ORDER

The Research Degree Committee of FRI University at its meeting held on 16.08.2013 has accepted the recommendations of R.A.Cs. concerned in respect of the under noted Research Scholars and has been pleased to extend their term of registration for the period as noted against each:

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Name of Research Scholar</th>
<th>Supervisor's Name</th>
<th>Period of extension approved by RDC</th>
<th>Fee to be deposited</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mr. Sachidanand Sunam, Ph.D. Research Scholar, Co. No. 1114, Rashtrapati Bhavan, Environment Division, FRI, Dehradun</td>
<td>Dr. H.B. Vastish, Scientist-E, Environmental Division, FRI, Dehradun</td>
<td>01.04.2013 to 28.02.2014</td>
<td>He will have to deposit a sum of Rs. 1000/- towards Annual fee and 1000/- for renewal of registration fee in FRI and Rs. 2000/- towards Library fee at IISTW, Bangalore.</td>
</tr>
<tr>
<td>2</td>
<td>Mr. Satish Kumar Sinha, Research Scholar, Institute of Wood Science &amp; Technology 18th Cross, Malleswaram, Bangalore-650003</td>
<td>Dr. R.V. Rao, Redt. Scientist-G, IISTW, Bangalore</td>
<td>01.03.2013 to 28.02.2014</td>
<td>He will have to deposit a sum of Rs. 11000/- (1000/- towards Annual fee and 1000/- for renewal of registration fee in FRI and Rs. 2000/- towards Library fee at IISTW, Bangalore).</td>
</tr>
<tr>
<td>3</td>
<td>Ms. Shivani Dobhal, Ph.D. Scholar, Co. No. 851, FRI</td>
<td>Dr. T.S. Rathore, Director, AFRJ, Jodhpur</td>
<td>01.03.2013 to 31.08.2013</td>
<td>She will have to deposit a sum of Rs. 11000/- (1000/- towards Annual fee and 1000/- for renewal of registration fee in IISTW, Bangalore.</td>
</tr>
<tr>
<td>4</td>
<td>Mr. R. Vivekanandan, Research Scholar, Co./Dr. N.V. Mathish, Scientist-E, Division of Plant Biotechnology, IFGTB, Coimbatore-2</td>
<td>Dr. N.V. Mathish, Scientist-E, Division of Plant Biotechnology, IFGTB, Coimbatore-2</td>
<td>29.02.2012 to 28.02.2014</td>
<td>He will have to deposit a sum of Rs. 17000/- (5000/- towards Annual fee and 1000/- towards renewal of registration fee for the year 29.2.2012 to 28.2.2013, Rs.10000/- towards Annual fee &amp; Rs. 1000/- towards renewal of registration fee for the year 1.3.2013 to 28.2.2014) in FRI and Rs. 2000/- towards Library fee in FRI.</td>
</tr>
<tr>
<td>5</td>
<td>Mr. Syed Waseem Balkhi, Co./Syed Bashir Ahmad, Head Office, Poetry Research, Dehra Dun</td>
<td>Dr. V.R.R. Singh, IFS, Director, IFRI, Shimla</td>
<td>01.03.2013 to 28.02.2014</td>
<td>He will have to deposit a sum of Rs. 1000/- towards Annual fee &amp; 1000/- towards Library fee in FRI.</td>
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Registered Fee
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<th>No.</th>
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<th>Institution</th>
<th>Date</th>
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<tr>
<td>6</td>
<td>Ms. Reenu Sharma</td>
<td>Scientist-F.</td>
<td>Systematic Botany, FRI</td>
<td>01.09.2013 to 31.08.2014</td>
<td>She will have to deposit a sum of Rs. 1200/- towards Annual fee and Library fee in FRIDU.</td>
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<td></td>
<td>C/o Dr. Anil Gupta</td>
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<td>A-13, Narain Nagar</td>
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<td>7</td>
<td>Ms. Arti Gaur</td>
<td>Scientist-F, Forest Genetics &amp; Tree Breeding Division, AFRI</td>
<td>Jodhpur</td>
<td>01.09.2013 to 31.08.2014</td>
<td>She will have to deposit a sum of Rs. 12000/- (Rs.10000/- towards Annual fee in FRIDU and Rs. 2000/- Library fee in AFRI Jodhpur).</td>
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<td>C/o Dr. U.K. Tomar</td>
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<tr>
<td>8</td>
<td>Mr. RSC Jayaraj</td>
<td>Scientist F, Forest Protection Division, IEGTB, Coimbatore 641002, Tamil Nadu</td>
<td></td>
<td>01.09.2013 to 31.08.2014</td>
<td>He will have to deposit a sum of Rs. 10000/- towards Annual fee in FRIDU.</td>
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<td>C/o Dr. A. Balu</td>
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<td></td>
<td>Scientist F, Forest Protection Division, IEGTB, Coimbatore 641002, Tamil Nadu</td>
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<tr>
<td>9</td>
<td>Mrs. Namita Vijay</td>
<td>Scientist-G, FGTB Division AFRI P.O. Krishi Mandi, New Pali Road, Jodhpur 342-005</td>
<td></td>
<td>01.09.2013 to 31.08.2014</td>
<td>She will have to deposit a sum of Rs. 12000/- (Rs.10000/- towards Annual fee in FRIDU and Rs. 2000/- Library fee in AFRI Jodhpur).</td>
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<td>C/o Dr. I.D. Arya</td>
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<td>Scientist-G, FGTB Division Arid Forest Research Institute, P.O. Krishi Mandi, New Pali Road, Jodhpur 342-005</td>
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<td></td>
<td>Dr. Sarita Arya</td>
<td>Scientist-F &amp; Head FGTB Division, AFRI</td>
<td>Jodhpur</td>
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<tr>
<td>10</td>
<td>Ms. Shikha Thakur</td>
<td>Scientist-G, Forest Pathology Division</td>
<td></td>
<td>01.09.2013 to 31.08.2014</td>
<td>She will have to deposit a sum of Rs. 12000/- towards Annual fee and Library fee in FRIDU.</td>
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<td>C/o Dr. N.S.K. Harsh</td>
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<td>Scientist-G, Forest Pathology Division</td>
<td>FRI Dehradun</td>
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<tr>
<td>11</td>
<td>Mr. Rajendra Prasad</td>
<td>Scientist-G, Forest Pathology Division</td>
<td></td>
<td>01.09.2013 to 31.08.2014</td>
<td>He will have to deposit a sum of Rs. 12000/- towards Annual fee and Library fee in FRIDU.</td>
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<td>FRI Dehradun</td>
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<td></td>
<td>Dr. V.K. Varshney</td>
<td>Scientist-F, Chemistry Division, FRI Dehradun</td>
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<tr>
<td>12</td>
<td>Mr. Pardeep Singh</td>
<td>Head, NWFP Division FRI</td>
<td></td>
<td>01.03.2013 to 28.02.2014</td>
<td>He will have to deposit a sum of Rs. 13000/- towards Annual fee, Library fee &amp; Rs. 1000 for renewal of registration in FRIDU.</td>
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<td>C/o Dr. A.K. Sharma</td>
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<td></td>
<td>Dr. A.K. Sharma</td>
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</table>
**Distribution:**

