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Variation in certain structural and physical properties of wood of ten clones of *Hevea brasiliensis*

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Abstract

Variation in timber yield, basic wood density, percentage of volumetric shrinkage and the proportion of tension wood in mature trees of 10 clones of *Hevea brasiliensis viz.* RRII 44, RRII 45, RRII 105, PB 235, PB 255, PB 260, PB 261, PB 310, PB 311 and RRIM 600 were studied. The timber volume (bole volume) of PB 235 was statistically superior to RRII 105, RRII 45 and PB 311 and the clones PB 310, PR 261, RRIM 600, PB 260 and PR 255 had the bole volumes statistically on par with PB 235. The clone RRII 105 showed the lowest bole volume among the ten clones studied. The basic wood density at different height positions within clones as well as between clones was the highest in RRII 105 and the lowest in PB 260. The wood density of RRII 105 was significantly higher than that of the other nine clones. The percentage of volumetric shrinkage in different drying conditions viz. green to air dry, green to oven dry and air dry to oven dry, varied considerably at different height positions within clones as well as between clones. Percentage of volumetric shrinkage was significantly higher in PB 235 (green to air dry condition) than that of the other eight clones and on par with RRII 105. The distribution pattern of tension wood varied from tree to tree, clone to clone and even within trees along the length of the trunk. Among the 10 clones, the percentage of tension wood was the highest in RRII 45 and the lowest in RRIM 600 and RRII 105. However, the clonal variation as well as variation at different height positions were not statistically significant. The present study revealed that though volumetric timber yield in RRII 105 is low, the wood quality of this clone is superior with respect to basic density, low level of volumetric shrinkage and less incidence of tension wood.

Key words: Hevea brasiliensis, timber volume, basic density, volumetric shrinkage tension wood

Introduction

The priorities and strategies of rubber cultivation in ndia have been subjected to serious debate in the context f emerging trends consequent to reforms and policy hanges in the external trade. Natural Rubber is unique mong the important plantation crops as the net farm icome enhancing measures have coincided with the tempts to explore potential of the major by-products, :., rubber wood (Viswanathan *et al.*, 2002). Accordingly, ie focus on future priorities will be streamlined towards aximization of net farm income rather than the unilateral nphasis given to enhancement of productivity of NR. ie eco-friendly credentials of rubber plantations (George id Joseph, 2002) have given international acceptance r rubber wood as an eco-friendly alternative source of nber and its potentialities for various industrial applications has been well established. In this context it is pertinent to enhance the timber potential of rubber plantations and explore avenues for maximum value addition to rubber wood.

In order to sustain the supply of rubber wood, the industry should not be complacent and continue to depend on traditional sources of wood. Rubber wood based manufacturers must take the initiative to ensure that their enterprises are safeguarded by the availability of raw materials in the longer term. Market acceptability of rubber wood, as well as experience and technical edge in agro-management of rubber trees as a plantation species makes rubber trees among one of the most suitable crop choices for forest plantations to meet future wood requirements (Othman, 2003).

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The volumetric yield of rubber wood per tree may vary due to the differences in agro-management practices, agro-climatic conditions, variety of clones, genetic and physiological parameters etc. (Viswanathan *et al.*, 2002). It has been estimated that in India, the timber yield per hectare is of the order of 180 m^3 in the estate sector and 150 m^3 in the small holdings (Joseph and George, 1996) whereas, in Malaysia it is 190 m^3 and 180 m^3, respectively (Arshad *et al.*, 1995). Viswanathan *et al.* (2003) studied the total timber volume of certain clones *viz.* RRII 201, RRII 208 and RRIM 600 and reported 193 m^3/ha for RRII 200 series and 167 m^3/ha for RRIM 600. As different clones produce different quantities of wood, a systematic analysis on the timber output and clonal variability, assumes much importance and considerable studies in this line have not been attempted so far. The structural, physical and strength properties of rubber wood also vary from clone to clone to a great extent. In general, researches agree that wood density is the most important wood quality parameter. Similarly, the shrinkage property of wood reflects the seasoning behaviour of wood and the reduction in shrinkage can be considered as a desirable physical property of rubber wood especially in the field of furniture industry. Although limited information on the strength properties of rubber wood is available (Shukala and Lal, 1985; Kamala and Rao, 1993), information on the volumetric timber yield and clonal variability in *Hevea brasiliensis* is lacking.

