1157
66 A	19	109 – 172	250 – 1050	13	109 – 172	460 – 1050
67 A	16	92 – 170	296.25 – 1225	8	111 – 170	505 – 1225
NC 71	30	96 – 146	180 – 642.50	7	103 – 143	401.25 – 642.5
NC 76 A	85	70.5 – 119	86 – 696.25	14	84 – 112	321 – 696.25
NC 76 B	27	82 – 127.5	102.5 – 349.25	2	92 – 94.5	281 – 316.70
Total	192			56		

TABLE 3. DETAILS OF SMALL SCALE TRIALS

Trial	No. of clones	Clones	Experiment details
Trial 1	15 ortets and 3 check clones	KO 1, KO 2, KO 3, KO 4, KO 5, KO 6, KO 7, KO 8, KO 9, KO 10, KO 11, KO 12, KO 13, KO 14, KO 15, RR11 105, RR11 600, GT 1	Design–Randomised Block Design Replications–3 Plot size–5
Trial 2	15 ortets and 3 check clones	KO 16, KO 17, KO 18, KO 19, KO 20, KO 21, KO 22, KO 23, KO 24, KO 25, KO 26, KO 27, KO 28, KO 29, KO 30, RR11 105, RR11 600, GT 1	Design–Randomised Block Design Replications–3 Plot size–5
Trial 3	17 ortets and 3 check clones	KO 31, KO 32, KO 33, KO 34, KO 35, KO 36, KO 37, KO 38, KO 39, KO 40, KO 41, KO 42, KO 43, KO 44, KO 45, KO 46, KO 47, RR11 105, RR11 600, GT 1	Design–Randomised Block Design Replications–3 Plot size–5

KO stands for Koney Estate where the ortet selection programme was undertaken

TABLE 4. MEAN PERFORMANCE OF CLONES IN SMALL SCALE TRIALS

Traits	Trial 1	Trial 2	Trial 3
Girth at opening (cm)	53.70*	54.02*	52.23*
Girth increment at immaturity (cm year ⁻¹)	7.54*	7.58*	7.51*
Girth increment under tapping (cm year ⁻¹)	3.31*	3.10*	3.40*
Tappability (%)	72.04	79.86	61.02
Clear bole volume (m ³ tree ⁻¹)	0.12*	0.12	0.11*
Yield of rubber over 5 years (g tree ⁻¹ tap ⁻¹)	37.86*	43.02*	36.82*
Volume of latex (mL tree ⁻¹ tap ⁻¹)	116.00*	118.00	76.18*
Dry rubber content (%)	40.09*	41.80	42.43*
Bark thickness (mm)	6.93*	7.27*	6.94*
No. of latex vessel rows	12.18*	13.68*	14.0*
Leaf retention % (abnormal leaf fall)	59.72*	56.93*	57.77*
Percent Disease Incidence (Powdery mildew) (%)	57.33*	56.67*	60.84*
Tapping panel dryness (%)	13.45*	9.66*	9.16*

*Significant at P = 0.05

Girth increment at immaturity in trial 2 ranged from 6.7 to 8.5 cm year⁻¹. KO 16, KO 27, KO 22 and GT 1 were the best clones in terms of girth increment at immaturity. Girth increment under tapping ranged from 1.64 to 5.06 cm year⁻¹. KO 30, KO 20 and KO 22 were the best in terms of girth increment under tapping. Girth at opening ranged from 47.47 to 58.97 cm, with the girth of KO 22, KO 24, KO 27 and KO 16 on par with GT 1.12 clones showed more than 70% tappareability with four clones *viz.*, KO 16, KO 22, KO 27 and GT 1 exhibiting 100% tappareability. Girth increment at immaturity in trial 3 ranged from 6.31 to 8.93 cm year⁻¹ (Table 5). Four clones *viz.*, KO 46, KO 38, KO 40 and KO 31 were superior in terms of girth increment at immaturity. Girth increment under tapping ranged from 1.83 to

5.4 cm year⁻¹ with clone KO 31 showing the highest girth increment under tapping. Girth at opening was highest for KO 46 (60.21cm) with a range of 45.06 to 60.21 cm. Nine clones exhibited more than 70% tappareability with two clones *viz.*, KO 40 and KO 46 giving 100% tappareability. There was wide variation of 10 to 100% for tappareability among the clones (Table 5).

