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Long term performance of certain ortets and hybrid clones of *Hevea brasiliensis* in a high altitude region in Kerala, India

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Abstract

Long term performance of four hybrid *Hevea* clones and 10 ortet selections including nine from a high elevation site within the traditional rubber growing tract of Kerala, was studied. Significant variability was observed among the hybrids and ortets for all major agronomic traits. Growth of rubber trees was invariably poor in the high altitude region and tappability by the 10th year of planting was less than 50 per cent. The hybrid clones RRII 203 and RRIC 100 showed highest growth vigour with 80 per cent tappability by the 13th year of planting. Among the ortets, P 270 and Iritty 1 recorded the highest tappability of 64 per cent. The ortet P 270 was the best performer with the highest girth at the opening (61 cm), girth increment during immaturity (5.5 cm) on tapping (3.4 cm) and bole volume (0.1 m^3). RRII 203 was the highest yielding clone with 56 g $tree^{-1}$ tap^{-1} over eight years of tapping. High annual yield (48 g $tree^{-1}$ tap^{-1}) and lean season yield of P 270 combined with high dry rubber content (drc) on par with the highest yielding clone RRII 203 indicated the specific adaptability of this ortet to high elevation areas. The ortets P 213 and Iritty 1 and hybrid clone RRIC 100 were the other promising clones exhibiting growth adaptation and high yield potential under high altitude conditions.

Keywords: Growth, *Hevea brasiliensis,* high elevation, yield

Introduction

The traditional rubber growing belt in peninsular India is situated at altitudes up to 300 m MSL. However, due to the compelling demand for area expansion, the species is now extended to the tropical high altitude areas in the traditional region as well as subtropical highlands and high latitude areas of the non-traditional region in North East India. The variable productivity due to the spatial distribution of the crop within the traditional region was earlier discussed by Vijayakumar *et al.* (2000) and Nair *et al.* (2010). Rubber cultivation at high altitudes is normally not advisable due to multiple constraints including low-temperature stress, irregular rainfall pattern, high wind velocity, low humidity during summer months, disease epidemics and altered soil physical properties (Priyadarshan *et al.,* 2005). Chattopadhyay (2015) highlighted the physiographic and ecological limit for growing rubber in Wayanad district, a high elevation area (>900 m above MSL) within the traditional rubber growing tract of India. Gahlod *et al*. (2017) have identified 32.5 per cent of the area comprising 69158 ha as marginally suitable for cultivation whereas 35 per cent of the area was observed to be unsuitable for rubber in this region. They also observed that marginally suitable areas for rubber cultivation could be brought under moderately suitable areas by adopting strategies to combat chilling stress and associated stress factors. At the same time, the area under rubber in Wayanad has shown a progressive increase over the last few decades (Karunakaran, 2013). This situation warrants identification of specifically adapted clones suitable to high altitude regions for profitable exploitation of the crop.

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Recently, to formulate a region-specific recommendation of *Hevea* clones, the traditional belt of South India was further divided into seven regions of which tropical high altitude region of Wayanad and Idukki has been treated separately (Mydin *et al.,* 2017). These areas are characterised by high altitude above 450 MSL, heavy South West monsoon with a mean annual rainfall of 4000 mm, very low temperature in January with over-hanging mist favourable for high powdery mildew infestation, which is followed by a dry spell of four months. Clones that can withstand low temperature and tolerance to powdery mildew will only be suitable for cultivation to sustain growth and yield in the region. The present study is the first step in this direction in Wayanad.

Screening of old seedling trees (ortets) in a small village Panamaram in Wayanad, Kerala State, India a high elevation site, was undertaken in the early 1990s based on growth, yield and tolerance to *Oidium heveae.* Another ortet selection from North Kerala, *i.e.,* Iritty 1, was also identified during the same period. These ortets were further evaluated in Ambalavayal in Wayanad district (>900 m above MSL), along with four hybrid clones *viz.*, RRII 105, RRII 203, RRIC 100, RRIC 102 and PB 86 a primary clone (ortet). The performance of these clones with respect to immature growth, test tap yield in the early mature phase and incidence of powdery mildew disease has already been reported by Lakshmanan *et al*. (2006). The results of long term evaluation of these clones over 21 years are discussed in this paper to identify clones with high yield and desirable secondary attributes suited to high altitude farming.

