Natural Rubber Research, 20 (1&2): 82-86, 2007 SHORT SCIENTIFIC COMMUNICATION

RELATIONSHIP OF THE ANGLE OF LEAN OF TRUNK AND GROWTH ECCENTRICITY WITH TENSION WOOD FORMATION IN FOUR CLONES OF *HEVEA BRASILIENSIS*

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Submitted:18 July 2005 *Accepted: 15 April 2006*

Mathew, F. and Reghu, C.P. (2007). Relationship of the angle of lean of trunk and growth eccentricity with tension wood formation in four clones of *Hevea brasiliensis*. *Natural Rubber Research*, 20 (1 & 2): 82-86.

The relationship between tension wood formation and growth eccentricity of leaning trunks for four clones of *Hevea brasiliens* (Tjir 1, GT 1, RRIM 600 and RRII 105) were studied. The growth eccentricity did not show consistent variation with respect to tree height. The leaning angle and proportion of tension wood were correlated for the clone RRII 105. For all the four clones the correlation between tree height and angle of lean was highly significant. Tree height and proportion of tension wood showed highly significant correlation for RRIM 600. The relationship between angle of lean and growth eccentricity was significant for GT 1.

Keywords: Growth eccentricity, *Hevea brasiliensis*, Leaning angle, Pith eccentricity, Tension wood.

Trees are subjected to various environmental stresses like wind, phototrophic and geotropic movements, intrinsic growth stresses etc., which displace the vertical orientation of trunks and branches. Hence, they show a tendency to develop special mechanisms to restore the original position by producing specialized tissues in the wood. Reaction wood is an example of this type of tissue produced by the cambium in response to the gravitational stimulus induced by the displacement of the axis from vertical (Wardrop, 1964; Timell, 1969; Cote *et al.*, 1969; Fischer and Stevenson, 1981). Reaction wood in angiosperms called tension wood (TW), is usually formed in the upper side of leaning axes, where tensile stress is exerted (Wardrop and Dadswell, 1948; Scurfield and Wardrop, 1963; Wardrop and Davies, 1964; Wardrop, 1964; Westing, 1968; Philipson *et al.*, 1971). In fast growing hardwood species like rubber (*Hevea brasiliensis*) the incidence of TW is much more in comparison with slow growing tree species, even though the influence of environmental factors and angle of tilt may be identical. Formation of TW is usually, but not always associated with growth eccentricity or pith eccentricity (PE). Patel *et al.*, (1984) reported that the growth eccentricity decreased with increase in specimen angle in *Kigelia pinnata*. Fischer and Stevenson (1981) extensively studied the influence of TW formation on tree architecture in various hardwood species and classified *H. brasiliensis* under Raugh's model of tree architecture, where the angle of orientation of the tree axis increased with a corresponding increase in TW formation in both the upper and lower parts of the bent axis. They further proved

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that the increase in the leaning angle of axes in *H. brasiliensis* initiated TW formation on the lower side. It has already been reported that PE associated with TW formation is a natural defect in wood and hence the degree of PE can be considered as a wood quality index (Harris, 1977; Timell, 1986). Hence the study on the extent of PE and its influence on TW formation in hardwood species assumes significance.

H. brasiliensis is a perennial hardwood species belonging to the family Euphorbiaceae. Since rubber plantations are mostly situated in hilly and undulating terrains the trees are affected by wind which makes them lean to one side resulting in the formation of TW and growth eccentricity

Tension wood formation has been considered as the most serious natural defect (Dijikman, 1951; Sharma and Kukreti, 1981; Vijendra Rao *et al.*, 1983; Reghu *et al.*, 1989b) which adversely affects the quality of rubber wood and restricts its versatile utilization in various wood-based industries.

The branching habit and canopy architecture of *H. brasiliensis* shows wide variability within and between clones even in the same geographical location. Hence the morphological characters of the clones can play a significant role in the formation of TW in response to wind and other environmental stresses. The present study was aimed at understanding the relationship between pith eccentricity, angle of leaning, tree height and proportion of TW in different clones of *H. brasiliensis.*

Four mature trees each of four clones *viz.*, Tjir 1, GT 1, RRIM 600 and RRII 105 were selected and clear felled from the experimental fields at Central Experiment Station of Rubber Research Institute of India, Chethackal, Ranni. The leaning angle of the trees were recorded prior to felling using an inclinometer (Bhat *et al.*, 1981). Wood discs of 7.5 cm thickness were cut from the main trunk at three height levels from the ground viz., 60, 210 and 300 cm. The cross sectional surface of each wood disc was scanned using Leica Q5001A image analysis system and the area occupied by compact tension wood was measured using Leica QWin V.2.1 image analysis software.

The influence leaning of angle of the trunk, percentage of growth eccentricity of wood disc at different heights and their influence on TW formation was studied. Growth eccentricity, in terms of percentage pith eccentricity (PPE) was calculated using the formula suggested by Akachuku and Abolarin (1989).

Percentage pith eccentricity =(D/G) x 100

where:

D = Distance between the geometric center and actual position of pith in the wood disc.
G = Geometric center of the wood disc (based on the mean radius of the disc)

Regression analysis was carried out to study the relationship between pith eccentricity, leaning angle and proportion of TW. Population mean of individual characters was calculated for each clone.

