Wood Science and Technology 34 (2001) 517–532 © Springer-Verlag 2001

Characterisation of juvenile wood in teak*

K. M. Bhat, P. B. Priya, P. Rugmini

Abstract Juvenile wood properties are studied in a ring-porous tropical hardwood – teak (*Tectona grandis* L. F), to assess the utilisation potential of short rotation timber. Compared to mature wood, it is characterised by wide rings, short fibres, small diameter, low vessel percentage, high cell wall, wide microfibrillar angle and relatively low or almost similar mechanical properties. While the average modulus of elasticity and modulus of rupture in juvenile wood are 85% and 82% respectively of the mature wood value, the longitudinal compression strength is similar. With relatively small fibrillar angle of 15° and the scope for genetic selection of individual trees, teak juvenile wood has potential for desired dimensional stability. The segmented regression models and visual interpretation of radial patterns of variation in anatomical properties reveal that juvenility in plantation grown teak extends up to 15, 20–25 years depending on the property, growth rate and individual tree and plantation site. The fitted regression models, to explain the age-related variations in juvenile wood properties range from simple, linear to exponential, reciprocal and quadratic equations. Fibre length, microfibrillar angle, vessel diameter/percentage and ring width appear to be the best anatomical indicators of age demarcation between juvenile and mature wood, although maturation age often varies among the properties. The projected figures for proportion of juvenile wood in plantation grown teak at breast height are 80–100% and 25% at ages 20 and 60 years respectively.

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*This is an extended version of the paper presented in IUFRO Division 5 Conference, 5–12 July 1997, Pullman, WA, USA

Received 3 November 1998

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The authors wish to gratefully acknowledge the financial support from the Department of Science and Technology (DST), New Delhi. The second author also acknowledges the award of CSIR Senior Fellowship.

Introduction

Teak (*Tectona grandis* L. F) has been identified as the most potential species for establishing high quality tropical hardwood plantations under the sustainable forest management (Keogh 1996). One main objective is to meet the market demands for sawn wood and veneer. Teak is quite often used as a reference species for standardisation of wood property evaluation and end-use classification of tropical hardwoods. Recently, there has been a renewed research interest in teak because of its success in yielding a mean annual increment of 10–12 m^3 per ha. For economic reasons, short rotations of 20–30 years are being proposed against the traditional rotation of 50–60 years (Bhat and Okuyama 1997). This forecasts the future supply of higher proportion of juvenile teak wood from tropical countries. Although it was thought that juvenile wood was not a problem in hardwoods, the negative impact on the product may often be as great as in conifers (Maeglin 1987). Panshin and de Zeeuw (1980) suggest that juvenile and mature woods must be recognised as two distinct populations in the same tree, the mature wood possessing the characters considered normal for the species while juvenile wood exhibiting inferior characteristics. The primary basis for defining the juvenile wood is anatomical structure with various properties. Both statistical and visual interpretation methods have been applied to analyse the radial patterns of variations for age demarcation between juvenile and mature wood (Bendtsen and Senft 1986; Raczkowska 1992; Abdel Gadir and Krahmer 1993a, b; Pezlen 1994; Lee and Wang 1996). The relevant information for characterising juvenile wood of tropical hardwoods is lacking.

The present study aims to: (a) determine the age demarcation between juvenile and mature wood of fast and slow grown teak (*Tectona grandis* L.f.) of three different plantation localities of southern India, (b) assess the wood property differences between juvenile and mature teak and (c) then project the proportion of juvenile wood at various ages from 20 to 60 years.

Materials and methods

Field sampling

Wood samples for the study were collected from 63-year-old plantations from three different localities in Kerala, India (Table 1.). From each plantation, three each of fast grown (phenotypically superior) and slow grown proximal trees

Table 1. Environmental conditions of study localities in Kerala (South India) and diameter of sampled (fast- and slow-grown) trees

Factor		Locality I (Nilambur)	Locality II (Konni)	Locality III (Arienkavu)
North latitude		11° 12′–11° 32′	9° 3′–9° 85′	8° 44′–9° 14
East longitude		75° 82′–76° 32′	76° 41′–77° 6′	76° 59–77° 1′
Altitude, m		100	175	215
Temperature range, °C		17–37	12–35	13–33
Mean rainfall, mm		2600	2900	2700
Soil type		Alluvial	Sandy loam	Sandy loam rich in organic matter
Drainage		Good	Good	Good
DBH, cm	Fast	54.1	44.0	59.0
	Slow	29.3	24.8	27.0

were chosen. Cross sectional discs were collected from 18 selected trees at breast height after felling. A pith-to-bark radial segment of 2 cm width was cut from each disc for anatomical studies from the northern cardinal direction of the standing trees.