Tension wood formation is considered as a natural defect leading to an abnormal structure of hardwoods especially in fast growing timber species like rubber. High incidence of tension wood adversely affects the physical, chemical and mechanical properties of wood to a great extent mainly due to the low level of lignin content in the cell wall of tension wood fibers (Reghu, 1983; Mathew, 2003). Its occurrence causes various wood working problems such as rough and wooly surface, irregular shrinkage, uncontrollable distortions and dimensional instability in different sectors of timber utilization due to differential drying (Reghu, 2002). As rubber plantations are mostly grown in hilly and undulating terrains, the trees are liable to various uncontrollable environmental stresses such as wind blow, phototropism, leaning of axes, crown imbalance etc. which tends to intensify the formation of tension wood fibers. Hence to evaluate rubber tree as a potential source of timber for various end uses, the extent and proportion of tension wood and its clonal variability has to be taken into account.

In this context the purpose of the present study is to provide information on patterns of variation in timber volume, basic wood density, percentage of volumetric shrinkage and proportion of tension wood in 10 clones of *Hevea brasiliensis* at the age of 23 years.

Materials and Methods

Mature trees of 10 clones of *Hevea brasiliensis viz.* RRII 44, RRII 45, RRII 105, PB 235, PB 260, PB 310, PB 311, PR 255, PR 261 and RRIM 600 at the age of 23 years were selected. The trial was planted in Randomized Block Design with three replications (25 trees per plot) at Central Experiment Station, Chethackal, Kerala. Six trees from each clone (2 trees each from three replications) were selected from which the bole volume (m^3) was estimated using quarter girth method (Chadurvedi and Khann 1982).

Wood discs of 7.5 cm thickness (in duplicate) were cut from the main trunk at three positions *viz.* bottom, middle and top. From each height position, one disc was sampled for the determination of basic wood density and percentage of volumetric shrinkage and the other one was used for the quantification of tension wood. The basic density (kg/m^3) was determined based on oven dry weight and green volume. The percentage of volumetric shrinkage was worked out at three different drying conditions *viz.* green to air dry (G-AD), air dry to oven dry (AD-OD) and green to oven dry (G-OD) as follows :

$$\text{G-AD}(\%) = \frac{(\text{Green volume} - \text{Air dry volume})}{\text{Green volume}} \times 100$$

$$\text{AD-OD}(\%) = \frac{(\text{Air dry volume} - \text{oven dry volume})}{\text{Air dry volume}} \times 100$$

$$\text{G-OD}(\%) = \frac{(\text{Green volume} - \text{oven dry volume})}{\text{Green volume}} \times 100$$

The quantification of tension wood was done by measuring the area occupied by tension wood from the cross sectional area of wood disc using Leica Q500IW image analysis system and Leica Q Win (V 2.1) image analysis software. Data obtained from each height position were considered for computing the clone average.

Analysis of variance (Panse and Sukhatme, 1985) was carried out and the significance was tested with reference to the standard F table.

Results and discussion

Table 1 explains the clone average with respect to bole

Table 1. Structural and physical properties of wood of 10 Hevea clones.

Clone	Bole vol. (m^3)	Basic density (kg/m^3)	Percentage of shrinkage G-AD(%)	G-OD(%)	AD-OD (%)	Tension wood (%)
PB 235	0.82	568.94	4.93	7.71	2.86	21.56
PR 255	0.65	538.55	2.39	7.00	4.87	23.77
PB 260	0.64	511.77	1.89	7.41	5.29	24.08
RRIM 600	0.64	563.94	2.05	7.79	5.85	16.68
PR 261	0.63	531.44	2.82	8.11	5.42	24.32
PB 310	0.60	556.50	2.00	7.63	6.09	17.50
PB 311	0.55	566.83	1.72	8.78	6.11	18.87
RRII 44	0.54	543.28	1.87	7.65	5.88	19.25
RRII 45	0.49	565.34	1.25	7.81	6.40	24.91
RRII 105	0.42	604.94	3.15	7.70	4.96	18.98
CD (P=0.05)	0.25*	25.47 **	1.84 *	NS	1.65**	NS

G-AD : green – air dry AD-OD : air dry – oven dry G-OD : green – oven dry.

volume, basic wood density, percentage of tension wood and volumetric shrinkage of 10 clones.