1. The Nodal Officer (AFRI, IFGTB, IWST, FRI) for information and necessary action.
2. The Supervisor/Research Scholars concerned for information and necessary action.
3. Personal file of the Research Scholars.

All the above Research Scholars shall have to deposit a fee as mentioned against their names through Bank Draft in favour of Registrar FRI (Deemed) University.

(Dr. A.K. Tripathi)
Registrar,
FRI (Deemed) University
This is to certify that Mr. SATISH KUMAR SINHA enrolment no. 0803/IWST/E-2137/R-1060/7A-253 dated 28.07.2008 carried out research work under Dr. R.V. Rao of Institute of Wood Science & Technology. The topic of the research registered with FRI (Deemed) University was “Influence of climate on the radial variation of specific gravity and certain anatomical properties in teak from Chandrapur and Thane, Maharashtra”. The scholar presented his work in the pre-thesis submission seminar held on 05-01-2015 and the RAC found the work to be satisfactory and approves the work to be presented in the form of thesis for evaluation by examiners for “Award of Ph.D. Degree” by FRI (Deemed) University.

(Dr. H.P. Borgaonkar)
Co-Supervisor

(Dr. T.S. Rathore)
Co-supervisor

(Dr. R. V. Rao)
Supervisor

(Dr. S.K. Nath)
Expert Member

(Dr. Nataraja Karaba)
Expert Member

(Dr. S.R. Shukla)
Expert Member & HoD

(Dr. Ritesh Tailor)
Expert Member

(Dr. V. Ramakantha)
Chairman RAC
# ORDER

The Research Degree Committee of FRI University at its meeting held on 15.09.2014 has accepted the recommendations of R.A.Cs. concerned in respect of the under noted Research Scholars and has been pleased to extend their term of registration for the period as noted against each:

<table>
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<tr>
<th>Sl. No.</th>
<th>Name of Research Scholar</th>
<th>Supervisor’s Name</th>
<th>Period of extension approved by RDC</th>
<th>Fee to be deposited</th>
</tr>
</thead>
</table>
| 1       | Aabid Rasool Zargar  
C/o Dr. Dinesh Kumar,  
Scientist-F, Silviculture Division, FRI, Dehradun | Dr. Dinesh Kumar,  
Scientist-F, Silviculture Division, FRI, Dehradun | 1.9.2014 to 15.1.2015 | He shall have to deposit a sum of Rs.12000/- (Rs.10000/- towards Annual fee and Rs.2000/- towards Library fee.) |
| 2       | Sachida Nand Suman  
C/o Dr. H. B. Vasistha,  
Scientist-E,  
Forest Ecology & Environment Division, FRI Dehradun | Dr. H. B. Vasistha,  
Scientist-E, Forest Ecology & Environment Division, FRI Dehradun | 1.3.2014 to 28.2.2015 | He shall have to deposit a sum of Rs.13000/- (Rs.10000/- towards Annual fee, Rs.2000/- towards Library fee and Rs.1000/- towards renewal of registration fee) |
| 3       | Ulsheeda Rashid  
C/o Dr. Dinesh Kumar,  
Scientist-F,  
Silviculture Division, FRI, Dehradun | Dr. Dinesh Kumar,  
Scientist-F, Silviculture Division, FRI, Dehradun | 1.9.2014 to 31.8.2015 | She shall have to deposit a sum of Rs.12000/- (Rs.10000/- towards Annual fee and Rs.2000/- towards Library fee.) |
| 4       | Satish Kumar Sinha  
C/o Dr. R.V.Rao  
Scientist-G Rtd. & Ex-Head, Wood Properties and Uses Division, IWST, Bangalore | Dr. R.V.Rao  
Scientist-G Rtd. & Ex-Head, Wood Properties and Uses Division, IWST, Bangalore | 1.3.2014 to 28.2.2015 | He shall have to deposit a sum of Rs.13000/- (Rs.10000/- towards Annual fee and Rs.1000/- towards renewal of registration fee at FRIDU and Rs.2000/- towards Library fee at IWST Bangalore) |
| 5       | Shri Sanjay Sood  
Conservator of Forests,  
Shimla Forest Circle,  
Shimla-171002 | Dr. K.S. Kapoor,  
Scientist-F,  
Confir Campus,  
Panthaghati,  
HFRI, Shimla-171009 | 1.3.2013 to 28.2.2015 | He shall have to deposit a sum of Rs.26000/- (Rs.20000/- towards Annual fee and Rs.2000/- towards renewal of registration fee for extended period in FRIDU, Dehradun and Rs.4000 towards Library fee in HFRI Shimla) |
| 6       | Asieleavio John  
C/o Dr. Krishan Kumar  
V.S.  
Scientist-F,  
Wood Working & Finishing Discipline, FRI Dehradun | Dr. Kishan Kumar  
V.S.  
Scientist-F, Wood Working & Finishing Discipline, FRI Dehradun | 1.9.2014 to 31.8.2015 | He shall have to deposit a sum of Rs.12000/- (Rs.10000/- towards Annual fee, and Rs.2000/- towards Library fee) |
<table>
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<th>No.</th>
<th>Name</th>
<th>Department</th>
<th>Date</th>
<th>Fee Details</th>
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</thead>
<tbody>
<tr>
<td>7</td>
<td>Deepika Dogra, Ph.D. Scholar, C/o Dr. S.P.S. Rawat, Scientist-F, Climate Change and Forest Influence Division, FRI, Dehradun</td>
<td>Dr. S.P.S. Rawat, Scientist-F, Climate Change and Forest Influence Division, FRI, Dehradun</td>
<td>1.9.2014 to 31.8.2015</td>
<td>She shall have to deposit a sum of Rs.12000/- (Rs.10000/- towards Annual fee and Rs.2000/- towards Library fee.)</td>
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<tr>
<td>8</td>
<td>Sudhir Kumar Dr. H.B. Vasishta, Scientist-E, Ecology &amp; Environment Division, FRI, Dehradun</td>
<td>Dr. H.B. Vasishta, Scientist-E, Ecology &amp; Environment Division, FRI, Dehradun</td>
<td>1.3.2014 to 28.2.2015</td>
<td>He shall have to deposit a sum of Rs.13000/- (Rs.10000/- towards Annual fee, Rs.2000/- towards Library fee and Rs.1000/- towards renewal of registration fee.)</td>
</tr>
<tr>
<td>9</td>
<td>Atri Shaw C/o Mr. R.P. Semwal, 121, Sahawala, Dehradun-248001</td>
<td>Dr. M.D. Omprakash, Assistant Professor, Ecosystem and Environment Management, Indian Institute of Forest Management, Bhopal</td>
<td>1.9.2014 to 31.8.2015</td>
<td>She shall have to deposit a sum of Rs.13000/- (Rs.10000/- towards Annual fee, Rs.1000/- towards renewal of registration fee at FRIDU and Rs.2000/- towards Library fee at IIFM Bhopal)</td>
</tr>
</tbody>
</table>