Anatomical quantification by image analysis

Measurements were taken in eight radial positions corresponding to the growth rings 1, 5, 10, 15, 20, 25, 30 and 60 from pith to depict the progressive changes of anatomical properties with age especially during the juvenile phase of growth. Transverse sections of 20 micrometer thickness of each ring was cut on a sliding microtome. The sections were stained, dehydrated and mounted in DPX. Properties viz. microfibrillar angle, vessel diameter, ring width, vessel, cell wall and ray percentages were quantified using a Video image analyser (Leica Quantimet 500+). Measurements were taken at five different fields covering the whole of the earlywood and latewood portions and the average values were determined for each annual ring for the corresponding property. Teak being a ring-porous wood, earlywood was distinguished from latewood by larger vessels with parenchyma and thinner walled fibres.

For measuring the microfibrillar angle, Senft and Bendtsen’s (1984) technique was followed to examine the fibrillar orientation under a light microscope. The angle was measured using image analyser in an interactive measurement mode. Fifty measurements were taken for each ring covering the entire width, and the mean value was considered for further analyses.

For determining fibre length, wood slivers from the same growth rings were macerated in a 1:1 mixture of hydrogen peroxide (30% concentration) and glacial acetic acid. After washing and staining the fibres with safranin, temporary slides were prepared. Using the image analyser, fibre length was determined based on the measurement of 100 unbroken fibres from each ring.

Mechanical testing

The basal logs of 1.3 m length of the felled trees were converted into pieces of 3 × 3 cm cross section to prepare test samples from pith to periphery in two opposite radii corresponding to the growth rings sampled at breast height. From each piece, 2 × 2 × 30 cm test sample was prepared for static bending (modulus of rupture-MOR, modulus of elasticity-MOE) and 2 × 2 × 8 cm for compression parallel to grain (maximum crushing stress-MCS). The mechanical properties were determined by Universal Testing Machine (UTM). Small cubical blocks were cut from tested samples to determine the wood specific gravity (unextracted) of air dried specimens (12% moisture content) by gravimetric method.

Statistical analyses

Critical age demarcation

To demarcate the juvenile wood from mature wood, segmented regression analyses were used to describe the relation between the measured properties as dependant variables and cambial age (rings from pith) as independent variable. Various models were fitted to the data depending on the patterns of radial variation in the properties studied. The analyses were carried out using spss/pc + NLIN procedure (SAS Institute Inc. 1985). Significant models with only those properties showing definite radial patterns of variation were used to determine the critical age of demarcation (Tables 2 and 3).

Table 2. Results of segmented regression analyses for an estimate of maturation age (x_0) for anatomical properties of fast-grown (Treatment-1) and slow-grown (Treatment-2) trees of two Localities

Treatment	Microfibrillar angle Model and parameters	Fibre length Model and parameters
Locality I		
1	$Y = a \cdot e^{bx}$ $a = 16.4511$ $b = -0.0101$ $x_0 = 25$ $p = 12.77$ $R^2 = 0.91$	$Y = a + b/x$ $a = 1564.6$ $b = -1375.3$ $x_0 = 25$ $p = 1509.5$ $R^2 = 0.94$
2	$Y = a \cdot e^{bx}$ $a = 15.81$ $b = -0.0099$ $x_0 = 25$ $p = 12.34$ $R^2 = 0.94$	$Y = a + bx$ $a = 1080.6$ $b = 10.04$ $x_0 = 25$ $p = 1331.5$ $R^2 = 0.95$
Locality II		
1	$Y = a + bx + cx^2$ $a = 17.699$ $b = -0.547$ $c = 0.065$ $x_0 = 20$ $p = 9.4$ $R^2 = 0.95$	$Y = a + b/x$ $a = 1455.13$ $b = -410.55$ $x_0 = 15$ $p = 1427.7$ $R^2 = 0.89$
2	$Y = a + bx + cx^2$ $a = 21.04$ $b = -0.667$ $c = 0.008$ $x_0 = 25$ $p = 10.78$ $R^2 = 0.96$	$Y = a + b/x$ $a = 1227.23$ $b = -314.27$ $x_0 = 15$ $p = 1206.28$ $R^2 = 0.90$

Table 3. Results of segmented regression analyses for an estimate of maturation age (x_0) for anatomical properties of fast- (Treatment-1) and slow-grown (Treatment-2) trees of Locality III

Treatment	Microfibrillar angle	Vessel diameter	Ring width
1	$Y = a + bx + cx^2$ $a = 19.51$ $b = -0.39$ $c = 0.004$ $x_0 = 25$ $p = 12.21$ $R^2 = 0.92$	$Y = a + bx + cx^2$ $a = 115.2$ $b = 6.2$ $c = -0.08$ $x_0 = 20$ $p = 208$ $R^2 = 0.75$	
2	$Y = a + bx + cx^2$ $a = 20.9$ $b = -0.55$ $c = 0.006$ $x_0 = 25$ $p = 11.18$ $R^2 = 0.89$	$Y = a + b/x$ $a = 195.2$ $b = -95.3$ $x_0 = 20$ $p = 190.4$ $R^2 = 0.94$	$Y = a \cdot e^{bx}$ $a = 4.006$ $b = -0.04$ $x_0 = 20$ $p = 1.76$ $R^2 = 0.87$

