GROWTH AND YIELD PERFORMANCE OF *HEVEA* CLONES IN KARNATAKA

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Fourteen *Hevea* clones were assessed for their growth and yield performance in a large scale trial planted in 1989 in Dakshin Kannada district in Karnataka state in southern part of India. Clone RRII 203 had the highest girth after 13 years of tapping (101 cm) which was significantly higher than that of the reference clone RRII 105. Annual girth increment during the immature period was also the highest for RRII 203 (6.4 cm year^{-1}) and this was significantly higher than that of RRII 105 (5.5 cm year^{-1}). Analysis of bole volume of 29 year old trees revealed that RRII 203, PB 255, KRS 25 and RRII 308 were significantly superior to RRII 105. Among the clones tested, RRII 203 recorded the highest (62.9 g t^{-1} t^{-1}) and significantly higher mean yield over 13 years of tapping than that of RRII 105 (44.9 g t^{-1} t^{-1}). Clones PB 255 and KRS 25 also had superior growth and yield, as well as tree stand, compared to that of RRII 105. Among the tested clones, PB 255, RRII 203, KRS 25, RRII 308 and reference clone RRII 105 had yield-stability index (YS_i) greater than the mean YS. Based on long term growth and yield performance, RRII 203, KRS 25 and PB 255 were selected for further on-farm evaluation prior to release for commercial cultivation.

Keywords: Clone evaluation, *Hevea*, Growth, Yield performance

INTRODUCTION

Identification of varieties suitable for agro-climatic conditions of various regions is crucial for successful commercial cultivation of any crop. Crop improvement programmes aim to identify characters important for economic utilisation of the crop, and the incorporation of the desired characters in the varieties intended for commercial cultivation. Crop improvement in *Hevea* started when early breeders started growing unselected seedlings and made critical examination of the population (Djikman, 1951). Later, the practice of selection of mother trees for collection of seeds and the standardisation of bud grafting technique brought improvement in latex yield. Subsequently, intensive breeding through various techniques like recombination, polycross breeding and ortet selection led to substantial increase in the latex yield of *Hevea* clones. Natural rubber is obtained from the latex collected by controlled wounding or tapping of the bark of the rubber tree. Tapping is usually initiated once 70 per cent of the trees in a plantation attain 50 cm girth at 125 cm height from the bud union which is achieved by 6-7 years in the traditional region (Rubber Board, 2012) and 8-9 years

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in non-traditional regions of India. The crop improvement objectives in *Hevea* include high latex yield, high vegetative vigour, early attainment of tappability, tolerance to biotic and abiotic stresses and specific and wide adaptability to the climatic conditions in the region of cultivation (Meenakumari *et al.*, 2011; Gouvea *et al.*, 2013; Mydin, 2014).

Hevea breeding protocol currently followed in India involves development of genotypes through artificial pollination or polycross breeding, their evaluation by screening and selection in seedling nurseries, multiplication through bud grafting, and further evaluation in clonal nurseries followed by evaluation in large scale trials and on-farm trials (Mydin and Saraswathyamma, 2005). The whole protocol requires around 23 years for identification and release of a variety and warrants their evaluation in respective regions of cultivation to assess their adaptability. Similar procedures have resulted in the identification of promising clones in all rubber growing countries of the world and it is prudent to evaluate them and identify adapted clones suitable for commercial cultivation in other regions. Hence, the present study was initiated in South Karnataka region in India to evaluate promising clones from India and other rubber growing countries like Malaysia, Indonesia, China and Thailand to assess their suitability.

MATERIALS AND METHODS

The study was undertaken at the Research farm of Hevea Breeding Substation of Rubber Research Institute of India at Nettana in Dakshin Kannada district of Karnataka in South India (12° 43′N; 75°32′ E; 120m MSL). The region experiences climate similar to traditional rubber growing regions of India, but is affected by severe moisture deficit for four to six months in summer. Four clones from India (RRII 105, RRII 203, RRII 300, RRII 308), two clones from Indonesia (PR 255, PR 261), two clones from Malaysia (RRIM 600, PB 255), three clones from Thailand (KRS 25, KRS 128, KRS 163) and three clones from China (SCATC 88/13, SCATC 93/114, Haiken 1) were included in the Large Scale Trial (LST) planted in 1989. Healthy scions of the clones were bud-grafted on assorted stock seedling and were used as planting material. The trial was planted with a spacing of 5m x 5m in Randomised Block Design, with three replications and 25 plants per plot and a common border with clone GT 1 for plots. All the recommended cultural practices were followed. Clone RRII 105, the popular clone in the traditional region, served as the reference clone.