Materials and methods

Layout and field upkeep

A small scale evaluation trial was laid out in 1995 in the Regional Research Station of the Kerala Agricultural University, Ambalavayal, Wayanad district (latitude 11°37'N, longitude 76°12'E; 974 m above MSL) Kerala State, India. The minimum temperature in the region ranged from 14 to 21°C and maximum from 21 to 31°C. The experiment was laid out in a randomised complete block design with three replications, comprising of ten ortet selections *viz.,* P 1, P 2, P 90, P 121, P 155, P 213, P 270, P 280, P 296 and Iritty 1 and five popular clones *viz.,* RRII 105, RRII 203, RRIC 100, RRIC 102 and PB 86. Out of the ten ortets, nine were from Panamaram in Wayanad and one from Iritty, Kannur district (Iritty 1). The details of test clones are given in Table 1. All cultural operations were undertaken as per the recommended package of practices (Rubber Board, 2019).

Growth measurements

The girth was monitored annually from the 4th year after field planting, by measuring the trunk girth at 125 cm height from the bud union. Annual girth increment for the immature and mature phases was calculated from annual girth data. The percentage of tappable trees attaining a girth of 50 cm at a height of 125 cm from the bud union was recorded during the 10th year of planting. At the end of the study period, *i.e.,* 21 years after field planting, clear bole height was measured as the distance from the bud union to the first forking. Clear bole volume was calculated from the data on bole height and corresponding girth of trees following the method given by Chaturvedi and Khanna (1982).

Dry rubber yield and yield components

Trees were opened for tapping in the 10th year of planting under the S/2 d3 6d/7 tapping system.

Table 1. Clones included in the study along with parentage

Clone	Parentage	Selected from/ Developed by
P 1	Ortet selection	Panamaram, Wayanad
P 2	”	”
P 90	”	”
P 121	”	”
P 155	”	”
P 213	”	”
P 270	”	”
P 280	”	”
P 296	”	”
Iritty 1	”	Iritty, Kannur
RRII 105	Tjir 1 x Gl 1	India
RRII 203	PB 86 X Mil 3/2	India
RRIC 100	RRIC 52 X PB 83	Sri Lanka
RRIC 102	RRIC 52 X RRIC 7	Sri Lanka
PB 86	Primary clone	Malaysia

Tree wise yield was recorded by cup coagulation method (Nair *et al.*, 2012), and dry weight of cup lumps was expressed as grams per tree per tap (g tree^{-1} tap^{-1}). The yield reduction in summer was calculated by deducting the lean season yield (Feb-May) from the annual yield and expressed in percentage. Monthly variation in yield was plotted from yield data over the first eight years of tapping. The volume of latex (mL tree^{-1} tap^{-1}) and dry rubber content (%) was determined on a seasonal basis during lean and peak yielding period. Disease incidence was monitored, and preventive measures were adopted whenever essential. Integrated use of systemic and non-systemic fungicides was used to avoid the chances of building up resistance in the pathogen against fungicides (Edathil *et al.*, 1998). Analysis of variance for all the characters was worked out as per the standard procedure and the observed differences among different treatments compared based on CD values.

Results and discussion

Ortet selection involves systematic screening of vast seedling plantations obtained through natural genetic recombination, identification and multiplication of elite trees, followed by field evaluation and selection of outstanding genotypes. Clones developed through ortet selection are called primary clones. In India, from the early screening of high yielding mother trees, RRII 5 was a promising ortet for latex and timber yield, and RRII 33 was noted for its tolerance to abnormal leaf fall (Marattukalam *et al.*, 1980). Later, several ortets were added to the pipeline (Mydin *et al.*, 2005; Mercykutty *et al.*, 2013; John *et al.*, 2013). The present ortets selected from Wayanad are relatively recent.

Girth and tappability

The percentage of tappable trees assessed from the 10th year of planting revealed wide clonal variation in the number of trees attaining tappability. RRII 203 attained a tappability of 53.3 per cent by 10th year after planting, followed by RRIC 100 (46.7 %). The other hybrid clones and ortets failed to attain tappable girth of 50 cm by 10th year. By the 13th year of planting, the hybrid clones RRII 203 and RRIC 100 attained the highest tappability