A quadratic model with plateau was fitted to the data for variables viz. vessel diameter (fast grown trees of Locality III, microfibril angle of fast and slow grown trees of Localities II and III) The model is,

$$\begin{aligned} &Y = a + bx + cx^2 && \text{if } x < x_0 \\ &Y = p && \text{if } x \geq x_0 \end{aligned}$$

where,

$$Y = \text{property of interest, } x = \text{age, } x_0 = \text{age of demarcation,}$$
$$a, b, c = \text{parameters, } p = \text{plateau} \ .$$

For the variable – microfibrillar angle (fast and slow grown trees of Locality I), an exponential model with plateau was fitted to the data. The model is,

$$\begin{aligned} &Y = a \cdot e^{bx} && \text{if } x < x_0 \\ &Y = p && \text{if } x \geq x_0 \end{aligned}$$

A reciprocal model with plateau was fitted to the data for the variables such as fibre length (fast- and slow-grown trees of Localities I and II) The model is,

$$\begin{aligned} &Y = a + b/x && \text{if } x < x_0 \\ &Y = p && \text{if } x \geq x_0 \end{aligned}$$

A linear model with plateau was fitted to the data for fibre length (for slow-grown, locality-I). The model is given as,

$$\begin{aligned} &Y = a + bx && \text{if } x < x_0 \\ &Y = p && \text{if } x \geq x_0 \end{aligned}$$

Thus, for the ages less than the critical age (x_0), the equation expressing the relationship between the measured properties and age is quadratic, exponential, reciprocal or linear and for the ages greater than or equal to the critical value (x_0), the equation is plateau.

After demarcating the juvenile wood from mature wood, weighted average values of the properties were compared by a ‘t’-test.

Results

Age-related variations in wood properties

The analysis of radial patterns of variation revealed that anatomical properties exhibited more consistent progressive changes with age than specific gravity and mechanical properties (Figs. 1–8). We observed the following trends:

a) Microfibrillar angle was maximum in the rings near the pith and gradually decreased with age before stabilising around 20 years in Locality II and 25 years in Localities I and III (Fig. 1). This implies that maturation age of the microfibrillar angle generally lies somewhere around 20–25 years in plantation grown teak.
b) With regard to fibre length, maturation age was found around 15 years in Locality II. In contrast, in trees of Locality I, fibre length increased up to 25

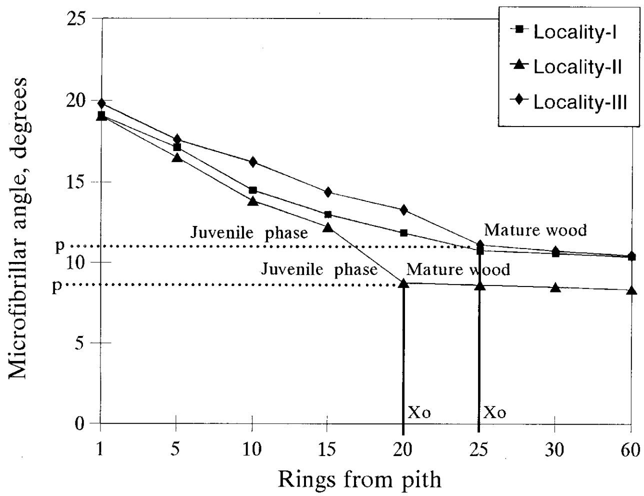

Fig. 1. Radial variation in microfibrillar angle in relation to age in three localities (I, II, III) of plantations; note critical age (X_0) of demarcation between juvenile and mature wood in teak

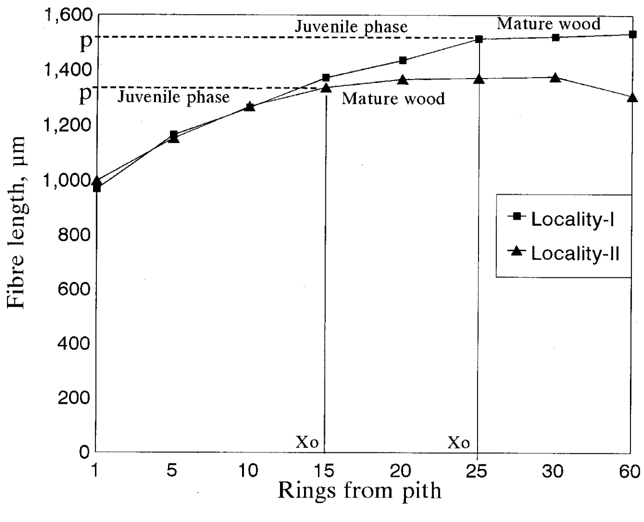

Fig. 2. Radial variation in fibre length in relation to age in two localities (I, II) of plantations; note critical age (X_0) of demarcation between juvenile and mature wood in teak

years before stabilising at a critical point of maturation age (Fig. 2 and Table 2).

c) Vessel diameter stabilised around 20 years after an initial increase during the juvenile phase of growth (Fig. 3).
d) In contrast, vessel percentage showed more steep increase after 20 rings from pith resulting in very high percentage of vessels in 60 years (Fig. 4).
e) Ring width generally decreased rapidly up to 25–30 rings and then more slowly up to 60 rings from pith (Fig. 5).