Majority of the selections were found to be high branching in nature. The clear bole volume for clones ranged from 0.06 to 0.21 m³ tree⁻¹ in trial 1, 0.07 to 0.17 m³ tree⁻¹ in trial 2 and 0.07 to 0.17 m³ tree⁻¹ in trial 3 (Table 5). Clone KO 7 exhibited significantly high clear bole volume of 0.21 m³ tree⁻¹ followed by KO 13 (0.18 m³ tree⁻¹), KO 22 (0.17 m³ tree⁻¹) and KO 31 (0.17 m³ tree⁻¹) respectively.

TABLE 5. RANGE IN VARIABILITY FOR DIFFERENT TRAITS IN SMALL SCALE TRIALS

Traits	Trial 1	Trial 2	Trial 3
Girth at opening (cm)	45.53 – 64.98	47.47 – 58.97	45.06 – 60.21
Girth increment at immaturity (cm year ⁻¹)	6.48 – 9.20	6.70 – 8.50	6.31 – 8.93
Girth increment under tapping (cm year ⁻¹)	1.72 – 5.13	1.64 – 5.06	1.83 – 5.40
Tappareability (%)	27.27 – 100	44.44 – 100	10.00 – 100
Clear bole volume (m ³ tree ⁻¹)	0.06 – 0.21	0.07 – 0.17	0.07 – 0.17
Yield of rubber over 5 years (g tree ⁻¹ tap ⁻¹)	22.20 – 56.44	31.33 – 71.00	21.70 – 56.75
Volume of latex (mL tree ⁻¹ tap ⁻¹)	47.50 – 195.00	42.33 – 227.00	40.83 – 132.50
Dry rubber content (%)	26.70 – 50.30	37.70 – 45.35	37.20 – 50.25
Bark thickness (mm)	5.87 – 7.99	6.74 – 8.11	6.42 – 7.78
No. of latex vessel rows	7.33 – 14.51	11.08 – 18.84	10.82 – 17.44
Leaf retention % (abnormal leaf fall)	31.70 – 78.3 0	38.30 – 73.30	36.67 – 78.33
Percentage Disease Incidence (Powdery mildew) (%)	33.70 – 84.00	26.00 – 79.30	36.00 – 84.00
Tapping panel dryness (%)	0.00 – 37.50	0.00 – 33.00	0.00 – 23.07
Wind damage (%)	0.00 – 20.00	0.00 – 20.00	6.00 – 33.33

Yield and Yield Attributes

Mean performance and range in variability for dry rubber yield, volume of latex per tapping and dry rubber content of ortets across three small scale trials are given in *Tables 4* and *5*. The mean yield over five years of tapping ranged from 22.2 to 56.44 g tree⁻¹tap⁻¹ with a general mean of 37.86 g tree⁻¹tap⁻¹ in trial 1. Clone KO 6 exhibited mean dry rubber yield of 56.44 g tree⁻¹tap⁻¹ followed by KO 9 (52.11 g tree⁻¹tap⁻¹) and KO 7 (50.60 g tree⁻¹tap⁻¹). Clones *viz.*, KO 11 (48.88 g tree⁻¹tap⁻¹), KO 13 (44.87 g tree⁻¹tap⁻¹) and KO 10 (42.09 g tree⁻¹tap⁻¹) gave higher yields than the check clones tested.

Clones evaluated in trial 1 gave a mean latex volume of 116.0 mL tree⁻¹tap⁻¹ which ranged from 47.50 to 195 mL tree⁻¹tap⁻¹. Clone KO 11 gave highest volume of latex which was significantly superior to the rest followed by KO 7 (173.33 mL tree⁻¹tap⁻¹). Eight clones were better than or comparable with clone RRII 105 for volume of latex. The dry rubber content ranged from 26.7 to 50.3 percent with a general mean of 40.09 percent. Clones KO 11, KO 9 and KO 6 gave significantly high percentage of dry rubber content.

The annual mean dry rubber yield over five years in trial 2 ranged from 31.33 to 71 g tree⁻¹tap⁻¹ with a general mean of 43.02 g tree⁻¹tap⁻¹. Clone KO 27 gave the highest yield of 71 g tree⁻¹tap⁻¹ which was significantly superior to the rest followed by KO 25, KO 16 and KO 26 with 61.34, 55.51 and 48.17 g tree⁻¹tap⁻¹ respectively. GT1 was the better performer than the other two check clones in trial 2.