Growth performance of the clones was assessed based on annual girth measured at a height of 150 cm from the bud union for 25 years. Annual girth increment before and after tapping was calculated based on annual girth. Timber yield in the 29th year after planting in terms of clear bole volume per tree was estimated following the quarter girth method (Chaturvedi and Khanna, 1982). The trees were opened for tapping in 2002 under S/2 d3 6d/7 system of tapping and were tapped round the year. Mean yield was recorded from the dry weight of cup coagulum collected once in a month and was expressed as gram per tree per tap ($g\ t^{-1} t^{-1}$). Girth and yield data were analysed statistically by ANOVA. Simultaneous selection for yield and stability over years was done using Kang's yield-stability index (YS_i) (Kang, 1993) for identification of promising clones for the region. Kang (1993) opined that genotypes with YS_i greater than the mean YS_i can be selected.

RESULTS AND DISCUSSION

Growth performance

Tree girth is an important parameter in determining the tapping panel length in the mature phase as well as timber yield of a clone (John *et al.*, 2013). In the present study RRII 203 had the highest girth at opening (82.9 cm), as well as, after 13 years of tapping (101 cm) and was significantly higher than the reference clone RRII 105 (Table 1). Annual girth increment of RRII 203 during the immature phase (6.4 cm year^{-1}) was also significantly higher than that of RRII 105 (5.5 cm year^{-1}). Annual girth increment of all clones decreased under tapping and was not significantly different between clones (Table 1). In rubber, very fast decrease in growth rate after the onset of tapping was reported earlier (Silpi *et al.*, 2006). Though none of the clones had significantly inferior girth compared to that of RRII 105 in the initial years, difference in vigour was evident in the subsequent years. Clones Haiken 1, PR 255, SCATC 88/13 and SCATC 93/114 recorded significantly lower girth than RRII 105 during the later immaturity period which remained low till the end of the study. On analysis of girth increment prior to and after initiation of tapping, it was seen that compared to reference clone RRII 105, clones KRS 25, KRS 128, KRS 163, RRII 203 and RRII 308 had higher girth increment before tapping and all these clones except KRS 163 maintained their superiority under tapping as well. High girth increment of RRII 203 under tapping was reported earlier by Mondal *et al.* (1999) in Assam in North East India. Clones KRS 25 and RRII 308 had

Table 1. **Growth performance of clones during immature and mature growth period**

Clone	Girth at 12 YAP (cm)	Mean immature girth increment (cm year^{-1})	Girth after 13 years of tapping (cm)	Mean mature girth increment (cm year^{-1})	Bole volume (m^3) at 29 YAP
KRS 25	72.2	6.0	93.5*	1.6	0.22*
SCATC 88/13	57.7#	4.5#	69.5	0.8	0.11#
RRII 105	67.7	5.5	77.1	0.8	0.15
PR 255	55.4#	4.3#	68.0#	1.0	0.11#
PB 255	67.4	5.0	82.1	1.1	0.24*
PR 261	63.7	4.9	76.4	1.0	0.16
KRS 163	71.5	5.7	81.8	0.8	0.19
RRII 203	82.9*	6.4*	101.0*	1.4	0.32*
KRS 128	73.1	5.8	84.7	1.0	0.18
SCATC 93/114	58.9#	4.7#	72.5	1.0	0.12
RRIM 600	62.3	5.0	80.4	1.3	0.13
RRII 308	71.4	5.9	88.4*	1.2	0.21*
Haiken 1	51.6#	4.2#	63.8#	0.9	0.11#
RRII 300	65.4	4.7#	83.0	1.4	0.19
CD (P<0.05)	6.1	0.7	7.7	NS	0.04

YAP- Years after planting

**significantly higher than RRII 105*

#significantly lower than RRII 105

significantly superior girth than RRII 105 under tapping, despite having comparable girth at opening, indicating the ability of these clones to sustain vegetative growth under tapping. High growth rate under tapping being an indicator of high timber yield (John *et al.*, 2013), RRII 203, KRS 25 and RRII 308 can be considered as promising timber clones. Good stem growth under tapping is believed to maintain constant production and reduce wind damage (Goncalves and Fontes, 2012). Most of the clones tested in the trial, despite having lower girth increment than RRII 105 (5.5 cm year^{-1}) prior to tapping, had better girth increment under tapping compared to RRII 105 (0.8 cm year^{-1}). Such changes in the growth behaviour of *Hevea* clones after tapping was reported earlier (Jayasekera *et al.*, 1994).