Among the 10 clones, PB 235 had the maximum bole volume (0.82 m^3) while the minimum was in RRII 105 (0.42 m^3). Six clones viz. PR 255, PB 260, RRIM 600, PR 261, PB 310 and PB 311 showed more or less identical bole volume within the range 0.55 – 0.65 m^3, Similarly, the clones RRII 44 and RRII 45 also depicted identical bole volume of 0.54 m^3 and 0.49 m^3 respectively. The analysis of variance indicated that the bole volume of PB 235 was statistically superior to RRII 105, RRII 45 and PB 311 whereas the clones PB 310, PR 261, RRIM 600, PB 260 and PR 255 had the bole volume statistically on par with PB 235. The results indicated that the timber yield of RRII 105 was significantly lower than that of PB 235. In all the other eight clones the volumetric yield of timber was more or less identical.

The basic wood density at different height positions within clones as well as between clones varied considerably (Tables 1 and 2). The wood density at the base, middle and top of the tree trunk as well as the clone average was the highest in RRII 105 and the lowest in PB 260. The average wood density and the density at the basal region of RRII 105 were significantly higher than that of the other nine clones. In the middle and the top portion, the density of RRII 105 was significantly higher over four clones *viz.* PB 260, PR 255, PR 261 and RRII 44 whereas the density of PB 235, PB 311, PB 310, RRII 45 and RRIM 600 was statistically on par with that of RRII 105.

The percentage of volumetric shrinkage in different drying conditions *viz.* green to air dry, green to oven dry and air dry to oven dry showed considerable variation at different height levels within clones as well as between

Table. 2. Structural and physical properties of wood at three trunk height positions of 10 clones of *Hevea brasiliensis*

	Basic density (kg/m^3) G. wt / O. D wt.			Volumetric shrinkage (%) Green –air dry			Green – oven dry			Air dry – oven dry			Tension wood(%)		
Clone	B	M	T	B	M	T	B	M	T	B	M	T	B	M	T
PB 235	577.50	570.00	556.67	5.02	5.19	4.58	7.73	8.11	7.30	3.27	3.06	4.58	13.36	25.66	25.66
PR 255	532.50	554.50	528.67	2.21	2.75	2.22	6.94	7.21	6.83	5.01	5.07	2.21	18.27	30.53	22.52
PB 260	515.33	511.00	509.00	1.83	1.67	2.19	7.66	7.19	7.38	5.62	5.61	2.19	16.76	25.54	29.90
RRIM 600	553.67	579.00	559.17	1.67	2.28	1.89	7.49	7.98	7.90	4.54	5.82	2.19	15.30	18.11	16.65
PR 261	533.16	535.83	525.33	2.77	2.74	2.95	7.92	8.26	8.14	6.31	5.68	2.94	17.20	31.37	24.41
PB 310	554.83	566.17	548.50	2.14	1.90	1.97	6.86	8.32	7.72	3.25	6.54	1.97	14.39	18.78	19.35
PB 311	558.83	575.17	566.50	1.38	2.16	1.64	7.53	7.70	8.09	5.98	5.66	1.64	13.76	18.25	24.63
RRII 44	539.00	547.33	543.50	1.88	1.50	2.23	7.65	7.73	7.56	5.76	6.32	2.23	15.89	18.49	23.37
RRII 45	562.50	547.33	565.83	2.09	1.61	1.70	7.71	8.03	7.68	6.67	6.54	1.70	20.02	26.15	28.56
RRII 105	632.33	587.67	594.83	3.63	2.98	2.84	7.68	7.61	7.80	6.58	4.74	2.84	15.46	22.39	19.11
CD (P=0.05)	52.11 **	31.22**	42.97 **	NS	2.03*	NS	NS	NS	NS	NS	1.83*	1.71**	NS	NS	NS