Clones evaluated in trial 2 gave a mean latex volume of 118 mL tree⁻¹tap⁻¹ with a range from 42.33 to 227 mL tree⁻¹tap⁻¹. KO 16 (227 mL tree⁻¹tap⁻¹) and KO 27 (220 mL tree⁻¹tap⁻¹) gave a higher latex volume than RRIM 600 (205.67 mL tree⁻¹tap⁻¹) which performed best

among the three check clones. The dry rubber content of clones evaluated in trial 2 showed a comparatively higher percentage ranging from 37.7 to 45.35 percent.

Clonal variation for mean yield over first five years was highly significant in trial 3. However, none of the clones gave higher yield than the high yielding control clone RRII 105 in this trial. Nevertheless, four clones *viz.*, KO 42 (51.39 g tree⁻¹tap⁻¹), KO 34 (47.33 g tree⁻¹tap⁻¹), KO 39 (46.07 g tree⁻¹tap⁻¹) and KO 40 (43.43 g tree⁻¹tap⁻¹) gave a yield comparable with that of the control clones RRII 105 and GT 1.

Mean volume of latex of clones evaluated in trial 3 ranged from 40.83 to 132.50 mL tree⁻¹tap⁻¹ with a mean of 76.18 mL tree⁻¹tap⁻¹. KO 34 showed the highest volume of latex (132.5 mL tree⁻¹tap⁻¹) followed by KO 42 (128.75 mL tree⁻¹tap⁻¹) which was comparable with that of check clones RRII 105 and GT1. In general, clones showed high dry rubber content in this trial which ranged from 37.2 to 50.25 with a general mean of 42.43 percent.

Bark Anatomical Parameters

Mean performance and range in variability for bark anatomical characters of the clones evaluated at the time of opening is given in *Tables 4* and *5*. The number of latex vessel rows ranged from 7.33 to 14.51 with a mean of 12.18 in trial 1, 11.08 to 18.84 with a mean of 13.68 in trial 2 and 10.82 to 17.44 with a mean of 14 in trial 3. Among the 18 clones, clone KO 7 exhibited significantly superior number of latex vessel rows (14.51) in trial 1. In trial 2, two clones *viz.*, KO 22 (18.84) and KO 24 (18.34) recorded significantly superior number of latex vessel rows followed by the high yielding clone KO 27 (15.50). Clones with high number of latex vessel rows in trial 3 included KO 46 (17.44), KO 47 (16.33), KO 40 (15.49), KO 39 (15.14) and KO 36 (15.13).

Among the check clones RRIM 600 performed better in terms of number of latex vessel rows. 15 clones had thicker bark comparable with that of clone GT1 which included selected clones KO 11, KO 6, KO 22, KO 27 and KO 16.

Incidence of Disease, Tapping Panel Dryness and Wind Damage

Reaction of clones to abnormal leaf fall and powdery mildew across three trials are furnished in *Tables 4* and *5*. The intensity of abnormal leaf fall due to infection by *Phytophthora spp.* over two years of observation varied significantly among clones in all the three trials with leaf retention percentage ranging from 31.7 to 78.3% with a general mean of 59.72% in trial 1, 38.3 to 73.3% with a mean value of 56.93% in trial 2 and 36.67 to 78.33% with a mean value of 57.77% in trial 3. Clones RRIM 105, GT 1 and four ortets *viz.*, KO 13, KO 9, KO 2 and KO 6 were found highly tolerant with more than 70% leaf retention in trial 1. Control clone RRIM 105 was found to be highly tolerant with more than 70% leaf retention in all the trials. A total of seven ortets *viz.*, KO 13, KO 9, KO 2, KO 6, KO 20, KO 31 and KO 38 exhibited very high tolerance with more than 70% leaf retention percentage.

All the clones evaluated were affected by powdery mildew caused by *Oidium heveae* with varying intensity (*Table 5*). The intensity of powdery mildew in terms of Percent Disease Incidence (PDI) ranged from 33.7 to 84 with a mean of 57.33% in trial 1, 26 to 79.3 with a mean of 56.67% in trial 2 and 36 to 84 with a mean of 60.84% in trial 3. Thirteen ortets showed less than 50% intensity of disease of which the lowest PDI was registered by clone KO 22 (26%).

The incidence of tapping panel dryness ranged from 0 to 37.5% in trial 1 with a general mean of 13.45 percent. In trial 2, it

ranged from 0 to 33 with a mean of 9.66% and 0 to 23.07 with a mean of 9.16% in trial 3. Out of the 47 ortets evaluated, 16 ortets were free from tapping panel dryness after five years of tapping.