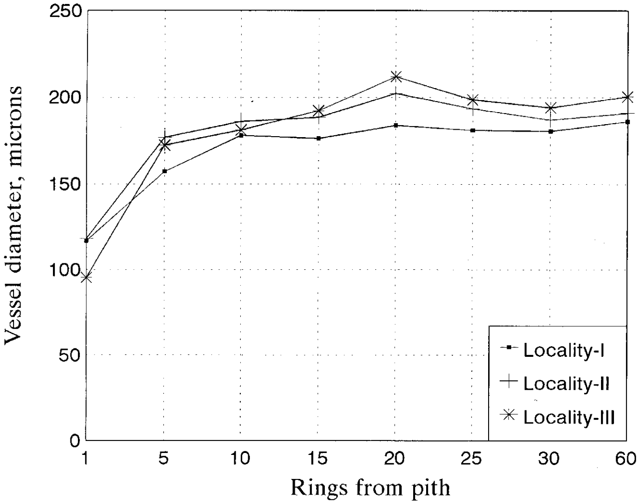

Fig. 3. Radial variation in vessel diameter in relation to age in three localities (I, II, III) of plantations; note maturation age (ring no. 20) at which vessel diameter gets stabilised in teak

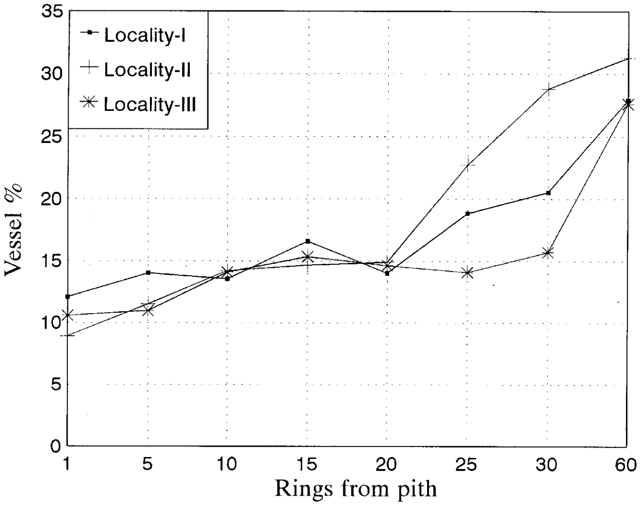

Fig. 4. Radial variation in vessel percentage in relation to age in three localities (I, II, III) of plantations; note maturation age (ring no. 20) at which vessel percentage gets stabilised in teak

f) Cell wall percentage, ray percentage, specific gravity and MCS varied relatively little from pith to bark while MOR with MOE improved slightly or showed insignificant changes without exhibiting distinct patterns of variation (Figs. 6–8).

g) Fibril angle decreased from early juvenile wood (ring no. 1 from pith) to late mature wood (ring no. 60) by almost 100% while fibre length increased by 50%. Similarly, vessel diameter and percentage of vessels increased by about

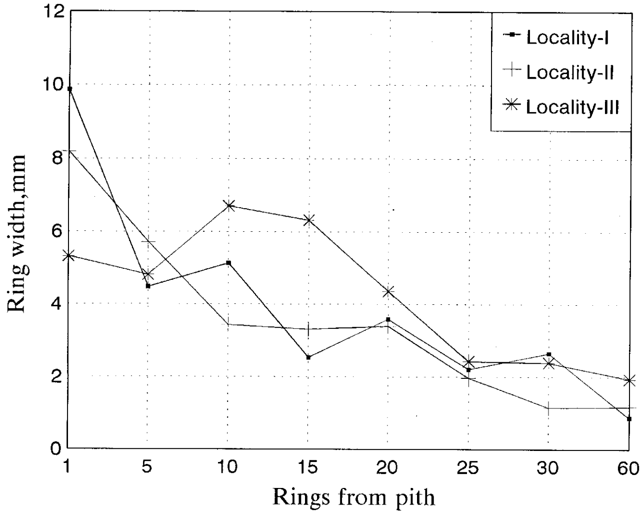

Fig. 5. Radial variation in ring width in relation to age in three localities (I, II, III) of plantations

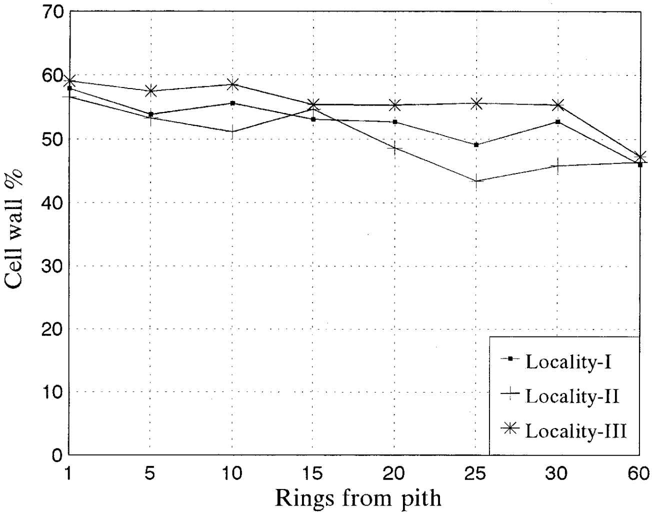

Fig. 6. Radial variation in cell wall percentage in relation to age in three localities (I, II, III) of plantations; note the lack of distinct pattern of variation with age