Analysis of bole volume of 29 year old trees revealed that RRII 203 (0.32 m^3), PB 255 (0.24 m^3), KRS 25 (0.22 m^3) and RRII 308 (0.21 m^3) were significantly superior to RRII 105 (0.15 m^3). Superior bole volume of RRII 203 compared to RRII 105 was reported from North East India (Das *et al.*, 2015) and the traditional rubber growing regions of India (John *et al.*, 2004; Lakshmanan *et al.*, 2014). The present study confirmed the superior growth performance of RRII 203 and indicates the spatial stability of the clone in terms of growth. Tree stand at the end of 13 years of tapping revealed that RRII 203 had the highest tree stand (88%) followed by KRS 128 (85.3%) and SCATC 93/114 (85.3%) (Table 2). Clones RRIM 600 and Haiken 1 had lower tree stand than check clone RRII 105 (60%).

Table 2. **Tree stand of clones after 13 years of tapping**

Clone	Tree stand at the end of 13 years of tapping (%)
Haiken 1	49.3
KRS 128	85.3
KRS 163	68.0
KRS 25	73.3
PB 255	70.7
PR 255	69.3
PR 261	62.7
RRII 105	60.0
RRII 203	88.0
RRII 300	76.0
RRII 308	65.3
RRIM 600	56.0
SCATC 88/13	65.3
SCATC 93/114	85.3

Yield performance

Clone RRII 203 recorded the highest (62.9 g t^{-1} t^{-1}) and significantly higher mean yield over 13 years of tapping compared to RRII 105 (44.9 g t^{-1} t^{-1}) (Table 3). Reports on the early yield performance of clones in the trial had shown that PR 255, KRS 25, KRS 128, KRS 163 and RRII 203 had higher mean yield than RRII 105 (Vinod *et al.*, 2010). Among these clones, KRS 25 and RRII 203 maintained higher mean yield than RRII 105 over 13 years of tapping as well. These clones also had >1 cm annual girth increment under tapping, suggesting the yield increase due to increase in tapping length. Several workers have reported a positive correlation between girth and yield of *Hevea* clones (Karunaratne *et al.*, 2005; Mydin *et al.*, 2011). Clones KRS 128 and KRS 163, which had superior yield than RRII 105 in the early years, showed a decreasing yield trend over the years thus had a lower long term mean yield compared to RRII 105. Long term yield analysis revealed that PR 261, RRII 300 and SCATC 93/114 had significantly lower yield than reference clone RRII 105. Studies at Nagrakatta, a cold prone sub-Himalayan

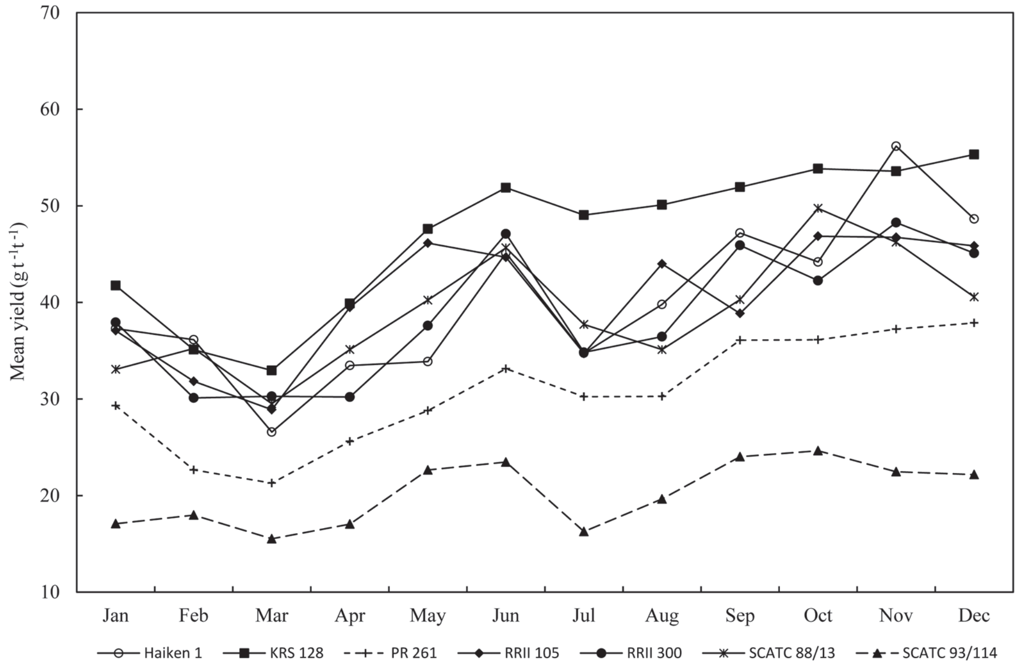

Fig. 1. Seasonal yield trend of clones having peak yield in the post monsoon season