All the above Research Scholars shall have to deposit a fee as mentioned against their names through Bank Draft in favour of Registrar FRJ (Deemed) University.

[Signature]
A.K. Tripathi
Registrar,
FRJ (Deemed) University

**Distribution:**

1. The Nodal Officer (IWSIT Bangalore, HFRI Shimla, IIFM Bhopal) for information and necessary action.
2. The Supervisor/Research Scholars concerned for information and necessary action.
3. Personal file of the Research Scholars.
Mass bleaching of corals in Andaman

Alloy development of corrosion-resistant rail steel

Dendroclimatic analysis of teak annual rings
Growth ring structure and specific gravity variation in juvenile and mature wood of natural-grown teak (*Tectona grandis* L. f.)

Satish Kumar Sinha1,*, R. Vijendra Rao2, T.S. Rathore2, H.P. Borgaonkar2

1ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India
2Institute of Wood Science and Technology, Bengaluru, India
3Indian Institute of Tropical Meteorology, Pune, Maharashtra, India

The radial variation of specific gravity and growth ring structures were investigated in juvenile and mature wood of *Tectona grandis* L. grown naturally in dry (Chandrapur) and moist (Thane) deciduous forests of Maharashtra. Five trees each from age group of 48-to 66-year-old from Chandrapur and 120 to 154-year-old trees from Thane were selected. The study revealed that the mean specific gravity of growth rings in juvenile wood was more than the mature wood from both the sites. The annual growth in juvenile and mature period was higher in dry site than moist site. Ring-width of juvenile and mature wood was 4.45 mm and 2.30 mm with the latewood content of 85.70 % and 72.97 %, respectively in dry site. The patterns of radial variation of ring-width, latewood content and specific gravity demonstrated inconsistency in juvenile to mature wood in both the sites. The specific gravity of all the five trees from both sites showed a poor association between ring-width and latewood content in juvenile wood; however, it was positive and strong in most of the samples from mature wood. Considering mean values, there was a strong positive association between ring-width and specific gravity in both juvenile and mature wood of both the sites. However, the latewood content did not show strong association with specific gravity. The overall result showed that ring-width, specific gravity and latewood content vary among individuals as well as between two sites. It is also important that individual tree variation needs to be studied while breeding for higher specific gravity rather than mean variation of all the trees in specific site.

**Keywords**: Juvenile wood, latewood content, mature wood, ring-width, specific gravity, teak

*Corresponding author: E-mail – sinhafri@gmail.com*
Dendroclimatic analysis of teak (Tectona grandis L. f.) annual rings from two locations of peninsular India

Satish Kumar Sinha, M. S. Deepak, R. Vijendra Rao and H. P. Borgaonkar

1Dendrochronology Laboratory, Wood Properties and Uses Division, Institute of Wood Science and Technology, Bangalore 560 003, India
2Indian Institute of Tropical Meteorology, Pune 411 008, India

Climate-related tree-growth variability in teak (Tectona grandis L. f.) has been studied based on response function analysis from dry deciduous forests of Mundagod (Karnataka) and Chandrapur (Maharashtra), peninsular India, representing two ecological zones. Rainfall during the monsoon months of the current year was found to be positively associated with radial growth of teak at both sites, whereas pre-monsoon April rainfall was found to be negatively associated. Rainfall and temperature of the current year during March have positive influence on the growth of teak at Chandrapur and Mundagod respectively. Furthermore, rainfall during October of the preceding year showed a negative influence on tree growth at Mundagod and positive influence at Chandrapur, which might be due to the difference in relative humidity and soil type at both the locations, apart from soil moisture.

Keywords: Annual rings, climate variability, tree growth, teak.

The pattern of radial growth in trees depends largely on the climatic conditions of different localities. Dominated by monsoon climate, the tropical dry deciduous forests of Karnataka and Maharashtra could form important sites for dendroclimatic analysis, especially in understanding tree-growth responses to climate. Attempts are being made to retrieve climatic information using annual growth rings of trees from several locations in India. Growth rings in a large number of tropical trees are studied as annual. It is estimated that about 25% of the total number of tree species produces growth rings. Among these, teak exhibits variable growth rings in trees to the exact formative year, which is a pre-requisite for dendrochronology. India is considered to be the only known centre for genetic diversity and variability of teak, having its natural distribution zone confined predominantly to the peninsular region below 24°N lat. It is reported that the location factor contributed as much as 31.4%, whereas seed origin contributed only 1.46% for variability in teak growth. Teak has been a subject of dendrochronological studies representing different forest types. It has been studied at several locations, viz. from moist deciduous forest in Thane, Maharashtra; dry deciduous forest in Korzi, Andhra Pradesh, the Western Ghats of Kerala, upper Narmada river basin in Central India and dry deciduous forest of Madhya Pradesh. These exploratory studies revealed that annual rings in teak could be valuable proxy data for dendroclimatic analysis. As dry deciduous forests of Karnataka and Maharashtra are well known for the best teak-growing locations in peninsular India, Mundagod and Chandrapur regions were selected for the present study. No detailed tree-ring analysis has been reported so far from these two locations as to how teak growth is influenced by changes in rainfall and temperature. An attempt has been made to study climate-related tree-growth variability in teak with reference to rainfall and temperature from these two locations.