100% and 250–300% respectively. The corresponding changes in cell wall and ray percentages were below 20% which reflected in small increase or insignificant differences in mechanical properties such as MOR, MOE and MCS. The significant regression models fitted into the data revealed that among the different properties studied, microfibril angle, fibre length, vessel diameter and ring width displayed more distinct pattern of radial variation (Tables 2 and 3 and Figs. 1–8). The age of demarcation between juvenile and mature wood, as determined from the critical values of X_0 where gradient/slope levels off to

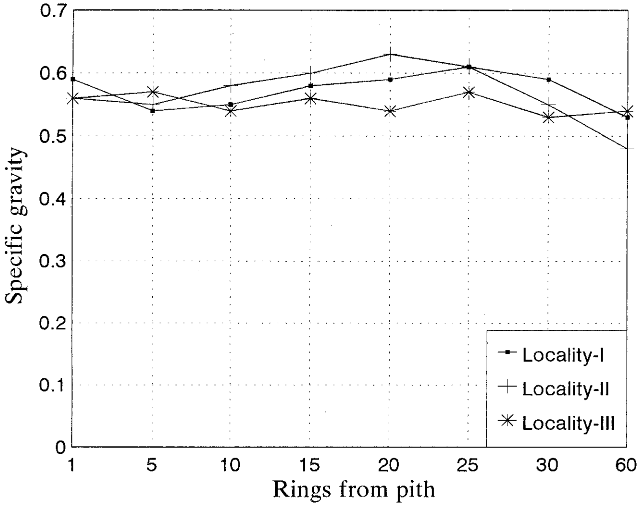

Fig. 7. Radial variation in specific gravity in relation to age in three localities (I, II, III) of plantations; note relatively uniform distribution from pith to bark

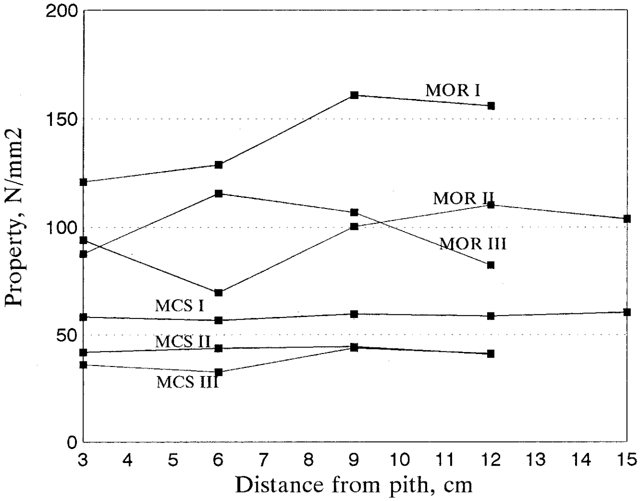

Fig. 8. Radial variation in MOR and MCS in relation to age in three localities (I, II, III) of plantations; note relatively uniform distribution of latter from pith to bark

form a plateau of mature wood region, varied from 15 years up to 20 or 25 years depending on the maturation age of the property and plantation locality.

Juvenile wood properties

The fibril angle decreased by almost 100% while fibre length increased by 50% from early juvenile wood (ring no. 1 from pith) to late mature wood (ring no. 60). Similarly, vessel diameter and vessel percentage increased by about 100% and

250–300% respectively (Figs. 3 and 4). The corresponding changes in cell wall and ray percentages were below 20% reflecting a small increase or insignificant differences in mechanical properties such as MOR, MOE and MCS. The significant regression models revealed that among the different properties, microfibrillar angle, fibre length, vessel diameter and ring width displayed more distinct patterns of radial variation (Tables 2 and 3 and Figs. 1– 8). The age of demarcation between juvenile and mature wood varied from 15 to 20 or 25 years depending on the maturation age of the property and plantation locality. This was determined from the critical values of x_0 where gradient/slope levelled off to begin the plateau of mature wood region.

Having demarcated the juvenile wood from mature wood, the comparison of average values of properties showed that the former was characterised by significantly wide rings, short fibres, a wide microfibrillar angle, small vessel diameter, low vessel and high cell wall percentage (Table 4). Except for higher specific gravity in slow grown trees, juvenile wood was not significantly different although the first formed wood around the pith was often slightly inferior or even *vice-versa* (Fig. 7).