Table 2. Girth at opening and girth increment rate of clones

Clone	Tappability (%) (10th yr)	Tappability (%) (13th yr)	Girth at opening (cm)	Girth during 21st year of planting (cm)	Girth increment rate at immaturity (cm)	Girth increment rate on tapping (cm)	Clear bole volume (m^3)
P 1	23.3	30.0	54.3	74.3	4.7	2.5	0.06
P 2	0.0	34.4	44.1	65.3	4.2	2.6	0.06
P 90	26.7	33.3	43.4	67.4	3.3	3.0	0.07
P 121	0.0	19.4	42.0	57.3	3.7	1.9	0.05
P 155	0.0	16.7	39.9	60.5	3.6	2.6	0.06
P 213	35.0	43.3	52.7	77.2	4.6	3.1	0.08
P 270	13.3	63.3	61.3	88.4	5.5	3.4	0.10
P 280	16.7	45.0	47.2	73	4.2	3.2	0.08
P 296	6.7	53.3	48.6	68.5	4.1	2.5	0.08
Iritty 1	20.0	63.9	52.5	71.5	4.4	2.4	0.06
RRII 105	0.0	19.4	44.4	51.1	3.8	0.8	0.04
RRII 203	53.3	80.0	59.8	80.7	5.2	2.6	0.10
RRIC 100	46.7	80.0	59.7	71.8	5.4	1.5	0.07
RRIC 102	31.7	38.3	46.5	51.1	3.9	0.6	0.04
PB 86	30.0	36.7	48.4	66.5	4.1	2.3	0.07
SE	-	-	3.9	5.5	0.42	0.45	0.01
CD	-	-	11.4	15.9	1.22	1.31	0.04

of 80 per cent followed by ortets Iritty 1 (63.9 %), P 270 (63.3 %) and P 296 (53.3 %). All the other clones failed to cross the threshold tappability of 50 per cent (Table 2). The ortets P 155, P 121 and clone RRII 105 showed the least tappability of less than 20 per cent even after 13 years of planting. Tuy *et al*. (1998) also observed an increase in immaturity period with altitude in the high lands of Vietnam. Growth parameters in terms of girth at the opening, girth during the 21st year and girth increment before and after tapping, showed significant clonal variation. Girth at opening varied from 39.9 cm (P 155) to 61.3 cm (P 270). The ortets P 1, P 213, Iritty 1 and hybrid clones RRII 203 and RRIC 100 showed opening girth on par with P 270 which recorded the highest girth. P 270 also exhibited the highest girth in the final year of girth recording, *i.e.,* 21st year of planting (88.4 cm). Three ortets P 1, P 213 and P 280 along with RRII 203, showed high girth on par with P 270 at the end of the study period. Iritty 1 and RRIC 100 were the other clones with a high girth of 72 cm. Girth increment (GI) rate before tapping varied from 5.5 cm (P 270) to 3.3 cm (P 90). Five ortets from Panamaram, Iritty 1, RRII 203 and RRIC 100 showed GI at immaturity on par with P 270. The trend of high GI at immaturity for P 270 was continued in the mature phase also with the clone exhibiting the highest GI rate on tapping (3.4 cm) followed by P 280 and P 213. The GI on tapping of all the hybrid clones was poor in the region, except RRII 203 and PB 86 (Table 2).

The growth trend of the ortets and hybrids for a long term period of 21 years is plotted in Figure 1. Among the hybrid clones, the differences in girth were not significant until the 6th year after planting. The girth of ortets P 270, P 90, P 296, P 1, P 213 and Iritty 1 was comparable and on par with that of the hybrid clones till the 6th year. Among the popular clones, RRII 105 recorded the lowest girth. Even though RRII 105 is a highly adapted high yielding clone for the traditional tract, its growth and yield