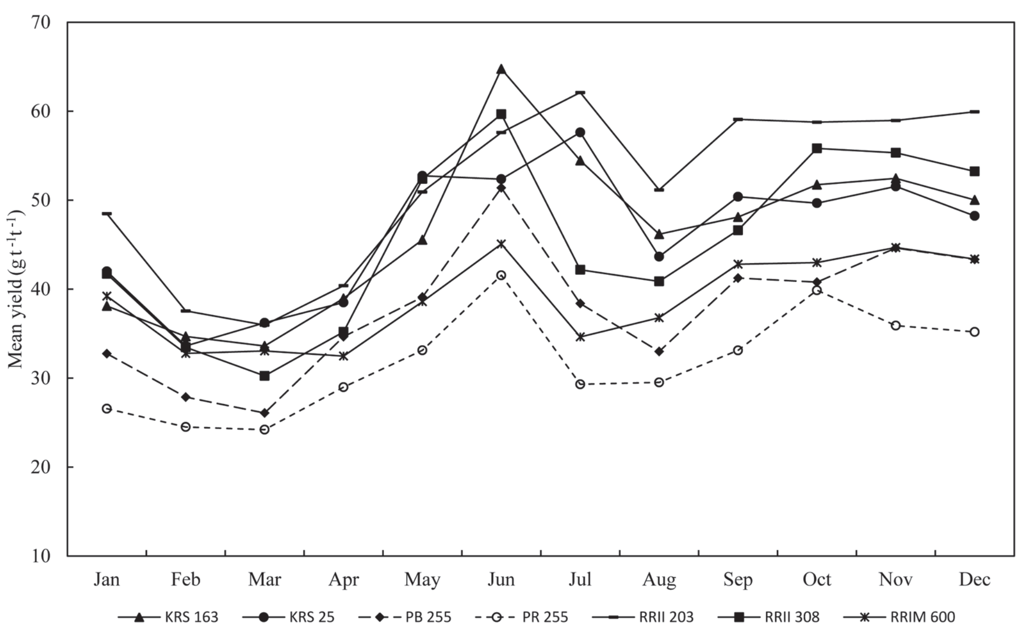

Fig. 2. Seasonal yield trend of clones having peak yield in the monsoon season

Table 3. **Selection for yield and stability using Kang's yield-stability index**

Clone	Mean yield over 13 years ($gt^{-1}t^{-1}$)	Yield rank (Y')	Adjustment to Y'	Adjusted Y	Stability variance (σi 2)	Stability rating (S)	Ysi =Y+S
RRII 203	62.9	14	2	16	89.7 *	-4	12
PB 255	53.1	13	1	14	45.5	0	14
KRS 25	51.8	12	1	13	72.9 #	-2	11
RRII 105	44.9	11	1	12	15.4	0	12
RRII 308	44.6	10	1	11	20.5	0	11
KRS 128	44.3	9	1	10	50	0	10
KRS 163	42.2	8	1	9	106.7 **	-8	1
SCATC 88/13	38.7	7	-1	6	26.8	0	6
PR 255	38.5	6	-1	5	16.5	0	5
Haiken 1	36	5	-1	4	50.3	0	4
RRIM 600	35.1	4	-1	3	79.5 *	-4	-1
RRII 300	31	3	-1	2	20.2	0	2
PR 261	30.4	2	-1	1	19.2	0	1
SCATC 93/114	16	1	-2	-1	42.3	0	-1
Grand Mean	40.7						6.2
CD (P<0.05)	13.4						

**Significant at 5% level **Significant at 1% level*

region of West Bengal, showed that after twelve years of tapping, clones SCATC 93/114, Haiken 1, RRII 300 and PR 261 attained high girth, while, PR 261 and RRII 308 showed better winter yield contribution (Kumar *et al.*, 2015). Although SCATC 93/114 performed well in terms of growth and yield in North east India (Dey *et al.*, 2004) the clone had significantly lower yield than RRII 105 as well as RRIM 600 in the present study, indicating the specific adaptability of these clones to low temperature conditions. Specific adaptability of SCATC 93/114 to cooler climate was suggested by Vinod *et al.* (2010) also, based on early performance of the clone in coastal Karnataka region.

It was interesting to note that, except PB 255, clones that had lower girth increment than RRII 105 during immature period also recorded lower mean yield than RRII 105. Among the clones with higher immature girth increment than RRII 105, KRS 25 and RRII 203 recorded high mature girth increment, girth and mean yield than RRII 105.