B - base M – middle T - top

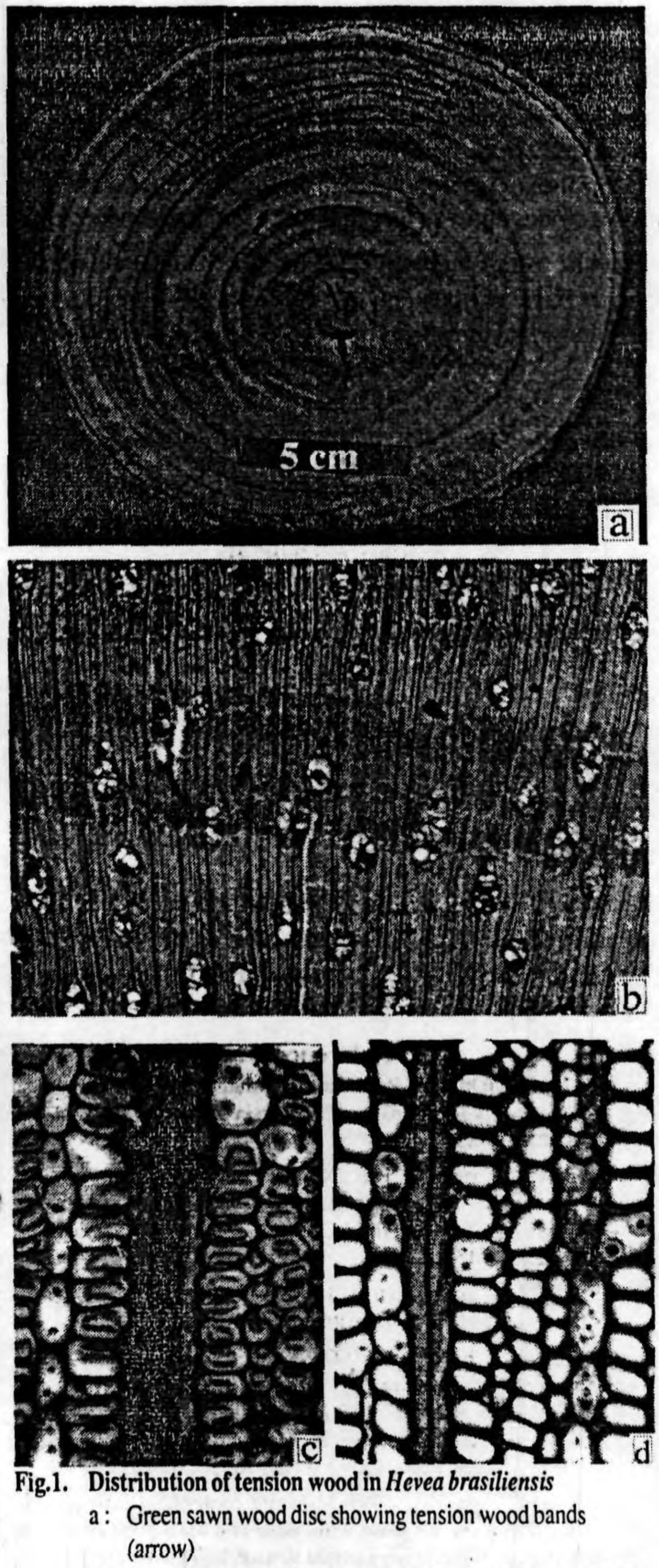

Fig.1. Distribution of tension wood in *Hevea brasiliensis*

a : Green sawn wood disc showing tension wood bands (arrow)

b : T.S. of wood showing compact tension wood (arrow) and normal wood (arrow head), X 34.

c : Tension wood fibers, X 500.

d : Normal wood fibers, X 500.

clones. Among the ten clones studied (Table 1) the wood of PB 235 showed the maximum shrinkage (4.93 %) during green to air dry state followed by RRII 105 (3.15%) and the minimum shrinkage was observed in RRII 45 (1.20%). Analysis of variance indicated that the shrinkage percentage was significantly higher in PB 235 than that of eight of the clones whereas it was statistically on par with RRII 105. Percentage of shrinkage at green to oven dry condition was almost similar in all the 10 clones. However, the variation in shrinkage at air dry to oven dry condition was significantly lower in PB 235 than in the other nine clones.

At different height levels (Table 2), the percentage of shrinkage varied from clone to clone and the variation was statistically significant only in the middle zone at green to air dry state and air dry to oven dry state. Significant variation was also observed in the top most zone at air dry to oven dry condition.