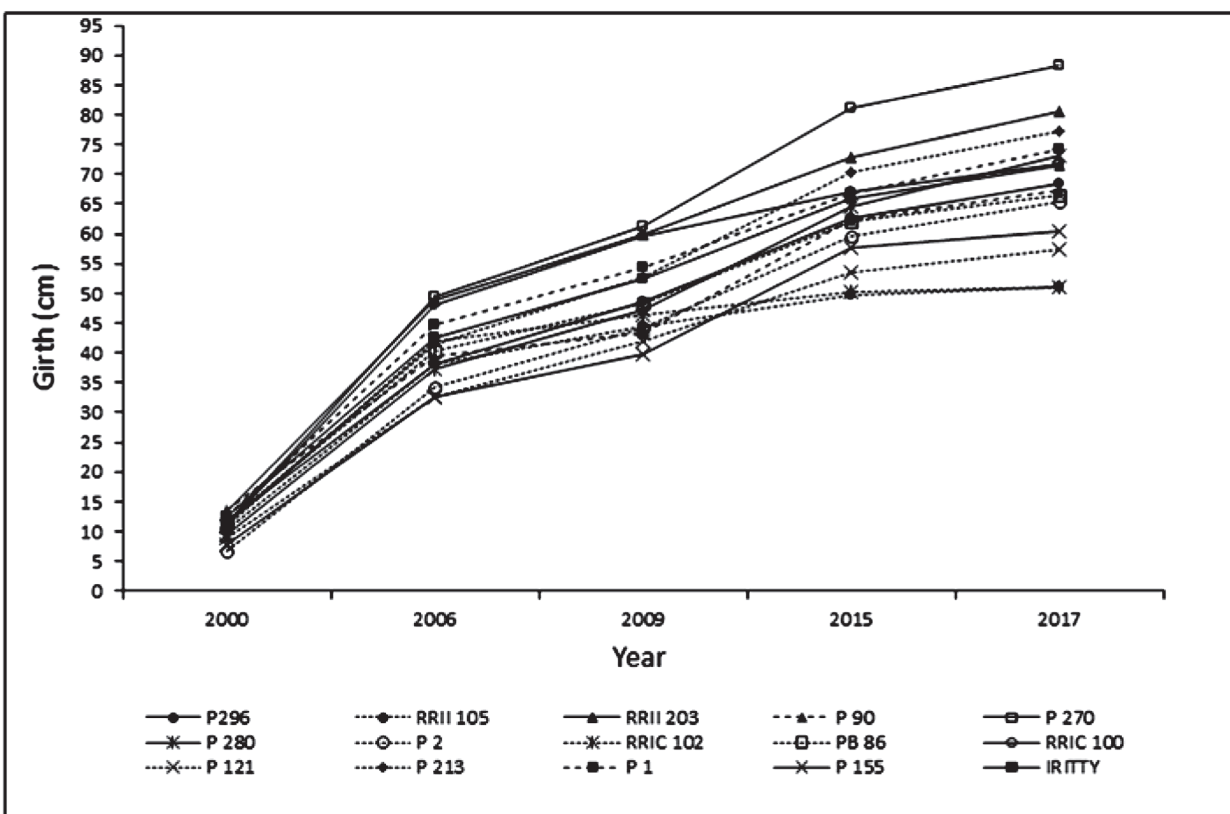

Fig. 1. Girth increment of clones during the study period

reduction under cold stress was reported (Sethuraj *et al*., 1989; Reju *et al*., 2007). From the 10th year after planting the ortet, P 270 showed the highest girth of 49.4 cm and was closely followed by RRII 203 (48.7 cm) and RRIC 100 (48 cm). Overall, P 270, closely followed by RRII 203, maintained the best growth throughout the study period. Compared to ideal growing conditions, relatively poor growth and high clonal variability for growth has been reported from other abiotic stress-prone areas also (Meenakumari *et al.,* 2017).

Crotch height is yet another highly variable trait. The clear bole height of trees usually varies from 4-5 m. In the present study, irrespective of clones, a lower first forking height ranging from 2.2 m to 2.9 m was noticed. However, timber yield in terms of clear bole volume showed significant clonal variation (Table 2). Highest bole volume was recorded by P 270 and RRII 203 (0.1 m^3). P 213 and P 280 were ranked the second best with 0.08 m^3. RRII 203 is categorised as a latex timber (LT) clone (Thomas *et al*., 2003) in the traditional region which has also recorded vigorous growth in the cold prone high altitude areas of non-traditonal NE India (Reju *et al*., 2007). High variability in bole volume was reported within the traditional region itself. The conducive climatic conditions in Kanyakumari region promoted better growth and high timber output, whereas Padiyur region in Kannur district of North Kerala faced with seasonal drought produced the least timber yield (Meenakumari *et al.,* 2017). The average bole volume of the clones evaluated in the high elevation site in this study is much lower than that observed in other parts of Kerala.

Table 3. Mean annual yield (g tree^{-1} tap^{-1}) and summer yield of clones

Clone	Annual yield (g tree^{-1} tap^{-1})			Lean season yield (g tree^{-1} tap^{-1})
	BO -1 panel	BO -2 panel (2 years)	Mean over 8 years	
P 1	27.3	28.6	27.6	25.0
P 2	23.6	23.8	23.7	20.6
P 90	23.8	31.4	25.7	21.6
P 121	21.6	29.7	23.6	20.5
P 155	22.2	29.8	24.1	20.9
P 213	42.1	55.2	45.4	38.7
P 270	45.6	54.6	47.9	40.8
P 280	20.0	27.7	21.9	22.4
P 296	26.3	27.1	26.5	23.5
Iritty 1	41.5	58.7	45.8	34.4
RRII 105	27.9	24.8	27.1	24.7
RRII 203	57.8	52.8	56.6	46.0
RRIC 100	50.3	63.5	53.6	40.0
RRIC 102	19.3	12.0	17.4	10.9
PB 86	46.0	67.6	51.4	39.0
SE	7.3	11.9	8.1	5.8
CD	21.2	34.5	23.5	16.8