The leaning angle of trees from the vertical and growth eccentricity were considered at three height positions to understand the directional effect of tree leaning on TW formation (Table 1). In all the clones studied, the leaning angle was minimum at 60 cm height and maximum 300 cm, indicating that the angle of inclination of tree

Table 1. **Angle of lean, pith eccentricity and tension wood in mature *H. brasiliensis* trees**

Clone	Height level (cm)	Angle of lean (° from vertical)	Growth eccentricity	Proportion of tension wood (%)
Tjir 1	60	4.00	11.70	15.76
	210	12.25	24.77	17.79
	300	20.00	22.03	22.82
	Mean	12.08	19.50	18.79
GT 1	60	5.25	14.65	11.69
	210	14.25	13.56	23.18
	300	22.25	32.12	17.63
	Mean	13.92	20.11	16.75
RRIM 600	60	6.00	28.59	17.30
	210	15.75	17.34	29.99
	300	26.00	18.32	32.19
	Mean	15.92	21.42	26.49
RRII 105	60	5.75	10.20	24.31
	210	18.00	24.96	28.28
	300	25.50	14.54	32.35
	Mean	16.42	16.57	28.31

trunk increased from base to top. The average leaning angle was the highest for the clone RRII 105 (16.42°) and lowest for Tjir 1 (12.08°). The leaning angles of GT 1 and RRIM 600 were 13.92° and 15.92° respectively.

The percentage of growth eccentricity did not show any consistent pattern with respect to tree height. For Tjir 1 and RRII 105, the eccentricity was highest at 210 cm height and lowest at 60 cm, while for GT 1 was maximum at 300 cm and minimum at 60 cm. In the case of RRIM 600, maximum growth eccentricity was seen at 60 cm and minimum at 210 cm. Similar type of growth eccentricity has also been reported earlier by Patel *et al.* (1984) for *K. pinnata,* who reported a decrease in growth eccentricity with an increase in leaning angle as observed for RRIM 600 in the present study. But Kaeiser and Boyce (1965) did not find any correlation between leaning angle and eccentricity. In the present study no correlation was observed in the case of RRII 105, Tjir 1 and GT 1. Hence the growth eccentricity is more dependant on the rate of cambial activity in upper and lower parts of the inclined axis.

Proportion of TW was maximum in RRII 105 (28.31 %) and minimum in GT 1 (17.50 %). In RRIM 600 and Tjir 1, it was 26.50 and 18.79 per cent respectively. The results indicated that both the leaning angle and proportion of TW was highest in RRII 105. Leaning angle was lowest in Tjir 1 whereas the lowest proportion of TW was observed in GT 1. Table 2 showed the correlation between angle of leaning, growth eccentricity and proportion of TW. It has already been reported that TW formation is associated with pith eccentricity in many broad leaved species including *Hevea* (Wardrop, 1964; Harris, 1977; Timell, 1986; Reghu *et al.,* 1989a). Akachuku and Abolarin (1989) observed that in *Tectona grandis* there is no relationship between the degree of pith eccentricity and the proportion of TW formation. The results of the present study showed that there is no relationship between growth eccentricity and

Table 2. **Correlation between tree height, angle of lean, pith eccentricity and proportion of tension wood in mature trees**

Clone	Source	Tree height	Angle of lean	Growth eccentricity	Proportion of tension wood
Tjir 1	Tree height	1.00	0.961**	0.363	0.337
	Angle of lean		1.000	0.468	0.411
	Growth eccentricity			1.000	0.065
	Proportion of TW				1.000
GT 1	Tree height	1.00	0.932**	0.545	0.315
	Angle of lean		1.000	0.617*	0.435
	Growth eccentricity			1.000	0.234
	Proportion of TW				1.000
RRIM 600	Tree height	1.00	0.887**	-0.249	0.733**
	Angle of lean		1.000	-0.227	0.528
	Growth eccentricity			1.000	-0.373
	Proportion of TW				1.000
RRII 105	Tree height	1.00	0.930**	0.162	0.397
	Angle of lean		1.000	0.247	0.417
	Growth eccentricity			1.000	-3.170
	Proportion of TW				1.000

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

TW formation in *H. brasiliensis* also in accordance with this report. Hence the magnitude of pith eccentricity need not be considered as a criteria to ascertain the extent of TW formation in *H. brasiliensis*. The remarkable increase in the cambial activity towards one side of the axis and the suppression of meristematic activity on the opposite side may result in growth eccentricity.

Correlation between tree height and angle of leaning was highly significant in all the clones studied (Table 2). Similar findings were reported earlier for *T. grandis* (Akachuku and Abolarin, 1989). This is presumably due to the fast growing nature of rubber trees in association with the effect of internal growth stress exerted through the movement of canopy and displacement of axis as suggested by Wardrop (1964), Hughes (1965), Scurfield (1973) and Wilson and Archer (1977).

An increase in the proportion of TW with a corresponding increase in tree height in three *H. brasiliensis* clones *viz.*, PB 86, PB 260 and RRIM 600 has been reported earlier (Reghu *et al.* 1989a; Sulaiman and Lim, 1992). However in the present study, tree height and proportion of TW showed a highly significant correlation only for RRIM 600. Angle of leaning and growth eccentricity were significantly correlated for GT 1.

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