Ten cross-sectional discs of teak were collected in April 1999 at the base of felled trees at Yellapur Forest Division, Mundagod (14°58'N lat and 75°16'60"E long), Karnataka and 15 discs were collected in November 2006 at the base of logged trees from Manali forest range of Lahara around Chandrapur (19°57'N lat and 79°E long), Maharashtra (Figure 1). Totally 25 discs, one from each individual trunk, were collected for tree-ring analysis either from the base of the logged trees or from the leftover stumps. The mean monthly temperature and rainfall data of two meteorological stations, viz. Belgaum and Chandrapur close to the tree-ring sampling sites have been used in the response function analysis of Mundagod and Chandrapur tree-ring samples. This record extends from AD 1941 to 1999 and AD 1901 to 2000 for Mundagod and Chandrapur regions respectively (Figure 2).

---

*For correspondence. (e-mail: sinhafri@gmail.com)
To,

✓ Sh. Satish Kumar Sinha
18th Cross, Malleswaram,
IWST Campus, Type-I (Old Quarter),
Bangalore – 560 003

Sub: -Registration for Doctor of Philosophy Degree in Forestry.

Dear Sir/Madam,

In response to your application dated 14.2.2008 for enrolment as Research Scholar for the Degree of Doctor of Philosophy in Forestry in this Institute, it is to inform you that the following decisions have been taken:-

1. You have been registered for Doctor of Philosophy w.e.f. 01.03.2008 to 28.02.2013 as an Internal Research Scholar.

   (For all further correspondence please quote your registration number.)

3. The Topic for research approved by the F.R.I University “Influence of climate on the radial variation of specific gravity and certain anatomical properties in teak (Tectona grandis Linn.f) from Chandrapur and Thane, Maharashtra”.

4. Name of Discipline: Wood Science & Technology
   (As per clause 3.3 of the Ph.D. Ordinance)

5. (i) Name of Supervisor: - Dr. R. V. Rao
   (ii) Name of Co-supervisor: -
       (i) Dr. T.S. Rathore
       (ii) Dr. H.P. Borgaonkar

6. (a) You are advised to deposit the balance installment of Laboratory fee Rs. 3000/- payable at FRIU/Research Centre concerned through bank draft in the month of March, 2009.

   (d) Library fee of Rs.1000/- per year payable at FRIU/Research Centre concerned in the month of March for each year of registration.

   (c) Annual fee of Rs.5000/- payable every year in the month of March during the period of Registration at FRI University.

   (d) The above mentioned fee should be deposited during the due month i.e. March failing which a late fee of Rs.500/- (Bank Draft) will also have to be deposited in this office.

   (e) You are also required to deposit the thesis fee for Rs.10000/- (Ten thousand only) at the time of submitting the thesis to the University.

7. Please note that the pursuance of following courses for 100 hours is compulsory for all the Internal Ph.D. Research Scholar at F.R.I. University or its Research Centres.
   i. Computer application course as per syllabus.
   ii. Statistical analysis course as per syllabus.
   iii. Basic course in Silviculture and Forestry subjects.

8. The research scholar is required to submit the six monthly progress reports till the work is presented in the pre-thesis submission seminar and is approved by the committee for submission of thesis.

P.T.O.
The surfaces of 25 discs were smoothened using different grades of sand paper to expose the growth rings and prepare the wood for microscopic analysis. A long radial strip of 1.5 cm width was cut from each disc collected from Mundagod and Chandrapur, including all rings from pith to bark. Each ring of the radial strip was dated to the calendar year of its formation applying cross-dating technique\(^1\). Ring widths along two radii of each disc from Mundagod and along a single radius from Chandrapur were measured to the nearest 0.01 mm under a Leica stereo-zoom microscope with a linear stage (Velmex) interfaced with a computer system to record the measurements. These measurements and dates were rechecked using the computer program COFECHA\(^{1,18}\) for any error in the measurement or dating of the samples.

Data were standardized to form site-tree-ring–width-index chronologies using detrending methods, viz. negative exponential or cubic spline fit of wavelength equal to 38.58% of \(N\), where \(N\) is the number of data points in individual tree-ring series in the computer program ARSTAN\(^{18-21}\), and chronologies of 59 and 132 years were prepared spanning AD 1941–1999 and AD 1875–2006 along with sample size variation from Mundagod and Chandrapur regions respectively (Figure 3a and b). The statistical properties of ring-width-index chronologies from the two sites (Table 1) assessed for their dendroclimatic potential. The chronology suitable for dendroclimatic study is generally believed to have good correlation between trees, high mean sensitivity, high standard deviation, high value of common variance, high signal-to-noise ratio (SNR), and high expressed population signal (EPS). Wigley et al.\(^{22}\) suggest that chronologies with EPS > 0.85 can be accepted as reliable chronology for dendroclimatic analysis. Moderately high values of standard deviation, mean sensitivity, EPS and common variance (mean correlation among all the tree samples) indicate the high dendroclimatic potential of these two chronologies. The value of SNR is moderately high for both chronologies, with the highest SNR for Chandrapur chronology. The values of different statistics of the chronologies after autoregression (residual version) are depicted in Table 1. The values in parenthesis are without autoregressive modelling. It was observed that after autoregression the overall statistical performance of tree-ring chronologies had improved. However, with these two chronologies climatic reconstruction is not possible as data are for a short period only.