Yield and yield components

Mean dry rubber yield in the two virgin panels along with mean yield over eight years of tapping and lean season yield is presented in Table 3. Yield in the BO-1 panel varied from 19.3 g tree^{-1} tap^{-1} (RRIC 102) to 57.8 g tree^{-1} tap^{-1} (RRII 203). Three ortets P 213, P 270 and Iritty 1 along with RRIC 100 recorded yield on par with RRII 203. However, in the BO-2 panel PB 86 and RRIC 100 were the high yielders with 67-63 g tree^{-1} tap^{-1}. P 213, P 270 and Iritty 1 maintained a rising trend in yield whereas RRII 203 recorded a slight drop in yield in the BO-2 panel. RRII 203 recorded the highest yield of 56.6 g tree^{-1} tap^{-1} over eight years of tapping. Three ortets P 213, P 270 and Iritty 1 along with RRIC 100 and PB 86 recorded yield in the range of 45.4 to 53.6 g tree^{-1} tap^{-1} which was on par with RRII 203. Three ortets *viz.,* P 213, P 270, Iritty 1, and two hybrids *viz.,* RRIC 100 and PB 86 exhibited a rising trend in yield whereas RRII 105, RRIC 102 showed a declining trend in yield over the years. Yield during the summer months also showed a similar trend. RRII 203 recorded the highest lean season yield (46 g tree^{-1} tap^{-1}). Three ortets P 213, P 270 and Iritty 1 along with RRIC 100 and PB 86 recorded summer yield on par with RRII 203. RRII 203 is a proven hardy clone combining high growth vigour with moderately high yield in the traditional region (Saraswathyamma *et al*., 1990). The specific adaptation of RRII 203 to high altitude areas has also been reported earlier (Reju *et al*., 2007). RRIC 100, a high yielding clone from Sri Lanka, was reported to be cold susceptible in the high latitude areas of sub-Himalayan West Bengal (Meti *et al*., 2003). However, the average minimum

