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Effect of monoclonal and Assorted Seedling Rootstocks on Long Term Growth and Yield of Hevea Clones

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Effect of monoclonal and assorted seedling rootstocks on long term growth and yield of *Hevea* clones

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Abstract

Seven *Hevea brasiliensis* clones were evaluated on two types of rootstocks, assorted seedling rootstocks (AR) and monoclonal rootstock (MR) over 19 years. Influence of rootstock on scion growth and rubber yield was assessed based on juvenile height, circumference of the main trunk (cm), number of branches, branching height and cumulative dry rubber yield (g per tree per tapping, conventionally abbreviated $gt^{-1} t^{-1}$). Highest cumulative yield (g per tree per tapping) over the 12 years for which the trees were tapped was obtained from clone RRII 105 (MR: 1076 g per tree per tapping and AR: 497 g per tree per tapping), followed by RRII 203 (MR: 661; AR: 538), RRII 208 (MR: 477; AR: 486), RRII 118 (MR: 497; AR: 452). Gl 1 yielded the least, 219 g per tree per tapping (MR) and 378 g per tree per tapping (AR); GT1 produced 335 g per tree per tapping (MR) and 375 g per tree per tapping (AR). RRII 118 had the greatest circumference at age 19 (91.4 cm on MR) 88.8 on AR, followed by RRII 105 (MR: 87.4 cm AR: 89.2 cm) and GT 1 (MR: 88.5 cm; AR: 84.4cm). Effect of scion clone was significant ($p < 0.01$) only for trunk circumference at opening, but not for cumulative rubber yield at age 11 (4 years after opening) or cumulative rubber yield at age 19 (12 years after opening). Most importantly, rootstock and clone x rootstock interaction did not significantly affect rubber yield or tree circumference at any evaluation time. There was no evidence to suggest that growth and yield of clones was influenced significantly by rootstock type.

Key words: Natural rubber, rootstock-scion, *Hevea brasiliensis*.

Introduction

Hevea brasiliensis (Willd. ex Adr. de Juss.) Muell.-Arg. the Para rubber tree, is one of only a few species that produces high quality natural rubber, an important commercial raw material with multiple applications. High yielding *Hevea* clones are commonly propagated through grafting in order to capture dramatic gains in rubber yield made through systematic breeding and selection (LICY et al., 2003; PRIYADARSHAN and CLEMET-DEMANG, 2004) and to help growers increase the size and uniformity of their trees. WHITBY (1919); SHARP (1940) and SENANAYAKE et al. (1975) reported that the coefficient of variation (CV) among seedling populations was very high. Intraclonal variability has also been reported (CHANDRASEKHAR et al., 1997). SENANAYAKE (1975) reported 27 percent CV among ramets of the clone RRIC 88; CV was 30 percent among ramets of clone RRIM 623 (ALIKA, 1980). Physiological and biochemical evidence (SOBHANA et al., 2001; YUAN et al., 2011) and studies on intraclonal variation of 13 clones and the association of juvenile yield and stem diameter (PREMAKUMARI et al., 2002) found that variability was very low for stem diameter, but higher for test tap yield up to year three.

Vegetative multiplication through bud grafting involves rootstock and scion. Rootstocks are mainly raised from healthy seeds and the scion belongs to an elite genotype. Since the adoption of budding as a method of propagation in *Hevea*, there have been host of studies investigating stock-scion interaction; similar studies have been published in other important vegetatively propagated tree crops like apple (ZHU et al., 1999; JENSEN et al., 2003), apricot (SALAZAR et al., 1991), citrus (CASTLE and YOUTSEY, 1998), cocoa (YIN, 2004), peach (TOMBESI et al., 2010), teak (SHARMA and UNIYAL, 2003). In *Hevea*, latex yield depends largely on the genotype of the scion (BUTTERY, 1961), but there are arguments supporting the influence of rootstock for example, KRISHNAKUMAR et al. (1992) reported variation in the expression of polymorphic isoenzymes caused the rootstock-scion interaction.

Production of clonal rootstocks is still not commercially feasible. Estimation of general compatibility (rootstocks and scion) and specific compatibility (for all combinations of six rootstocks and scions) for rubber yield, showed a strong rootstock effect on yield (CARDINAL et al., 2007). Long term data related to the effect of rootstock on scion performance in the traditional rubber growing belt of southern India is meager, and most of the previous studies were confined to parameters other than long term growth and yield. The objective of the present work was to demonstrate the influence of rootstock-scion combination on juvenile characteristics, growth and yield of seven popular *Hevea* clones grown on monoclonal rootstock (MR) and randomly assorted rootstocks (AR) over a period of nineteen years.