Climate–tree-growth associations can be assessed reliably by means of response function analysis\(^{23}\). This procedure is a multiple regression analysis in which monthly climatic parameters (temperature and rainfall) are predictors and tree-ring parameters are predictands. The resulting regression equation quantifies the response of the tree to variations in the most important climatic variables. Monthly mean temperature and rainfall at Mundagod and Chandrapur were entered as predictor variables and tree-ring indices as the predictand variables. The analyses were based on the time period 1941–1999 for Mundagod and 1901–2000 for Chandrapur, which were common to both meteorological and tree-ring data respectively. The initiation of growth period in teak starts around March and reaches a peak in June–July, and by the first week of October there is no wood formation. Shedding of leaves starts by December and by the first week of February, all the trees are leafless\(^{3,34}\). In constructing the response functions, a total of 26 variables were used as predictor variables, including 13 for temperature and 13 for rainfall from the previous October (end of previous growing season) to the current October (end of current growing season). Since many of the climatic variables are highly intercorrelated, principal components for 26 data series were obtained. Ring-width-index chronologies of Mundagod and Chandrapur were regressed on the climate principal components to obtain response-function coefficients. Standardized regression coefficients for response functions on a monthly scale for tree-ring chronologies from Mundagod and Chandrapur

---

Table 1. General statistics of tree-ring chronologies (values within brackets are without autoregressive modelling)

<table>
<thead>
<tr>
<th></th>
<th>Mundagod</th>
<th>Chandrapur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronology timespan</td>
<td>AD 1941–1999</td>
<td>AD 1875–2006</td>
</tr>
<tr>
<td>Number of trees (radii)</td>
<td>10 (19)</td>
<td>15 (15)</td>
</tr>
<tr>
<td>Mean tree-ring width (mm)</td>
<td>2.14</td>
<td>2.97</td>
</tr>
<tr>
<td>Mean sensitivity</td>
<td>0.220</td>
<td>0.306</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>0.319</td>
<td>0.281</td>
</tr>
<tr>
<td>Lag-1 autocorrelation</td>
<td>0.02 (0.61)</td>
<td>-0.05 (0.13)</td>
</tr>
<tr>
<td>Number of trees (radii)</td>
<td>9 (18)</td>
<td>15 (15)</td>
</tr>
<tr>
<td>Mean correlation between trees</td>
<td>0.247</td>
<td>0.312</td>
</tr>
<tr>
<td>Signal-to-noise ratio</td>
<td>5.902</td>
<td>6.813</td>
</tr>
<tr>
<td>Expressed population signal</td>
<td>0.855</td>
<td>0.872</td>
</tr>
<tr>
<td>Variance explained percentage in first eigenvector</td>
<td>30.95</td>
<td>38.18</td>
</tr>
</tbody>
</table>
are depicted in Figure 4. Vertical bars in the figure indicate 95% confidence interval; the coefficient is considered to be statistically significant ($P < 0.05$) only when its confidence interval does not include zero.

Analysis of tree-growth and climate relationship at Mundagod suggests that rainfall during June–August of the current year had positive influence on the growth of teak, whereas April rainfall of the current year and October rainfall of the preceding year had negative influence. March temperature during current year showed positive response with tree growth, whereas April temperature showed negative. Positive tree growth and climate relationship during June–August of the current year suggests that the southwest monsoon rainfall plays an important role in the growth of teak. Mundagod is situated in the eastern part of the Western Ghats, which is a hot, semiarid ecological region having negligible coastal effects. It is evident from the average annual rainfall of 1116.9 mm and high potential evapotranspiration (PET) of 1600–1800 mm, that relative humidity in this region is low, predominantly with laterite soil, where October rainfall of the preceding year showed negative influence on tree growth. This might be due to nonavailability of moisture and nutrients as meagre rainfall may have deprived the nutrients to the nonavailability zone. Experience in India has indicated that teak performs poorly on laterite soils. The inverse relationship with April rainfall and April temperature might be due to lower net photosynthetic rate, presumably due to higher evapotranspiration. During these monsoon rainfall is less, but temperature is at its maximum in the region (Figure 2). Thus increased rainfall during the hot summer accelerates the rate of evapotranspiration, which might have caused water stress-like conditions for teak trees. March temperature
Figure 4 a-d. Response functions of tree ring chronologies of teak at Mundgod and Chandrapur using monthly temperature and rainfall at Belgaum and Chandrapur respectively. Vertical bars indicate 95% confidence interval.

showed significant effect on the growth of teak, as it favours opening of dormant foliar buds and also the initiation of cambial activity.12,24

Analysis of tree growth and climate relationship at Chandrapur suggests that the rainfall during March and June–September of the current year and October of the preceding year has positive influence, whereas April rainfall has negative influence on the growth of teak. Temperature does not show any significant effect on the growth of teak in this region (Figure 4c and d). Positive tree growth and climate relationship during June–September suggests that the southwest monsoon rainfall plays an important role in the growth of teak. Besides, rainfall during October of the previous year also plays an important role. This might be due to mobilization of stored nutrients that aid in the initiation of growth for ensuing growing season13. This may also be due to high relative humidity because Chandrapur falls under the hot, semi-humid ecological region. The average annual rainfall in this region is 1275.3 mm, PET is 1400–1700 mm (ref. 25), and soil type of the region is sandy loam. In this type of soil, drainage and aeration is more, which is essential for better root growth. Aeration helps soil organisms to survive. These organisms often help by making nutrients available to the plants. Rainfall during March also showed positive response to tree growth. This is supported by a study, where pre-monsoon showers were recorded to play an important role in breaking cambial dormancy of teak.24 The inverse relationship with April temperature might be due to lower net photosynthetic rate, concomitant with higher rate of evapotranspiration. During April–May, rainfall is less and temperature is maximum in this region (Figure 2). Thus increased rainfall during the hot summer accelerates the rate of evapotranspiration, which might have caused water stress-like conditions for teak growth.

Tree-ring analysis of teak from peninsular India has great importance since it adds novel information to understanding the chronological variability in the growth of teak with changes in climate. Mundgod and Chandrapur are dominated by the southwest monsoon with similar dry deciduous forests. However, a radial variation in the growth of teak has been studied at both the locations. This study corroborates that the pattern of radial growth in teak varies with the local edaphic and climatic conditions, namely rainfall, relative humidity and temperature as well as soil type of different locations and plays a significant role in influencing the growth of teak.