While MOR and MOE of fast grown (phenotypically superior) trees were significantly lower in juvenile wood by 20–21%, MCS of both fast- and slow-grown trees and MOR and MOE of slow grown trees did not differ between juvenile and mature wood (Table 4). The small differences in physical and mechanical properties between juvenile and mature wood were partly attributed

Table 4. Comparison of juvenile- and mature wood properties in fast-grown (Treatment-1) and slow-grown (Treatment-2) trees of three localities

Property	Treatment	Juvenile wood	Mature wood	't' -value
Ring width, mm	1	6.6	2.5	**
	2			
Microfibrillar angle °s	1	15	10	**
	2	16	10.1	**
Vessel diameter µm	1	173.2	196.31	*
	2	160.4	186.2	*
Vessel %	1	13.8	18.5	**
	2	12.9	27.7	**
Ray %	1	18.6	20.3	ns
	2	18.7	18.7	ns
Cell wall %	1	55.7	51.1	*
	2	54.1	47.2	*
Specific gravity	1	0.56	0.57	ns
	2	0.57	0.54	*
Fibre length µm	1	1281	1500	*
	2	1101	1377	ns
MOR (N/mm^2)	1	98.3	124.2	**
	2	114	134.6	ns
MOE (N/mm^2)	1	12695	15746	**
	2	14460	16220	ns
MCS (N/mm^2)	1	45	47	ns
	2	54	53	ns

ns – not significant at 0.05 level
* significant at 0.05 level
** significant at 0.01 level

to the high percentage of vessels in the narrow rings of mature wood (Fig. 9). In ring-porous species, narrowing of rings generally results in lower percentages of latewood and fibres and in higher percentage of vessels that contribute to the more void volume or low specific gravity of wood.

When a comparison was made between localities, we observed the following trends:

a) Microfibrillar angle was maximum in the rings near the pith and gradually decreased with age up to 20 years in locality II and 25 years in localities I and III and stabilised thereafter (Fig. 1). From the regression equations, the estimated critical ages of demarcation between juvenile and mature wood were also found as 20 and 25 years in Location II and I /III respectively (Tables 2, 3). This implies that the maturation age of the microfibrillar angle generally lies somewhere between 20–25 years in plantation-grown teak.
b) With regard to fibre length, the maturation age was found around 15 years in Locality II. In contrast, in trees of localities I and III, fibre length increase continued up to 25 years before stabilising at a critical point of the maturation age (Fig. 2 and Table 2).
c) The vessel diameter stabilised around 20 years after an initial increase during the juvenile phase of growth (Fig. 3). Large diameter vessels in the mature wood region perhaps contribute to the higher percentage of vessels noted after 20 rings from pith (Fig. 4).
d) Ring width was significantly greater during the first 20 years of the juvenile phase of growth (Table 4) and then decreased gradually up to 25 years before displaying fluctuating trends in three localities.

Specific gravity and MCS varied relatively little from pith to bark while MOR with MOE improved slightly or showed insignificant differences without exhibiting distinct patterns of variation (Figs. 6, 7).

Locality vis-à-vis growth effects on properties

After fast- and slow-grown trees of all the localities had been treated separately, it was found that the former showed a tendency to prolong the period of juvenility as compared to the latter. Vessel diameter in fast-grown trees continued to increase while it stabilised in ring 10 of slow grown trees (Fig. 10). However, the

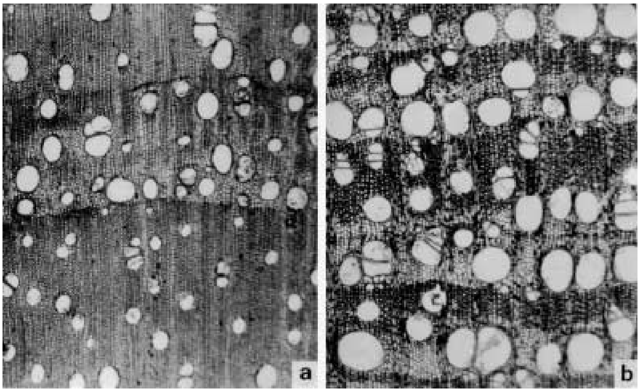

Fig. 9a, b. Transverse sections of juvenile (*a*) and mature wood (*b*); note narrow rings with high percentage of vessels and low percentage of fibres in mature wood, ×27

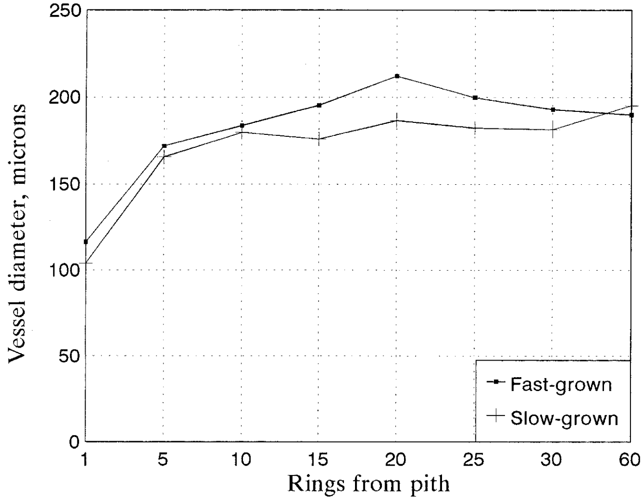

Fig. 10. Radial variation in vessel diameter in relation to age in fast and slow grown trees (localities combined); note maturation age as ring no. 20 in fast grown and ring no. 10 in slow-grown trees at which vessel diameter gets stabilised