Wind damage incidence among the clones ranged from 0 to 20% with less than 3% trees affected in trial 1, 0 to 20% with less than 3% trees affected in trial 2 and 6 to 33.33 with 6.97% of trees affected in trial 3. Out of 47 ortets evaluated 31 were free from incidence of wind damage.

DISCUSSION

The viability of any agricultural enterprise depends largely on the use of high yielding cultivars. In *Hevea*, crop productivity can be maximised by planting high yielding clones which have been selected effectively for the target production system. Mother tree selection or ortet selection was the oldest method adopted in rubber breeding to select favourable cultivars from a population with large genetic variability. In the improvement of rubber, before releasing the clone for wide scale planting, evaluation and selection of clones for yield potential and secondary attributes at different stages of evaluation is imperative. Though rubber tree is valued for its yield of latex, tree girth, which is one of the major determinant of timber yield has also been employed as an important selection parameter in *Hevea* breeding programmes. In the present study, besides identifying the promising latex yielders with secondary attributes, attempts have also been made for quantifying timber yield of the clones developed under the ortet selection programme.

In the initial screening for selecting outstanding individual seedling from the base population, a greater emphasis was given to latex yield and tree girth. Tree girth, besides being an important determinant of

TABLE 6. PERFORMANCE OF PROMISING SELECTIONS FROM THE SMALL SCALE TRIALS

Clone	Girth at opening (cm)	Girth increment at immaturity (cm year ⁻¹)	Girth increment under tapping (cm year ⁻¹)	Tappability (%)	Bole volume (m ³ tree ⁻¹)	Yield over 5 years (g tree ⁻¹ tap ⁻¹)	Dry rubber content (%)	Bark thickness (mm)	No. of latex vessel rows	Abnormal leaf fall retention (%)	Powdery mildew Percentage Disease Incidence (PDI)	Tapping panel dryness (%)	Wind damage (%)
KO 27	57.73	8.30	2.83	100	0.14	67.00	41.50	7.82	15.56	66.67	79.30	9.09	0.00
KO 25	52.10	7.34	3.14	92.31	0.10	61.34	44.80	6.85	13.08	58.30	68.00	23.07	0.00
KO 6	57.47	7.89	3.20	90.91	0.13	56.44	46.20	7.16	12.39	71.70	64.30	0.00	6.60
KO 11	58.56	8.36	3.41	100	0.13	48.88	50.30	8.00	13.25	63.30	47.70	10.00	0.00
KO 16	56.79	8.50	2.80	100	0.10	55.51	41.55	7.11	11.33	45.00	45.30	0.00	0.00
KO 9	55.79	8.02	4.77	90	0.14	52.11	47.20	7.06	12.58	75.00	61.70	12.5	20.00
KO 7	64.98	9.20	5.13	100	0.21	50.60	43.60	6.79	14.51	68.30	63.00	7.14	0.00
KO 13	60.43	8.47	4.57	75	0.18	44.87	44.55	6.66	12.38	78.30	64.3	9.09	13.3
KO 46	60.21	8.93	4.08	100	0.15	32.35	44.65	7.08	17.44	66.67	79.33	0.00	0.00
KO 31	55.24	8.03	5.40	78.57	0.17	32.78	42.25	6.92	11.92	75.00	70.33	0.00	20.07
KO 22	58.97	8.01	4.09	100	0.17	40.00	43.75	8.11	18.84	50.00	26.00	7.14	0.00
GT 1	55.22	7.84	3.30	83.75	0.11	37.22	38.68	7.49	13.08	70.31	69.90	12.53	4.42
RRIM600	47.80	6.75	3.14	44.80	0.10	33.08	34.50	7.14	14.73	46.12	38.56	6.11	0.00
RRII105	50.45	7.18	2.00	56.85	0.08	43.84	40.70	6.41	11.37	73.34	45.46	20.45	4.43

area of tapping panel, also determines the bole volume, which in turn contributes to timber yield. Apart from yield and girth, secondary characters like incidence of stem and leaf diseases, tapping panel dryness, branching habit, trunk condition (round/ fluted/ straight) of the seedling trees were also scored. In addition, competition and suppression effects of the selected trees in their local environment were also considered, which points to the efficiency of the ortet selection procedure adopted. The inherent genetic variability of the seedling population screened was evident from the data which enabled effective selection from the seedling population.