Psychophily in Stachytarpheta jamaicensis (L.) Vahl. (Verbenaceae)

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Department of Environmental Sciences, Annamalai University, Vellalapattu 608 004, India

Stachytarpheta jamaicensis is a seasonal shrub which produces flowers for a lengthy period during rainy and winter seasons. The floral characteristics such as bluish violet flowers, no perceptible smell, narrow tubular corolla and concealed nectar accumulated at the corolla base conform to ‘psychophilous pollination syndrome’. The aggregated arrangement of flowers on the inflorescence is economical and energetically rewarding for the butterflies. The lower lip of the corolla is elaborate and provides comfortable landing place for the butterflies. The nectar is sucrose-rich with 28% sugar concentration and also carbohydrate-rich with little protein content. It is also an important source of five of the ten essential amino acids required by butterflies; they include isoleucine, valine, lysine, methionine and threonine. Further, it also contains the non-essential amino acids such as alanine, butyric acid, cysteine, glutamic acid, glycine, hydroxyproline, proline, serine, aspartic acid and cystine. With these floral morphological and functional characteristics, the plant is exclusively pollinated by butterflies. Among butterflies, nymphalids and pierids are relatively more diverse in species and consistent foragers than papilionids and hesperids. Therefore, the interaction between S. jamaicensis and the butterflies is mutualistic; the former for pollination and the latter for nourishment. This floral source is available for a long period and hence is an important nectar source for the maintenance of local butterflies. Additionally, bees also visit the flowers for forage and their visits

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Effect of growth Rate and Latewood content on basic Density of Wood from 120-to 154-Year-old Natural-grown Teak (Tectona grandis L. f.)

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Abstract

The relationship between the radial variations of growth ring features and basic density were investigated in juvenile and mature wood for five 120-to154-year-old trees of Tectona grandis L. grown naturally in moist deciduous forest of Thane, Maharashtra. The study showed that the mean basic density of growth rings in juvenile wood was 0.665 (0.602-0.702) g cm\(^{-3}\) and 0.613 (0.562-0.665) g cm\(^{-3}\) in mature wood. The annual growth in juvenile period was high with a ring width mean of 4.03 mm and the latwood content represented 76.36% of the annual growth, while in mature period was low with a ring width mean of 1.24 mm and the latwood content represented 59.41% of the annual growth. The patterns of radial variation of ring width, latewood content and basic density were more inherent in the juvenile wood than mature wood of all trees due to cambial ageing. The basic density of five individual trees showed an insignificant correlation between ring-width and latewood content in juvenile wood, whereas a significant positive correlation was found in mature wood of most of individual trees. The mean ring width value of all trees showed a highly significant positive correlation with basic density in both types of wood but mean latewood content showed a non-significant or low significant correlation.

Keywords: Growth rate, juvenile wood, mature wood, ring-width, teak, basic density.

Introduction

Wood is a non-homogenous, anisotropic material throughout the tree stem. The structure and properties of wood vary from pith to periphery, from the tree base to the top, from stem to branch and root\(^1\). The variation in wood properties results from environmental differences, genetic differences, and their interactions. Wood density has a strong additive genetic component, where minor environmental differences may not easily affect. However, it can greatly be changed by large differences in environment. Review showed that wood density of hardwoods has received far more study than any other property because of its relation to strength, workability, pulpability and ease of measurement. It is, in fact, not a single wood property but a combination of wood properties like latewood proportion, wall thickness, cell size, and others\(^2\).

Wood density is not only influenced by genotype, environment but also affected by cambial age and growth rate. Ring width, which reflects the radial growth of a tree resulting from vascular cambial activity, has been used as the indicator of growth rate. Studies suggest that variation in basic density is influenced by ring width in both juvenile and mature wood of ring-porous hardwood. The reason is that, generally, the earlywood zone of ring-porous hardwoods has a relatively high proportion of vessels and the width of earlywood remains fairly constant from year to year, however, in latewood proportion, vessels are fewer and it increases as ring-width increases\(^3\). The relationship between growth rate and wood density is very complex in hardwoods; it has been much studied, and sometimes, it creates confusion. Wood density of diffuse-porous hardwood is almost independent of growth rate, in contrast, there is a positive correlation between growth rate and wood density in the ring-porous hardwood. In ring-porous woods, wide rings imply wood of high density. There are, of course, exceptions mostly due to the amount and structure of latewood\(^4\).

Teak (Tectona grandis L. f.) is a ring-porous tropical hardwood known for its strength, durability, and aesthetic qualities. Old growth natural teak has been used primarily for yachts, decking, interior panelling and fine furniture\(^5\). India is considered to be the only known centre for genetic diversity and variability of teak, having its natural distribution zone confined predominantly to peninsular region below 24° N latitude\(^6\).

Several studies reported contradictory findings with regard to the relationship between growth rate in terms of ring width and wood density in teak from tropical regions\(^7\,\,8\). The moist deciduous forest of Thane is well known for natural-grown teak in Maharashtra state of peninsular India. No detailed studies have been reported so far from this location on old growth natural teak of different age-group. Hence, the present study was undertaken to investigate the relationship between the radial variations of growth ring features (ring width and latewood content) and basic density in juvenile and mature wood of 120-to154-year-old teak trees.
Material and Methods

The present study was carried out in the Institute of Wood Science and Technology, Bangalore. Wood samples were collected from different trees of various age-groups from natural teak forest of Thane, Maharashtra. Sampling details are given below.

Sampling: Five cross-sectional discs, one from each individual, of different age-groups, were collected from the left over stumps (20-30 cm above ground level) located at natural-grown teak trees (coded T1 to T5) at Shirshad forest range of Thane, Maharashtra (table-1).

Table-1
Details of environmental conditions and characteristics of teak discs sampled for the study

<table>
<thead>
<tr>
<th>Factor</th>
<th>Thane (Location)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude (N)</td>
<td>19° 12’</td>
</tr>
<tr>
<td>Longitude (E)</td>
<td>73° 02’</td>
</tr>
<tr>
<td>Forest Type</td>
<td>Tropical moist deciduous forest</td>
</tr>
<tr>
<td>Mean annual rainfall</td>
<td>2500 mm</td>
</tr>
<tr>
<td>Mean temperature range</td>
<td>24.4-30.2 °C</td>
</tr>
<tr>
<td>Soil Type</td>
<td>Red laterite well drained soil</td>
</tr>
<tr>
<td>Age group (years)</td>
<td>120, 130, 134, 148, 154</td>
</tr>
<tr>
<td>Mean Diameter (cm)</td>
<td>40.4 - 47.7</td>
</tr>
<tr>
<td>Mean Heart wood (%)</td>
<td>85.91</td>
</tr>
</tbody>
</table>

The surfaces of five discs were smoothed using different grades of sand paper to expose the growth rings and prepare the wood for microscopic analysis. The age of trees were determined by counting each annual growth ring in the disc [figure-1(a)]. The age used to demarcate the border between juvenile and mature wood was determined from literature studies. In teak, the age demarcation point between juvenile and mature wood was estimated around 20 years.[13] A long radial strip of 1.5 cm width was cut from each disc including all rings from pith to bark and transported to the laboratory for detail study.