effects of growth rate on maturation of properties were more pronounced between the locations than within the plantation as illustrated in Figs. 1–4. The analysis of variance revealed that except for ring width and MOE, properties did not differ significantly between the fast- and slow-grown trees (Table 5). On the other hand, plantation locality had significant effects on microfibrillar angle, ray percentage and mechanical properties, implying that site factors influence tree growth and strength properties of plantation-grown teak. For instance, MOR and MOE values were significantly greater in slow-growing Locality II, probably because of a lesser degree of microfibrillar orientation, while MCS was greater in Locality I than in the other two localities (Table 5).

Further, we found considerable between-tree variation in the microfibrillar angle of two fast-grown trees of the same plantation. The juvenile wood of Tree No. 2 in Locality II showed a consistently smaller angle than in Tree No. 1, probably due to genetic differences (Fig. 11).

Changes in proportion of juvenile wood with age

Plantation managers very often desire to manipulate the proportion of juvenile wood in short rotation timbers. In view of this, projections are made at various ages from 20 to 60 years from the predictive curves (Table 6 and Fig. 12). The juvenile core area was estimated by giving weightage to individual ring width that represented the range from pith to maturation age (ring number 20 for Locality II and 25 for I and III) in relation to cross sectional area of the disc (without bark) at breast height (bh). At 20 years, the proportion of juvenile wood in Locality I is about 80% in contrast to 100% in Localities I and III (Fig. 12). This difference is due to the fact that trees had early maturation of wood in Locality II. After declining significantly to the lower limit of 25–30% at 45–50 years, the juvenile wood proportion remained almost constant up to 60 years. This implies that extending rotation above 45–50 years will not be worthwhile to minimise the juvenile wood proportion of the timber.

Table 5. Mean properties and coefficients of variation for fast- (Treatment 1) and slow-grown (Treatment 2) trees of three localities

Property	Treat-ment	Locality						F-value of	
		I		II		III		ANOVA	
		Mean	CV%	Mean	CV%	Mean	CV%	Locality	Treatment
Ring width,	1	4.8	69	4.4	71	6.3	60	ns	**
mm	2	3.0	91	2.6	103	2.2	116		
Fibril angle,	1	13	23	11	34	14	22	**	ns
°s	2	13	24	13	39	14	27		
Vessel diameter,	1	177	17	186	13	184	22	ns	ns
µm	2	162	15	174	19	177	19		
Vessel %	1	17	31	15	30	15	27	ns	ns
	2	13	38	22	63	16	57		
Ray %	1	16	18	19	13	22	23	**	ns
	2	17	20	17	18	22	17		
Cell wall %	1	53	9	52	9	57	7	ns	ns
	2	53	12	48	19	54	12		
Fibre length,	1	1405	13	1377	11	–	–	ns	ns
µm	2	1288	17	1168	11	–	–		
MOR, N/mm^2	1	95	19	112	17	100	19	*	ns
	2	118	25	134	12	117	23		
MOE, N/mm^2	1	10753	32	17956	18	13507	8	**	*
	2	13165	16	17003	14	12736	23		
MCS, M/mm^2	1	59	6	42	20	38	20	**	ns
	2	60	17	54	7	47	7		

* Significant at 5% level; ** Significant at 1% level; ns – not significant

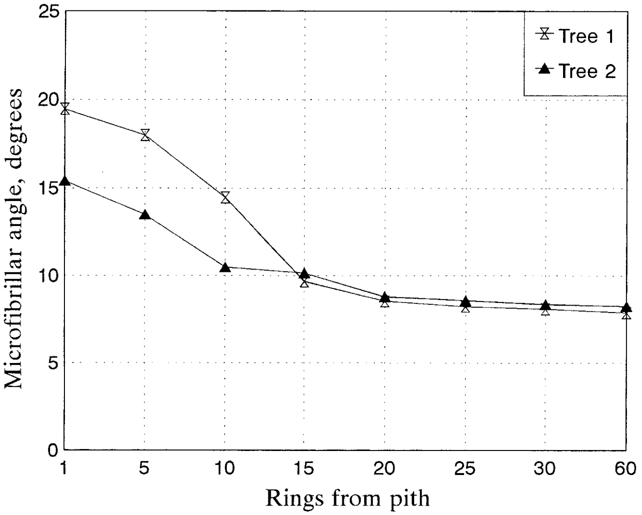

Fig. 11. Tree-to-tree variation in microfibrillar angle in two phenotypically superior trees of Locality II

Table 6. Regression equations for prediction of juvenile wood percentage (Y) in teak at different ages in localities I, II and III

Equation	R^2 %	Sy.x
$Y_I = 208.01 - 6.81x + 0.06x^2$	99.3	2.4
$Y_{II} = 169.04 - 5.44x + 0.05x^2$	99.1	3.0
$Y_{III} = 180.42 - 5.30x + 0.05x^2$	98.2	4.2