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Materials and Methods

Location and Plant materials

The study was performed at the Central Experiment Station of the Rubber Research Institute of India at Chethackal, Kerala State, South India (Latitude 9°22'N, Longitude 76°5'E; Altitude 100 m). The planting materials consisted of seven clones developed for high rubber yield and of different genetic background (*Table 1*). These seven clones were budded onto monoclonal rootstocks (MR) from self pollinated seeds selected from clonal plantations as described earlier (NG et al., 1981). The same scions were budded onto rootstock (AR) raised from seeds of unknown origin. Details of different rootstock-scion combinations are shown in the *Table 2*. The clones were budded onto corresponding rootstocks in the nursery. After successful bud grafting, stumps were planted in polythene bags (55 cm x 25 cm when laid flat) filled with about 10 kg soil and raised in a nursery.

Field planting and crop management

Six month-old, two-whorl, brown-budded plants were planted in the field site in July 1984 in a randomized-complete-block-split-plot design with two blocks. Plot size was fixed to 25 trees at a spacing of 4.9 m x 4.9 m. The field had slightly undulating topography. Crop management practices such as weeding, sun-scorch prevention, mulching and manuring were performed appropriately throughout the experiment as detailed in the PUNNOOSE et al. (2000).

Assessment of growth and yield

Parameters observed from the field grown plants in the first year after planting were (a) total height of the plant and (b) circumference of the main trunk (TC) measured at a height of 150 cm from the bud union. In the third year of planting, number of branches (c) above 2.5 m and height up to the lowest branch (d) were recorded. TC measurements were continued every year in the month of January. All trees were opened for tapping in the seventh year after planting. The tapping system followed was S/2 d3 6d/7 (according to the conventions used in the rubber industry, S/2 indicates half spiral tapping, d/3 indicates tapping every third day, and 6d/7 indicates available tapping days per week, i.e. 100 tappings per year). Dry rubber yield was measured from each experimental tree in grams per tree per tapping ($gt^{-1}t^{-1}$) by coagulating the latex in collection cups once in a month (30-day interval). Mean dry rubber yield was recorded from 12 samples and expressed as $gt^{-1}t^{-1}$. Cumulative mean yield ($gt^{-1}t^{-1}$) was computed at age 11 and 19.

Table 1. – Details of *Hevea* scion clones and their origin.

Clone/scion	Country of origin	Parentage	General features
RRII 105	India	Tjir 1 x GI1	A high yielding clone identified in India, most popular variety occupying 80 percent of rubber cultivating areas in the traditional zone; trunk tall, branches with strong unions; canopy dense but restricted to the top, tolerant to abnormal leaf fall disease (NAIR and GEORGE, 1969; ANNAMMA et al.,1990).
RRII 118	India	Mil 3/2 x Hil 28	An Indian clone with vigorous growth; trunk tall and stout; prominent heavy branches; canopy dense, balanced crown. Yield is average (NAIR and GEORGE, 1969; ANNAMMA et al.,1990).
RRII 203	India	PB 86 x Mil 3/2	A clone developed in India, with moderate rubber yield and high timber yield (SARASWATHIAMMA et al., 1990).
RRII 208	India	Mil 3/2 x AVROS 255	Clone of Indian origin with above average yield; and vigorous growth characters (SARASWATHIAMMA et al., 1990).
GT1	Indonesia	Primary clone	A primary clone developed in Indonesia, extensively planted in almost all rubber growing countries. Trunk upright, main branches long. Moderate yielder with rising yield trend (RRIM, 1970 b).
GI 1	Malaysia	Primary clone	A moderate yielding Malaysian primary clone, tolerant to abnormal leaf fall disease, comparatively less vigorous in growth (NAIR et al., 1975).
RRIM 600	Malaysia	Tjir 1 x PB 86	A clone of Malaysian origin extensively grown in almost all rubber growing countries. Trunk is straight, moderate to fairly heavy branches; with broom shaped crown. Susceptible to abnormal leaf fall disease (RRIM, 1970a).

Table 2. – Stock-scion combinations and long term rubber yield.