Ring-width, latewood content and basic density: The width of each annual growth ring in the radial strip was measured to the nearest 0.01 mm under a Leica stereo-zoom microscope using LAS live measurement software. The transition from earlywood to latewood is gradual in each growth ring of teak. While determining ring width, latewood width was measured in all the radial strips after making an arbitrary demarcation between earlywood and latewood, by identifying the earlywood with wide vessels, parenchyma and thin-walled fibres and latewood with narrower vessels and more thick-walled fibres [figure-1(b)]. Latewood content (%) was calculated by the formula: (latewood width/growth ring width) × 100.

The radial strips were then cut along tangential plane to separate each growth-ring into smaller blocks for measurement of basic density. Two or more narrow rings were combined in few blocks of the mature wood zone of the strip, where these rings were too small to separate and measure individually. Green volume of the block was determined by the water displacement method. Basic density of the individual block was then calculated as oven dry weight over green volume. The same basic density value was put for each narrow ring equal to the density of individual block with the assumption that the ring width of each narrow ring in the block was more or less same.

Data analysis: Scatter plots with linear regression lines were produced using MS-Excel in order to find out the relationships between growth ring features viz., ring width and latewood content with basic density. The relationships were compared between juvenile and mature wood of trees using t-test to confirm significant differences, if any.

Results and Discussion

Growth ring features and wood density: Table-2 shows the number of rings, the mean growth ring features (ring width and latewood content), mean wood density and standard deviation in juvenile and mature wood of each individual tree. The mean annual ring width of wood in former and latter was 4.03 mm and 1.24. However, variation among individual trees for annual ring width varied greatly and it ranged from 1.75 mm to 7.52 mm (juvenile wood) and 1.02 mm to 1.51 mm (mature wood). The latewood content in juvenile wood was 76.36 % of the annual ring width and it was 59.41 % in mature wood. The mean basic density in juvenile wood was 0.665 g cm⁻³ that ranged between 0.602 g cm⁻³ and 0.702 g cm⁻³. However, the mean basic density in mature wood was 0.613 g cm⁻³ and it varied between 0.562 g cm⁻³ and 0.665 g cm⁻³.

The teak tree bearing number T2 revealed a very high wood density in both type of wood. The wider growth rings of Thane teak showed considerably more latewood than narrow rings, whereas earlywood width remained more or less constant [figure-1(b)]. Bhat has reported a similar result, indicating that juvenile wood of teak is characterized by wide growth rings with high proportion of latewood as compared to mature wood[14]. He also reported the high wood density in juvenile wood in comparison to mature wood among slow growing teak trees in Kerala.

Radial variation of ring width, latewood content and wood density: Radial variations for ring width, latewood content and basic density among five studied individuals (T1-T5) are illustrated in Figure-2. Ring width of all five studied trees showed roughly a similar radial trend [figure-2(c)]. Ring width increased or fluctuated initially up to 20 years from pith and then it decreased up to 59 years. Finally, it remained more or less constant towards the periphery. This clearly indicating the fluctuation of growth rate in juvenile period of tree growth and then decreased. In some cases, it became constant after maturation of the cambium. This pattern was observed in almost all individuals, and it indicated that the trait may be controlled.
The initial 4 progress reports may come through Chairman and Member Secretary R.A.C. The rest can come through Head of Division and Supervisor concerned. The RAC shall consider the progress reports and forward the same with recommendations and comments, if any, to the Registrar, Otherwise the progress report will not be counted.

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ii. The attendance in case of internal Research Scholar is less than 75% in any term.

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14. The research scholar should normally submit the thesis within 5 calendar years from the date of registration. Further extension of the term on yearly basis is possible only on specific recommendation of R.A.C., if approved by the R.D.C. However no extension is possible beyond 7 years of registration. The recommendation of Research Advisory Committee for extension of term of registration should reach this office before expiry of term of registration.

15. Further the performance of the Research Scholar shall be evaluated at the end by the R.A.C. concerned in the pre-thesis submission seminar and R.A.C. shall send the minutes to Registrar, F.R.I. UNIVERSITY with full comments.

16. Please ensure that the clause 7 of the Ph.D. Ordinance is fully complied with before submission of the thesis to University.

17. Please note that your Registration as Research Scholar is governed as per rules, regulation and ordinances of F.R.I. University, with applicable amendments made by the University from time to time. For all further correspondence please quote your registration number.

(T.C. Nautiyal)
Registrar
F.R.I. University

Encl: 1. Fee receipt No.6154 dated 21.7.2008 for Rs.16,000/-
2. Format of progress report

Copy to:
1. Dr. R.V. Rao, Scientist-F & Head, Wood Properties and Uses Div., IWST, 18th Cross, P.O. Malleswaram, Bangalore for information and necessary action.
2. Dr. T.S. Rathore, Scientist-F, Institute of Wood Science & Technology, 18th Cross, P.O. Malleswaram, Bangalore for information and necessary action.
3. Dr. H.P. Borgaonkar, Scientist-D, Climatology and Hydrometeorology Div., IITM, Pune – 411008.
4. The Nodal Officer, FRIU, Institute of Wood Science & Technology, P.O. Malleswaram, Bangalore for information and necessary action.

(T.C. Nautiyal)
Registrar
F.R.I. University
by inherent. In several studies, teak showed a rapid initial growth, slowing down after 15 or 20-25 years, which corresponds to the juvenile period. Decreasing trend of growth is rapid from 25 to 30 years and then it is slower towards 60 years.

Latewood content in growth ring of all five trees also showed roughly a similar radial trend like ring width. High proportion of latewood was found in wider rings and it was least in narrow rings. Bhat has reported that the mean latewood proportion in 7, 13, 20, 40 and 147 years teak trees were 92, 90, 48, 44 and 70 percent of the mean ring width respectively.