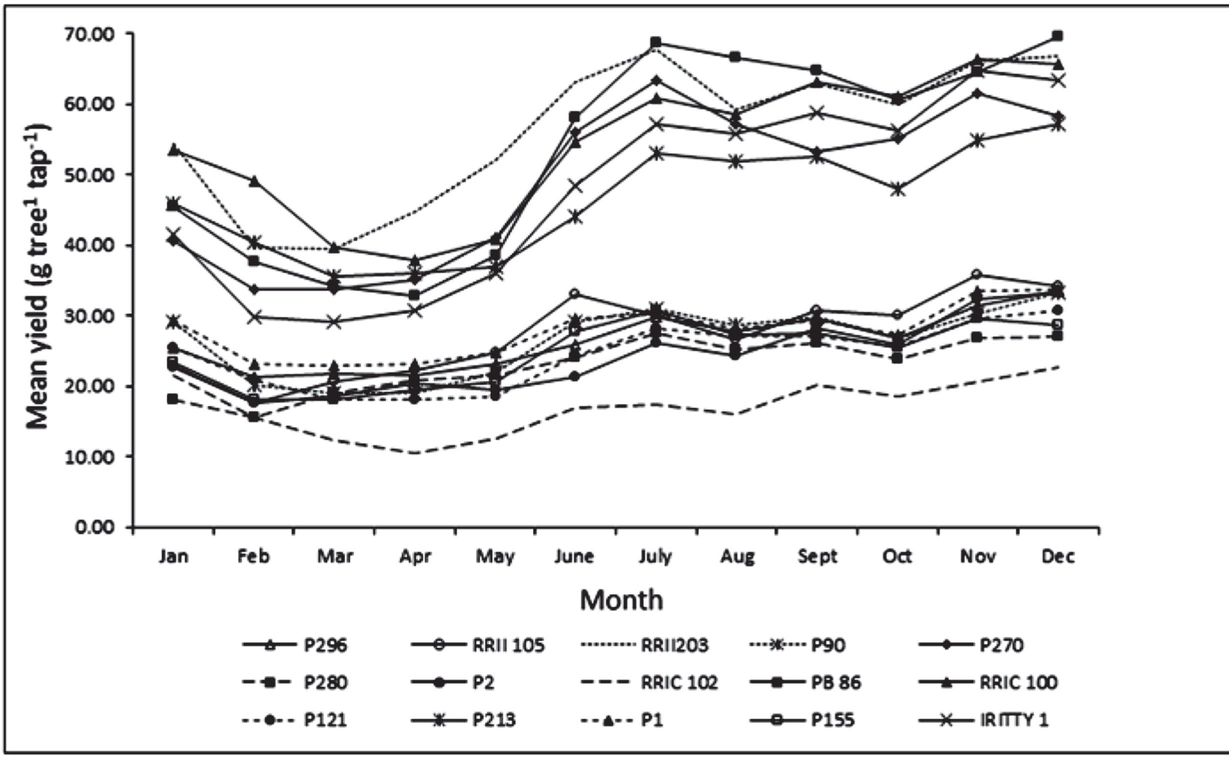

Fig. 2. Seasonal variation in yield

temperature in Wayanad does not go below 15 °C to adversely affect the growth and yield of trees as compared to the very low-temperature stress experienced in Northern West Bengal. PB 86 is one of the oldest primary clones and is a prime progenitor of many of the modern-day clones (Priyadarshan, 2003a) including RRII 203.

Monthly variations in yield were more predominant during the wet months (Fig. 2). The yield pattern of high yielders and low yielders were distinct and consistent throughout the year. The high yielders including hybrids PB 86, RRII 203, RRIC 100 and ortets Iritty 1, P 270 and P 213 showed significantly higher yield compared to low yielders. An increasing trend in yield was observed for all the clones/ortets from May with peak yield in July followed by a declining trend except for RRII 105 and RRIC 100 which showed a peak yield in June followed by a declining trend thereafter. The second peak in yield was observed during November for all clones/ortets. Meteorological data from the study site (Lakshmanan *et al.,* 2006) indicated that the yield trend observed coincide with the rainfall pattern of the region. The decline in yield was noticed during the winter period (November to February) for all clones and ortets, which may be attributed to the elevation induced low winter temperature stress coupled with the onset of wintering. According to Priyadarshan (2003b), temporal yield variations in stress-prone areas are more prominent due to the influence of fluctuating weather variables on specific adaptation.

The volume of latex and dry rubber content (drc) per cent are among the major component traits contributing to high rubber yield. Iritty 1 and RRIC 100 were the best performers in terms of the total volume of latex (258 mL tree^{-1} tap^{-1}) (Table 4). P 213, P 270, RRII 203 and PB 86 recorded latex volume on par with the superior clones. Dry rubber content of clones varied from 30 per cent (RRII 105) to 41.5 (P 270) and clonal variations was significant. Except for P 121, P 155, RRII 105 and RRIC 102, all the ortets and hybrids recorded relatively high drc.

Table 4. Major yield components of clones

Clone	Latex volume (mL $tree^{-1}$ tap^{-1})	Dry rubber content (%)
P 1	102.9	34.1
P 2	79.0	35.2
P 90	84.0	38.5
P 121	94.4	32.7
P 155	114.7	34.4
P 213	172.6	37.0
P 270	168.3	41.5
P 280	93.9	37.0
P 296	69.2	42.0
Iritty 1	258.1	38.5
RRII 105	103.2	30.0
RRII 203	162.5	37.0
RRIC 100	257.4	35.7
RRIC 102	58.0	30.5
PB 86	230.6	35.7
SE	42.2	2.1
CD	122.2	5.9

Overall performance of clones was assessed by a rank-sum method (Kang, 1988), based on mean values for growth, annual yield, and yield components, to identify elite clones (Table 5). P 270 emerged as the top-ranking clone with superior performance for major agronomic traits. It is noteworthy that P 270 registered vigorous growth comparable to the modern clone RRII 414 and its yield was on par with RRII 105, in a clonal nursery evaluation in Central Kerala (Meenakumari *et al*., 2018) indicating the phenotypic plasticity of this clone. Two ortets, P 213 and Iritty 1 and hybrids RRII 203 and RRIC 100 were the other top-ranking clones. Of these, Iritty 1 is reported to show a high degree of tolerance to powdery mildew disease, whereas P 213 and RRIC 100 showed good disease control after prophylactic treatment. RRII 203 and P 270 were, however, found susceptible to powdery mildew disease (Edathil *et al*., 2011). It appears that the interaction of multiple stress factors affects the long term performance of the clones in the high altitude region of Wayanad. Further, large scale/on-farm evaluation of the selected ortets and hybrids is however essential to bring out the best clones suited to the region.