The results from the present study helped to identify high yielding ortet clones with other secondary attributes (*Table 6*). Dry rubber content and volume of latex are the most important components of rubber yield⁸⁻⁹. The present results of small scale evaluation revealed the superiority in dry rubber yield of nine clones *i.e. viz.*, KO 27, KO 25, KO 6, KO 16, KO 9, KO 42, KO 7, KO 11 and KO 26. Further, clones KO 27, KO 16, KO 11 and KO 7 were selected for high dry rubber yield and latex volume. The performance of five clones *viz.*, KO 27, KO 25, KO 6, KO 16 and KO 9 were significantly superior in dry rubber yield than RRII 105 with mean yields ranging from 52.11 to 71.0 g tree⁻¹tap⁻¹ and comparable among themselves as determined by the weighted 't' test.

Structural attributes like bark thickness and number of latex vessel rows are clonal characters which influence rubber yield¹⁰. Clones KO 22, KO 24, KO 46, KO 47 and KO 27 could be selected for high number of latex vessel rows while clones KO 22, KO 11, KO 27, KO 38 and KO 30 were superior for bark thickness.

Vigour in terms of tree girth is also an important selection parameter in rubber. Early opening and good early yield are only possible

in a tree which grows vigorously when young⁸. An ideal rubber clone would be the one which maintains both high rubber yield as well as vigorous growth so as to sustain a high yield trend for many years. Therefore, incorporation of yield and growth attributes would be of great value in selection of superior clones in rubber². The present study identified stable and vigorous ortet clones like KO 7, KO 11, KO 16, KO 22, KO 27, KO 40 and KO 46 which was evident from achieving 100% tappareability by the seventh year after planting. High girth coupled with high growth rate during the immature phase shown by clones KO 7, KO 13, KO 46, KO 38, KO 5, KO 11, KO 16, KO 22, KO 24, KO 40 and KO 27 indicate early attainment of tappareability of these clones. In order to obtain sustainable yield over a long period, a satisfactory rate of growth of trees are to be maintained¹¹. The inherent vigour of clones KO 7, KO 9, KO 13, KO 22, KO 30, KO 31, KO 38, KO 40 and KO 46 are evidenced by their maintenance of high growth rate even under tapping.

The yield and timber obtained from a rubber tree comprises mainly of the clear bole volume¹² 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 high timber volume, clones KO 7, KO 13, KO 31, KO 30, KO 46 and KO 22 maintained a high growth rate in the tapping phase also, which is an indication of their timber yield potential in later years. Among these clones KO 22, KO 7 and KO 13 showed a high branching habit also. Clones with high girth along with a high branching habit are preferred for use as timber clones since the waste generated by felling, logging and sawing would be less¹³. Clones KO 7, KO 13, KO 22 and KO 31 were identified as potential timber yielding clones among the newly evolved primary clones.