Clones	Rootstock type: Monoclonal[z] (MR)	Rootstock type: Assorted[y] (AR)	Cumulative rubber yield (g per tree per tapping, $gt^{-1}t^{-1}$): 11-year-old trees[x,w] MR	AR	19-year-old trees[w,v] MR	AR
RRII 105	RRII 105	Unknown	252	140	1076	497
RRII 118	RRII 118	Unknown	111	63	497	452
RRII 203	RRII 203	Unknown	154	142	661	538
RRII 208	RRII 208	Unknown	124	123	477	486
GT1	GT1	Unknown	75	78	335	375
Gl 1	Gl 1	Unknown	57	122	219	378
RRIM 600	RRIM 600	Unknown	230	102	643	196

[z] Rootstock seedlings grown from monoclonal seeds.
[y] Rootstock seedlings from randomly collected seeds with unknown polyclonal origin.
[x] Cumulative yield at age 11, first 4 years after opening, S.E. = 63.6.
[v] MR versus AR comparison NS at $P = 0.05$.
[w] Cumulative yield at age 19, first twelve years after opening, S.E. = 236.

Statistical analysis

The experiment was a simple two-factor randomized complete block design with two replications. There were seven clones on two rootstock types. The linear model was:

$$y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

where the ijkth observation was the sum of the overall mean (μ) plus the effect of ith clone (α_i) in the jth replication (β_j) and the effect of clone x rep interaction $(\alpha\beta)_{ij}$ and the error ε of replication k associated with factor level ij. Rootstock, scion and rootstock-scion interaction effects on each variable were determined using analysis of variance, all comparisons were based on plot means, with comparisons adjusted using the Tukey-Kramer Method as implemented in SAS software, v. 9.1 (Carey, NC). Observations from the trees with wind damage or disease were eliminated from the analysis.

Results

Commercial exploitation by tapping begins only after a tree attains 50 cm TC, a trait commonly referred to as earliness. Earliness is one of the most important breeding parameters for selection. The overall mean for TC in the seventh year for scions budded on to MR was 46.4 cm versus 43.8 cm for scions on AR; highest TC the seventh year was recorded for scions of RRII 105 on MR (52.7 cm) whereas TC for RRII 118 on AR was 51.7 cm in the seventh year (*Table 3*). RRII 118 had the largest overall stem circumference at age seven (52.2 cm) but this was not significantly different than the clone with the smallest TC at the same age, RRII 208 (38.7 cm). The pooled average (across clones) TC at opening (after seven years) was not significantly affected by rootstock type ($F_{1,7} = 2.19$, $P = 0.18$) or rootstock-scion interaction, although a scion effect was barely significant ($P < 0.0442$). The mean TC of all scions after 19 years on monoclonal root stocks (86.8 cm) was not significantly ($P < 0.05$) different than the mean for all scions on random root stocks (82.6 cm). RRII 118 had the largest TC after 19 years of growth (MR: 91.4 cm; AR: 88.8 cm). RRII 105 had the greatest TC at age 1 (11.9 cm, = 3.7 cm in diameter) when budded on AR versus MR (11.3 cm). Branch number at the age three was greatest for clone RRII 118 budded onto MR (3.1) versus AR (2.7); Gl1 had the fewest branches (on AR) in the third year of growth. Number of branches did not significantly differ among clones irrespective of stock, the average number of branches across different clones budded on MR (2.4) compared to that of AR (2.3) was not significantly ($P < 0.05$) different. Among the seven clones evaluated, highest branching height was recorded for RRII 105 (2.5 m when budded on MR and 2.8 m on AR). Gl1 had lowest branching height, 2.3 m for trees on MR rootstocks, 2.0 m for trees on AR.

Analysis of variance (*Table 4*) showed no significant differences among clones ($P < 0.01$) for any juvenile characters, including early height, girth, number of branches and branching height. Rootstock and interaction (clone x rootstock) effects also were not significant for these traits. A similar result was obtained for TC at opening and TC after 19 years, although, as described above, there were barely significant differences among clones for TC at opening ($P < 0.0442$). Rootstock and rootstock x scion effects were non-significant at age 19.

Table 3. – Juvenile characteristics and trunk circumference.