Radial variations of basic density for the five individual trees studied are illustrated in figure-2(a). In tree T1, basic density declined slightly in first few rings from pith and then increased towards middle growth sheaths and finally decreased towards periphery. In tree T2, basic density decreased rapidly up to 30 years and then increased up to 60 years, thereafter, it remained more or less constant and finally, it decreased towards periphery. In trees T3, T4 and T5, the basic density increased up to 10 years and then slightly decreased towards middle and finally, it remained more or less constant towards the periphery with a slight decrease in few outer rings.

Relationship between ring width and basic density: Association of radial variations in mean ring width and basic density of five individuals (T1-T5) with cambial age from pith is illustrated in figure-4. Generally, mean ring width and basic density values gradually decreased up to 59 years and finally, it remained more or less constant towards the periphery with a slight decrease in few outer rings. Correlation coefficients between ring width and basic density of five individual trees and their mean values in juvenile and mature wood are shown in figure-3. It is clear from scatter plots that there was no significant correlation between ring width and basic density in juvenile wood of trees bearing no. T1, T3, T4 and T5 except T2. However, the mean value of all trees show a significant positive correlation at 1% and 0.1% level in juvenile wood; while a significant positive correlation was found at 0.1% level in mature wood of all sampled trees except T5 and it was non-significant.

### Table-2

<table>
<thead>
<tr>
<th>Tree No.</th>
<th>Type of Wood</th>
<th>No. of rings (N)</th>
<th>Ring-width (mm)</th>
<th>Latewood content (%)</th>
<th>Basic density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Juvenile</td>
<td>20</td>
<td>3.41 ± 0.88</td>
<td>78.67 ± 7.41</td>
<td>0.602 ± 0.031</td>
</tr>
<tr>
<td></td>
<td>Mature</td>
<td>134</td>
<td>1.02 ± 0.68</td>
<td>58.59 ± 13.61</td>
<td>0.562 ± 0.070</td>
</tr>
<tr>
<td>T2</td>
<td>Juvenile</td>
<td>20</td>
<td>1.75 ± 1.20</td>
<td>71.01 ± 9.14</td>
<td>0.702 ± 0.055</td>
</tr>
<tr>
<td></td>
<td>Mature</td>
<td>128</td>
<td>1.14 ± 0.82</td>
<td>59.16 ± 16.13</td>
<td>0.665 ± 0.061</td>
</tr>
<tr>
<td>T3</td>
<td>Juvenile</td>
<td>20</td>
<td>7.52 ± 2.06</td>
<td>71.96 ± 7.80</td>
<td>0.693 ± 0.018</td>
</tr>
<tr>
<td></td>
<td>Mature</td>
<td>114</td>
<td>1.50 ± 1.23</td>
<td>56.17 ± 14.99</td>
<td>0.624 ± 0.054</td>
</tr>
<tr>
<td>T4</td>
<td>Juvenile</td>
<td>20</td>
<td>3.99 ± 1.32</td>
<td>81.29 ± 6.54</td>
<td>0.685 ± 0.023</td>
</tr>
<tr>
<td></td>
<td>Mature</td>
<td>110</td>
<td>1.05 ± 0.76</td>
<td>58.65 ± 14.65</td>
<td>0.595 ± 0.065</td>
</tr>
<tr>
<td>T5</td>
<td>Juvenile</td>
<td>20</td>
<td>3.48 ± 1.34</td>
<td>78.89 ± 5.59</td>
<td>0.645 ± 0.029</td>
</tr>
<tr>
<td></td>
<td>Mature</td>
<td>100</td>
<td>1.51 ± 0.91</td>
<td>64.46 ± 11.95</td>
<td>0.620 ± 0.065</td>
</tr>
</tbody>
</table>

(a) Macroscopic picture of a polished *Tectona grandis* wood cross-section showing distinct annual growth rings; the black arrow indicates the boundary between juvenile and mature wood (b) Microscopic photograph showing gradual transition from earlywood (EW) to latewood (LW) within an annual growth ring; white arrows indicate the arbitrary demarcation between EW and LW; black arrow indicates the direction of growth.
Figure 2
Radial variation of (a) basic density (b) latewood proportion and (c) ring-width in juvenile (JW) and mature wood (MW) of five teak trees
**Figure-3**

Scatter plots illustrating the relationships between growth-ring features (ring-width, latewood content) and basic density in juvenile and mature wood of teak trees (T1-T5) and their mean value.
The effect of growth rate in terms of ring width on wood density has been subjected to many investigations and much controversy. For instance, Bhat and Indira reported significant positive correlation between ring width and basic density\(^7\), while many authors found non-significant or negative correlation between these traits\(^8\)-\(^11\).

**Relationship between latewood content and basic density:** Association of radial variations in mean latewood proportion and basic density of five individuals (T1-T5) with cambial age from pith are illustrated in figure-5. The relationship between latewood proportion and basic density was similar to that of trend recorded between ring width and basic density. Correlation coefficients between latewood proportion and basic density of five individuals and their mean values in juvenile and mature wood are shown in figure-3. It is clear from scatter plots that there was no significant correlation between latewood proportion and basic density in juvenile wood of trees bearing no. T1, T4, T5. However, this relationship was significant at 0.1% and 5% in T2 and T3, respectively. Interestingly, a significant positive correlation was found in mature wood of all sampled trees, except T5, which show non-significant relationship. This result is supported by Zobel and van Buijtenen, where latewood proportion with fewer vessels increases as ring width increases and vice-versa\(^3\). However, this influences the variation in basic density of both juvenile and mature wood of a ring-porous hardwood.
Based on the results of the present study, it was observed that the basic density of five individuals showed non-significant relationship with ring width and latewood content in juvenile wood. However, the relationship was significantly positive in mature wood of most of the studied individuals. The mean ring width value of all studied trees showed a strong relationship with basic density in both juvenile and mature wood. However, mean latewood content showed a non-significant or weak relationship.

Conclusion

The mean ring width, latewood content and basic density values are found more in juvenile wood than mature wood of all teak trees. The patterns of radial variation of ring width, latewood content and basic density are more inherent in the juvenile wood than mature wood resulting from cambial ageing. This study shows that there is no relationship between growth ring features and basic density in juvenile wood, while a strong relationship is found in mature wood of most of individual trees within the site. It is important to consider individual tree variation while breeding for high wood density rather than mean variation of all the trees of a site.

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References

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ABSTRACTS

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