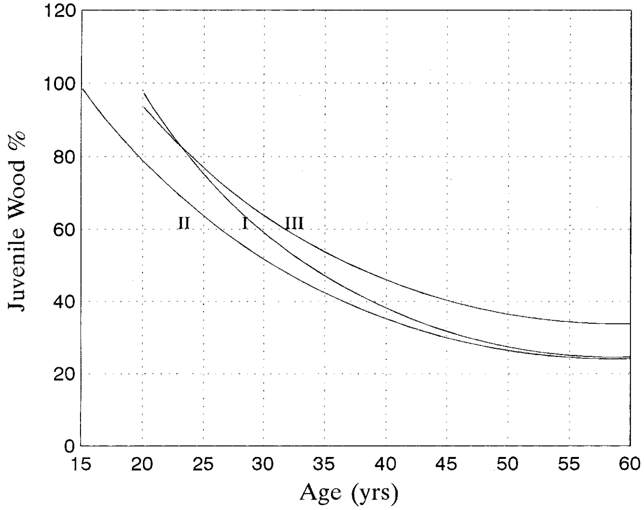

Fig. 12. Projected proportion of juvenile wood (predictive curves) at breast height in teak at ages 20–60 years grown in three localities (I, II, III) in India

Discussion and conclusions

Age demarcation between juvenile and mature wood

Based on the visual interpretation of the data plots and the regression equations, we conclude that the age demarcation between juvenile and mature wood in teak trees lies around 15 or 20–25 years. Since the changes in structure and properties from juvenile to mature wood are rather gradual, an exact demarcating line cannot be fixed with respect to a particular growth ring even for a single property as discussed by Lewark (1986).

Further, it is noted that the juvenile phase or maturation age varies among different properties as displayed by fibrillar orientation, fibre length and vessel diameter. The trend depicted in radial variability of the fibril angle and fibre length indicates that teak has a longer period of juvenile wood formation in certain plantation localities where trees grow fast. This is substantiated by previous observations that in juvenile wood the fibre length increases rapidly up to 9 rings from pith before slowing down the rate of increase after 10 years or later (Kedharnath et al. 1963; Bhat et al. 1989a).

The significant regression models reveal that among the properties analysed, microfibrillar angle, fibre length and vessel diameter/percentage seem to be more consistent in radial variation and can be used as anatomical indicators of age demarcation between juvenile and mature wood. However, in temperate hardwoods, MOE is often considered as the most sensitive indicator of the transition between juvenile and mature wood within a tree (Gartner et al. 1995).

Evidently, juvenile wood formation in teak continues up to 15 or 20–25 years although it varies considerably depending on the properties, plantation localities, growth rate and individual trees.

Juvenile wood behaviour

The definition offered for the juvenile wood of conifers and temperate hardwoods (Bendtsen 1978; Senft 1986) does not apply fully in tropical ring-porous hardwoods. This is striking here as specific gravity and often strength properties remain unchanged with age. Assuming that the first seven rings comprised juvenile wood, Sanwo (1987) concludes that the juvenile wood of 27-year-old teak grown in Nigeria is not inferior to mature wood in terms of specific gravity and strength. A rather different trend of variation in specific gravity and mechanical properties, as compared to anatomical properties, is also recorded in both softwoods and hardwoods of temperate region (Bendtsen and Senft 1986). The significant anatomical differences noticed will be of relatively little practical value as processing of mature timber at ages 50–60 years is expected to contain about 25% juvenile wood. Furthermore, unlike conifers, the relatively small differences noticed between juvenile and mature wood properties support the view that 20–25-year-old juvenile teak wood is qualitatively comparable to mature timber at least in mechanical behaviour especially in longitudinal stress. Although, beam stiffness with maximum bending stress of juvenile wood of fast grown timber is likely to be slightly lower (by about 15–18%), as reflected from the MOE and MOR values, the juvenile wood of slow grown trees does not seem to behave differently from mature wood. The absence of juvenile wood effect on mechanical behaviour of temperate hardwoods such as white oak (*Quercus garryana* Dougl.) has been noticed while it was not the case in red alder (Gartner et al. 1995).

Another acceptable feature of teak juvenile wood is a relatively small angle of microfibillar orientation, the average value being 15°, causing negligible longitudinal shrinkage (Bhat et al., unpublished data). In some timbers, it exceeds 25–30° resulting in drastically increased shrinkage (Zobel and van Buijtenen 1989). Probably, this is also another reason why teak is reputed for greater dimensional stability and structural performance (Bhat 1998). As in specific gravity (Bhat et al. 1989b), tree-to-tree variation recorded in the fibrillar angle of two phenotypically superior trees (Locality II) offers scope for the selection of individual trees for further improvement of dimensional stability of juvenile wood.

Thus, juvenile teak wood, with a relatively more uniform radial distribution of properties has potential to meet the critical requirements of solid wood uses. If the log shape can be improved by plantation management practices to conform with market specifications, teak juvenile wood may emerge as a new tropical raw material resource from sustainable forest management.

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