Clones	Juvenile characters[z]								Trunk circumference			
	Height[y] (m)		Trunk Circum-ference[y] (cm)		Number of branches[x]		Branching height[x] (m)		At opening[w] (cm)		After 19 years[z] (cm)	
	MR	AR	MR	AR	MR	AR	MR	AR	MR	AR	MR	AR
RRII 105	3.9	4.0	11.3	11.9	2.5	2.8	2.5	2.8	52.7	51.7	87.4	89.2
RRII 118	3.6	3.3	11.3	11.5	3.1	2.7	2.6	2.6	52.2	51.3	91.4	88.8
RRII 203	2.9	3.2	10.6	10.8	2.9	2.5	2.4	2.2	43.2	44.5	82.4	76.3
RRII 208	2.5	2.7	11.1	11.1	2.1	2.0	2.3	2.1	38.7	37.4	81.0	79.7
GT1	2.6	2.6	10.9	10.9	2.2	2.4	2.3	2.2	52.1	40.0	88.5	84.4
Gl 1	2.5	2.1	10.5	10.2	1.9	1.6	2.3	2.0	43.2	37.4	88.2	82.4
RRIM 600	2.5	3.0	11.0	10.4	1.8	2.3	2.1	2.3	43.0	44.4	82.4	88.9
Mean	2.9	3.0	10.9	11.1	2.4	2.3	2.4	2.3	46.4	43.8	86.8	82.6
CV	24.9		7.5		28.7		13.9		7.9		6.4	

[z] All comparisons of MR versus AR not significant at $P = 0.05$, see *Table 4*, all tabulated data are means (n = 50).
[y] 1st year after planting, all comparisons were not significant at $P = 0.05$, see *Table 4*.
[x] 3rd year after planting.
[w] 7th year after planting.

Table 4. – Mean square values of analysis of variance for the effect of stock, scion and their interaction on juvenile and mature growth characters.

Source of variation	df[y]	MS[z]							
						Trunk circumference		*Cumulative rubber yield*	
		Height[x,w]	Trunk circum-ference[x,w]	Number of branches[x,v]	Branching height[x,v]	At opening	At age 19[x]	At age 11[x,u]	At age 19[x,u]
Clone	6,6	2.39	0.66	0.93	3.35	4.53*	1.08	0.71	0.77
Rootstock	1,7	0.05	0.48	0.03	0.30	2.19	2.10	1.32	1.37
Clone x rootstock	6,7	0.55	0.16	0.53	0.85	1.02	0.30	0.79	0.72

[z] Type 3 test of fixed effects.
[y] X,Y where X = df for the numerator, Y = df for the denominator.
[x] Only effects indicated with asterisk (*) significant $P < 0.05$.
[w] Measured in 1st year of growth.
[v] Measured in 3rd year of growth.
[u] Cumulative yield of 11-year-old trees = first 4 years after opening; cumulative yield of 19-year-old trees = first 12 years after opening.

Discussion

Vegetative propagation through bud grafting is an accepted practice in the production of planting material in *Hevea*. The present investigation confirms that the difference between monoclonally derived seedling rootstocks and the randomly selected seedling rootstocks used in the study were not significantly different in their effect on growth and dry rubber yield. Difference in performance largely depended on the genotype of the scion. The study was unique in terms of its longevity and emphasis on the most important economic traits, i.e., dry rubber yield and growth. Previous studies of *Hevea* rootstock-scion interactions have focused on isoenzymes (KRISHNAKUMAR et al., 1992), identification and analysis of proteins related to rootstock-scion interactions (YUAN et al., 2011), genetic relationship of polyclonal seedlings raised from cultivated clones (THOMAS et al., 2004), intraclonal variability (ALIKA, 1980; CHANDRASEKHAR et al., 1997), and growth and yield of scion (DIJKMAN, 1951; BUTTERY, 1961; YAHAMPATH, 1968; YEANG et al., 1995; SAGY and OMOKHAFE, 1996). None of these studies considered the long term effect of MR and AR except NG et al. (1981), who suggested use of poly clonal seeds rather than monoclonal stocks for enhanced yield of the scion. The results of the present study are not completely in agreement with NG et al. (1981) and GONCALVES et al. (1994) since we found that in general the tested rootstocks imparted no influence on the growth and yield of different scions. Similar results reported in tea wherein the taste traits showed significant differences in quality score between scions, but no differences between rootstocks, nor any stock × scion interaction (TUWEI et al., 2008). Studies by TANDONNET et al., (2010) in young grafted grapevines, also demonstrated the major effect of the scion genotype on most of the parameters of development, especially in the root.

Results of the present study indicated that healthy assorted root stocks and seedling stock from (presumably self-pollinated) seeds from monoclonal plantations do not result in differences in the growth and yield of clonal scions. Future conditions such as the outbreak of wide spread disease may warrant root stock selection and even breeding for elite stocks.

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