Table 5. Ranking of clones based on overall performance

Clone	Rank sum	Rank
P 270	126	1
RRII 203	113	2
P 213	101	3
RRIC 100	96	4
IRITTY 1	89	5
PB 86	80	6
P 1	79	7
P 280	75	8
P 296	73	9
P 90	59	10
P 2	47	11
P 155	43	12
RRII 105	39	13
P 121	29	14
RRIC 102	20	15

Conclusion

The effect of high elevation induced low-temperature stress varied among the 15 clones under study with respect to growth and latex yield. Two ortets P 270 and Iritty 1 and two-hybrid clones RRII 203 and RRIC 100 were selected for high yield and growth adaptation under the agroclimatic conditions in Wayanad. Even though ortet P 213 recorded high mean yield, the clone showed low tappability indicating high growth variability. PB 86 was a high yielder in the region with medium girth. The promising performance of P 270 in Central Kerala region also renders adaptive plasticity for this clone. The top-ranking clones may be considered for further large scale/on-farm evaluation in the region.

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References

Chaturvedi, A.N. and Khanna, L.S. 1982. *Forest Mensuration*. International Book Distributors Dehradun, 310p.

Chattopadhyay, S. 2015. Environmental Consequences of Rubber Plantations in Kerala, NRPPD Discussion Paper 44. Centre for Development Studies, Trivandrum. 53p.

Edathil, T.T., Jacob, C.K. Idicula, S.P. and Joseph M. 1998. Efficient management of powdery mildew disease of *Hevea* rubber plants with integrated use of systemic and non systemic fungicides. In: *Development in Plantation Crops Research*. (Eds.) Mathew, N.M. and Jacob, C.K. Rubber Research Institute of India, Kottayam. pp. 287-291.

Edathil, T.T., Lakshmanan, R., Thomas, V. 2011. Evaluation of clones and ortet selections of rubber (*Hevea brasiliensis*) for growth and tolerance to powdery mildew at a high altitude station, Ambalavayal. *Natural Rubber Research* **22**(1&2): 151-155.

Gahlod, N.S., Binjola, S. Ravi and Arya, V.S. 2017. Land-site suitability evaluation for tea, cardamom and rubber using Geo-spatial technology in Wayanad district, Kerala *Journal of Applied and Natural Science* **9**(3): 1440-1447.

John, A., Nazeer, M.A., Idicula, S.P., Thomas, V. and Varghese, Y.A. 2013. Potential new primary clones of *Hevea* evolved by ortet selection in India. *Journal of Natural Rubber Research* **16**(2): 134-146.

Kang, M.S. 1988. A rank-sum method for selecting high yielding stable corn genotypes. *Cereal Research Communications* **6**: 113-115.

Karunakaran, N. 2013. Shift to rubber cultivation and consequences on environment and food security in Kerala. *Journal of Rural Development* **32**(4): 395-408.

Lakshmanan, R., Thomas, V., Saraswathyamma, C.K., Edathil, T.T, Sethuraj, M.R. and Aipe, K.C. 2006. Evaluation of certain *Hevea* clones at a high altitude station in Wyanad district of Kerala, India *Proceedings of Inernational Natural Rubber Conference* 13-14, Nov 2006, Vietnam.

Marattukalam, J.G., Saraswathyamma, C.K. and George, P.J. 1980. Crop improvement of *Hevea* through ortet selection in India. *International Rubber Conference,* 23-28 Nov 1980, Rubber Research Institute of India, Kottayam, India, pp. 47-60.

Meenakumari, T. Lakshmanan, R., Soman, T.A., Mondal, G.C., Gireesh, T. and Mydin, K.K. 2018. Early yield prediction of clones from diverse locations in a clonal nursery in the traditional region. *Rubber Science* **31**(2): 130-139.

Meenakumari, T., Lakshmanan, R., Soman, T.A., Reghu, C.P., Thomas, V. and Mydin, K.K. 2017. Variability for latex and timber yield of RRII 400 Series Clones of *Hevea brasiliensis*. *Abs. National Conference on Tree Improvement Research in India: Current Trends and Future Prospects* 2-3 Feb 2017. Institute of Wood Science and Technology, ICFRE, Bengaluru p. 96.

Mercykutty, V.C., Meenakumari, T. and Mydin, K.K. 2013. Promisig high yielding clones of *Hevea brasiliensis* evolved by ortet selection programme in Central Kerala. *Rubber Science* **26**(1): 66-77.

Meti, S., Meenattoor, R., Mondal, G.C. and Chauduri, D. 2003. Impact of cold weather condition on the growth of *Hevea brasiliensis* clones in North West Bengal. *Indian Journal of Natural Rubber Research* **16**(1&2): 53-59.