Analysis of seasonal yield pattern revealed two major yield peaks, around monsoon period (June-July) and post monsoon period (October-November). Clones KRS 25, KRS 163, PB 255, PR 255, RRII 203, RRII 308 and RRIM 600 recorded peak yield in monsoon period and the remaining clones had peak yield in post monsoon period (Fig. 1 and 2). Majority of the clones displayed yield depression during February-March and July-August corresponding to re-foliation and fruit maturation, respectively. In *Hevea*,

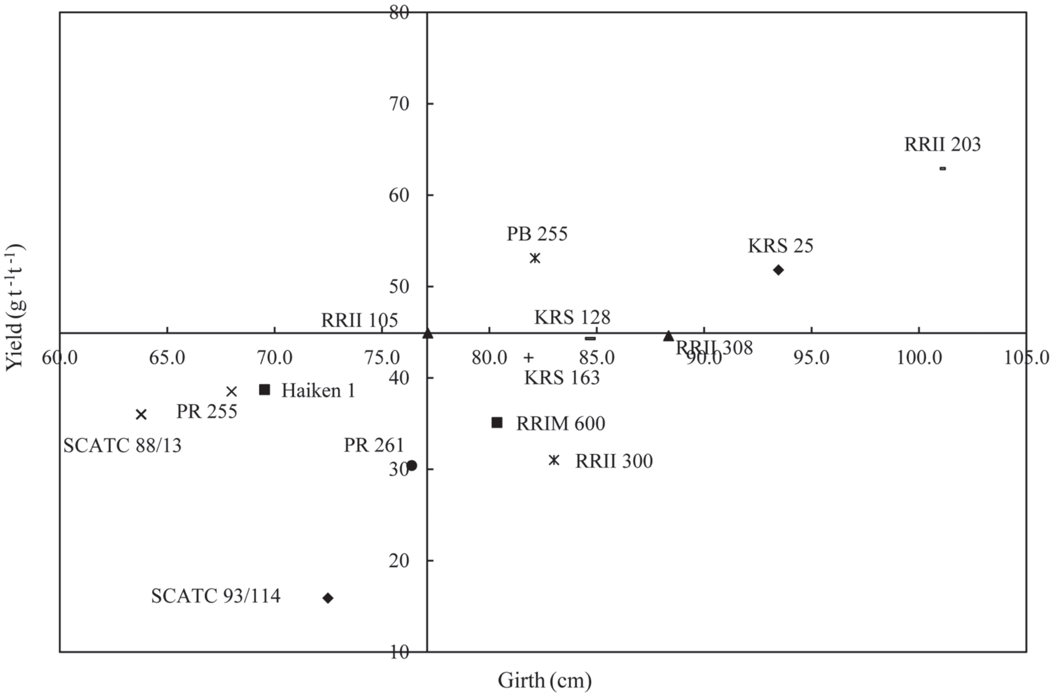

Fig.3. Growth and yield performance of clones with respect to reference clone RRII 105

minimum yield coincides with defoliation period and maximum yield after fruit shedding (Ortolani *et al.*, 1998).

Among the tested clones, lowest temporal stability variance over years was observed for check clone RRII 105 (15.4) while, KRS 163 (106.7) had significantly high stability variance (Table 3). Among high yielders PB 255, RRII 308 and RRII 105 had low stability variance indicating the stability of these clones over years. However, high yielding clones RRII 203 and KRS 163 were reported to have high stability over different seasons in the South Karnataka region (Vinod *et al.*, 2010). Among the tested clones, PB 255, RRII 203, KRS 25, RRII 308 and reference clone RRII 105 had YS_i greater than the mean YS_i and can be considered as promising clones for mean yield and stability over the years.

Identification of promising clones

Analysis of girth and yield performance revealed that RRII 203, the best clone among the clones tested, as well as PB 255 and KRS 25 had superior growth, yield, yield stability index, bole volume and tree stand compared to the reference clone RRII 105. Vinod *et al.* (2010) also reported the superior growth and yield performance of RRII 203 and KRS 25 in coastal Karnataka region based on the performance in the early years. Hence based on long term growth and yield performance, RRII 203, KRS 25 and PB 255 were selected for further on-farm evaluation prior to release for commercial cultivation.

The present study revealed that RRII 203, KRS 25 and PB 255 had superior yield, growth, yield stability index and bole volume compared to that of the reference clone RRII 105. This indicates the utility of these clones as latex timber clones suitable for commercial cultivation in Karnataka region. These clones also maintained a tree stand of more than 70 per cent trees even after 13 years of tapping, which will ensure better tree population in the plantation. Hence, the clones RRII 203, KRS 25 and PB 255 were selected for further evaluation in on-farm trials in the region.

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