The distribution pattern of tension wood varied from tree to tree, clone to clone and even within trees along the length of the trunk. The compact tension wood was visible as white wooly lustrous bands in cross sectional plane of the wood disc (Fig. 1).

Among the ten clones, the percentage of tension wood was the highest in RRII 45 (24.91%) followed by PR 261 (24.32%), PB 260 (24.08%) and lowest in RRIM 600 (16.68%) (Table 1). The clones PB 310 (17.50%), PB 311 (18.87%) and RRII 105 (18.98%) also showed relatively lower percentage of tension wood. However, the clonal variation for this trait was not statistically significant.

The proportion of tension wood at different height levels is presented in Table 2. In five clones *viz.* RRII 45, PB 311, PB 310, RRII 44 and PB 260, the percentage of tension wood at different height levels showed a gradual increase from base to top of the tree trunk whereas in RRII 105, RRIM 600, PR 261 and PR 255, the percentage increased from base to middle portion while there was a decreasing trend towards the top. All the 10 clones had the lowest percentage of tension wood in the basal zone of the trunk. In PB 235, the percentage of tension wood was almost the same in the middle and top portion of the trunk. Analysis of variance indicated that the variation in the percentage of tension wood was not statistically significant irrespective of all height positions.

The present study revealed that though the volumetric timber yield in RRII 105 is low, the basic density is high in comparison with other clones. It has been reported that the growth rate is inversely proportional to wood density in fast growing timber species (Kennedy, 1968) and the beneficial influence of fast growth rate on volumetric growth of trees may be counter balanced by the reduction in density of wood (Beaudoin *et al.*, 1992). The present study revealed that the wood quality of RRII 105 was superior to the rest of the clones in terms of wood density whereas with respect to wood quantity, PB 235 ranked top. The clones RRIM 600, PB 311, PB 310 and RRII 45 also had desirable wood quality as revealed by their basic density values 563.94 kg/m^3, 566.83 kg/m^3, 556.50 kg/m^3 and 565.34 kg/m^3, respectively. The density of PB 260 (511.77 kg/m^3) was far below among the 10 clones studied. It has been reported from Malaysia that the basic density of RRIM 600 at the age of 24 years was 620 kg/m^3 and that of PB 260 at the age of 14 years was 580 kg/m^3 (Midon, 1994). But the present study revealed that the performance of these two clones with respect to wood density is relatively low in Indian conditions.

In majority of the clones studied, the wood density is high at the base of the trunk, decreases at mid height and increases towards the top. This observation reflects the influence of tension wood on reduction in wood density as reported by Panshin *et al.* (1964) indicating that the occurrence and proportion of tension wood is one of the major factors of wood density variation at different height levels. In majority of the clones studied the percentage of tension wood also showed a gradual increase from base to top of the trunk. In this context the low level of tension wood formation in RRII 105 may be attributed to the high basic wood density in this clone.

In general, the shrinkage of wood consequent to drying from green condition and subsequent dimensional changes with variation in atmospheric conditions is one of the most important properties of wood. It has also been reported that the shrinkage varies widely with timber species and a high ratio of longitudinal to radial shrinkage is an indication of the timber being liable to cracking, splitting and warping (Jain and Arora, 1995). Kamala and Rao (1993) examined percentage of volumetric shrinkage (green to air dry) of rubber wood as 11 % in unspecified clones from different parts of Kerala and compared the value with that of teak wood as 6.9 %. In the present study, the percentage of volumetric shrinkage at three different stages of drying have been studied. The results showed significant clonal variability in shrinkage from green to air dry as well as air dry to oven dry conditions and were within the range of 1.25 – 4.93% in the former and 2.86 – 6.4 % in the latter. All clones in the present study had the shrinkage values lower than that of teak wood which can be considered as a desirable physical property of rubber wood. The low level of shrinkage may be attributed to the reduction in the proportion of tension wood in all the 10 clones studied as these clones showed less than 25% tension wood.

The present study revealed that the volumetric timber yield, basic wood density, percentage of volumetric shrinkage and the proportion of tension wood varied from clone to clone. Though the volumetric timber yield of the popular clone RRII 105 is low, the quality of wood is superior with respect to high basic density, less incidence of tension wood and low percentage of volumetric shrinkage.

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