TABLE 7. CHARACTERISTICS OF PROMISING PRIMARY CLONES

Clone	Promising features
KO 27	Tall, straight and cylindrical trunk. Vigorous main and secondary branches with medium to dense canopy. High rubber yield with above average dry rubber content and high volume of latex. High girth at opening, high girth increment at immaturity and average girth increment under tapping. Promising timber yield potential. Above average bark thickness. High number of latex vessel rows. Below average tapping panel dryness and moderate resistance to abnormal leaf fall disease.
KO 25	Tall, straight, cylindrical stem with smooth bark. High branching with dense canopy. High rubber yield with high dry rubber content. Above average girth at opening. Above average girth increment on tapping. Average bark thickness and above average number of LVR. Moderate resistance to abnormal leaf fall.
KO 6	Tall and straight main stem with smooth bark. High branching with canopy. High rubber yield with high dry rubber content. High girth at opening. High girth increment at immaturity. Above average girth increment on tapping. Above average bark thickness and above average number of latex vessel rows. High resistance to abnormal leaf fall disease, absence of tapping panel dryness.
KO 11	Tall, straight and cylindrical main stem with smooth bark. Moderately high rubber yield with high dry rubber content. High girth at opening, high girth increment at immaturity and above average girth increment under tapping. Promising timber yield potential. High bark thickness with above average number of latex vessel rows. Below average tapping panel dryness, moderate resistance to abnormal leaf fall.
KO 16	Straight and cylindrical stem with smooth bark. Heavy branches with dense canopy. High rubber yield with high dry rubber content and high volume of latex. High girth at opening. High girth increment at immaturity and average girth increment under tapping. Absence of tapping panel dryness, moderate resistance to powdery mildew.
KO 9	Tall and cylindrical stem. Vigorous growth habit, good branching with prominent leader. High rubber yield with high dry rubber content. High girth at opening, high girth increment at immaturity and high girth increment under tapping. Promising timber yield potential. Average bark thickness and average number of latex vessel rows. High resistance to abnormal leaf fall.
KO7	Vigorous, cylindrical main stem and smooth bark. High and uniform branching. High rubber yield with high volume of latex and high dry rubber content. Excellent growth with high girth at opening, high girth increment at immaturity and high girth increment under tapping. High timber yield potential. Average bark thickness with high number of latex vessel rows.
KO13	Tall, straight cylindrical stem with smooth bark. High and heavy branching with dense canopy. Moderately high yield with a rising yield trend. High dry rubber content. Excellent growth with high girth at opening, high girth increment at immaturity and high girth increment under tapping. High timber yield potential. High resistance to abnormal leaf fall.
KO 46	Tall, straight and cylindrical stem. High timber yield potential. Excellent growth with high girth at opening, high girth increment at immaturity and high girth increment under tapping. High number of latex vessel rows and above average bark thickness. Absence of tapping panel dryness, moderate resistance to abnormal leaf fall.
KO 31	Cylindrical stem, leader prominent with high branching. High timber yield potential. High girth at opening, high girth increment at immaturity. Very high girth increment on tapping, absence of tapping panel dryness and high resistance to abnormal leaf fall.
KO 22	Tall, straight and cylindrical stem. High and moderate to heavy branches. High timber yield potential. High girth at opening. High girth increment at immaturity and high girth increment under tapping. High bark thickness and high number of latex vessel rows. High resistance to powdery mildew and moderate tolerance to abnormal leaf fall. Absence of tapping panel dryness.

Resistance to various biotic and abiotic stresses is of great significance in assessing the performance of rubber clones. Abnormal leaf fall is the most destructive disease of rubber in India¹⁴, while pink disease, predominant in young rubber trees is the most serious among stem diseases¹⁵. Tapping panel dryness, generally considered to be a physiological disorder associated with excessive exploitation¹⁶, occurs in varying intensities among clones¹⁷⁻¹⁸.

Among the promising ortet clones, KO 9 and KO 31 showed very good leaf retention and clones KO 7, KO 6, KO 11, KO 13, KO 27, KO 24 and KO 40 showed above average tolerance to abnormal leaf fall disease. Clone KO 22 exhibited the lowest powdery mildew incidence. Other promising clones tolerant to powdery mildew were KO 11 and KO 40. Clones KO 6, KO 16 and KO 31 were free from tapping panel dryness. Other promising ortets with less incidence to tapping panel dryness were KO 7, KO 13, KO 11, KO 27 and KO 22. Though clones KO 34 and KO 42 are good yielders, they were not selected owing to their very high susceptibility to tapping panel dryness and wind damage.

CONCLUSIONS

Production of new planting materials of rubber with high productivity assumes importance in view of increasing demand for the raw material in the rubber industry. Exploitation of genetic variability through ortet selection programmes for identification of superior clones assumes significance in crop improvement of rubber.

The ortet selection programme conducted at Koney estate and subsequent evaluation of the selections in small scale trials have led to the development of 11 new primary clones. From a comprehensive study of various parameters of the ortet clones, five clones *viz.*, KO 27, KO 25, KO 6, KO 16 and KO 9 emerged as high latex yielders. Four clones KO 7, KO 13, KO 22, KO 31 could be selected for high timber

yield. Seven clones *viz.*, KO 7, KO 11, KO 13, KO 16, KO 22, KO 27 and KO 46 emerged as most vigorous clones. Three clones *viz.*, KO 27, KO 7 and KO 11 were performing both in terms of yield and timber. Clone KO 13 showed rising yield trend coupled with secondary attributes while clones KO 22 and KO 46 excelled in terms of vigour, timber yield and tolerance to biotic and abiotic stress. These clones, apart from serving as future planting materials could be incorporated in hybridisation programmes for widening the genetic base of *Hevea*. These 11 new primary clones could be recommended for the next stages of evaluation and clonal selection *viz.*, large scale trials and on farm trials in different locations.

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