Mydin, K.K., John, A., Nazeer, M.A., Prem, E.E., Thomas, V. and Saraswathyamma, C.K. 2005. Promising *Hevea brasiliensis* clones evolved by ortet selection with emphasis on latex-timber traits and response to stimulation. *Journal of Plantation Crops* **33**(1): 18-28.

Mydin, K.K., Meenakumari, T., Narayanan, C., Thomas, V., Gireesh, T., Suryakumar, M., Antony, D., Idicula, S.P., Joseph, A., Mandal, D., Dey, S.K., Das, G., Krishan, B., Singh, M. and Jacob, J. 2017. Region-specific advisory on *Hevea* clones suited to traditional and non-traditional rubber growing areas of India. *Rubber Science* **30**(2): 95-110.

Nair, D.B, Jacob, J. and Nair, N.R. 2012. A simple method for rapid determination of residual water content in rubber cup lumps. *Journal of Plantation Crops* **40**: 35-39.

Nair, N.U, Nair, K.M. Meti, S., Rao, D.V.K.N., Chandy, B. and Naidu, L.G.K. 2010. Land and soil controls over the spatial distribution and productivity of rubber (*Hevea brasiliensis*) in Southern India. *19th World Congress of Soil Science, Soil Solutions for a Changing World,* 1- 6 August 2010, Brisbane, Australia.

Priyadarshan P.M. 2003a. Breeding *Hevea brasiliensis* for environmental constraints. *Advances in Agronomy* **79**: 351-400.

Priyadarshan P.M. 2003b. Contributions of weather variables for specific adaptation of rubber tree (*Hevea brasiliensis* Muell.- Arg) clones. *Genetics and Molecular Biology* **26(**4): 435-440.

Priyadarshan, P.M., Hoa T.T.T, Huasun, H. and Gonçalves, P. de S. 2005. Yielding potential of rubber (*Hevea brasiliensis*) in suboptimal environments. *Journal of Crop Improvement* **14**: 221-247.

Reju, M.J., Thapliyal, A.P, Singh, R.P., Soman, T.A., Nazeer, M.A. and Varghese, Y.A. 2007. Promising *Hevea brasiliensis* clones for the subtropical climate of Meghalaya. *Natural Rubber Research* **20**(1&2): 50-55.

Rubber Board (2019). Rubber Grower's Guide, 2019. Government of India, Ministry of Commerce and Industry, 97p.

Saraswathyamma, C.K., George, P.J., Panikkar, A.O.N., Claramma, N.M., Marattukalam, J.G. and Nair, V.K.B.

1990. Performance of RRII selections from 1956 breeding programme in the large scale trial. *National Symposium on New trends in Crop Improvement of Perennial Species,* Kottayam, India, August 30, 1990, 134 p.

Saraswathyamma, C.K., George, P. J., Panikkar, A.O.N., Claramma, N.M., Marattukalam, J.G. and Bhaskaran Nair, V.K. 1990. Performance of RRII selections from 1956 breeding programme in the large scale trial. *Proceedings of National Symposium on New Trends in Crop Improvement of Perennial Species*. Rubber Research Institute of India, pp. 84-91.

Sethuraj, M.R., Potty, S.N., Vijayakumar, K.R. Krishnakumar, A.K., Rao, G.G., George, M.J., Soman,T.A. and Meenatoor, R. 1989. Growth performance of *Hevea* in the non- traditional regions of India. *Proceedings of the Rubber Planters 'Conference*, Kuala Lumpur, Malaysia. pp. 212-227.

Thomas, V., Meenattoor, J.R. and Saraswathyamma, C. K. 2003. Latex Timber clones for small growers in India. *Proceeddings of IRRDB Annual Meetings and Symposium,* Thailand. 15-19 September. 2003.

Tuy, L.M., Hoa, T.T.T., Lam, L.V., Duong, P.H. and Phuc, L.G.T. 1998. The adaptation of promising rubber clones in the central highlands of Vietnam. In "*IRRDB Symposium on Natural Rubber," Vol. I. General, Soils and Fertilisation and Breeding and Selection Sessions*. Ho Chi Minh City, 14–15 October, 1997, pp. 155-163.

Vijayakumar, K.R., Chandrasekhar, T.R. and Philip, V. 2000. Agroclimate. In: *Natural Rubber: Agromangement and Crop Processing* (Eds.) George P.J. and Jacob, C.K.) Rubber Research Institute of India, Kottayam, India, pp. 97-116.