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Original Article

Teak Physico-Chemical Profiles: A Study of Five Vidarbha Divisions

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Abstract

India is one of the megadiverse countries. Teak is a botanical marvel of India, one of the iconic species of the country, which has proven its durability, resilience, and elegance over thousands of years. In India, teak wood has been supplied by state forest departments, state forest corporations, and private teak producers.

This study investigates the potential physicochemical characteristics of Tectona grandis (Teak) from the Vidarbha region of India to support further research and potential applications. The study focuses on teak plantations across five divisions, Nagpur, Bhandara, Gondia, Yawatmal, and Chandrapur in Vidarbha, analysing various physical and chemical properties. These include morphology, growth patterns, moisture content (GMC), green density, basic density, shrinkage percentage, thermal conductivity, specific heat capacity elemental carbon, ash content, and temperature.

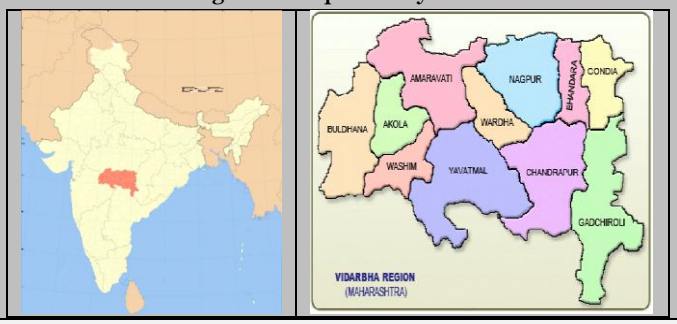
Keywords: *Tectona grandis, morphology, growth patterns, moisture content (GMC), green density, basic density, shrinkage percentage*

Introduction

India's megadiverse status, encompassing 8% of global biodiversity, is reflected in its vast area of 328.73 million ha, making it the seventh largest country. About one-fifth of India's geographical area is covered with forests, and approximately 45,000 plant species exist in India. The commercially important tree Tectona grandis (Teak) is classified within the Lamiaceae family and is a major species used in tree plantations, which is naturally distributed in India. (K.Palanisami et.el (2009)). India possesses the world's most extensive collection of teak genetic resources. In India, Tectona grandis forests are widely distributed in Maharashtra, Madhya Pradesh, Tamil Nadu, and Karnataka. Kerala, Uttar Pradesh, Gujarat, Orissa, and Rajasthan. (India State Forest Report 2023) Studying the physical characteristics of Teak requires various mensuration techniques, requisite a core aspect of forestry that deals with the determination of dimensions, form, age, and increment of single trees, stands, or whole woods, or logs. (Durgesh K Tripathi, et al. (2017)). Though Tectona grandis plantations are spread throughout the Vidarbha region but data is very scanty, and little is known about the characteristics of Teak of the Vidarbha region. Hence, it is important to elucidate the physicochemical characteristics of this species. Highlighting the importance of tree mensuration, during this study, physical and chemical properties were studied by using various mensuration techniques.

Study Area

Figure 1. Map of study area.



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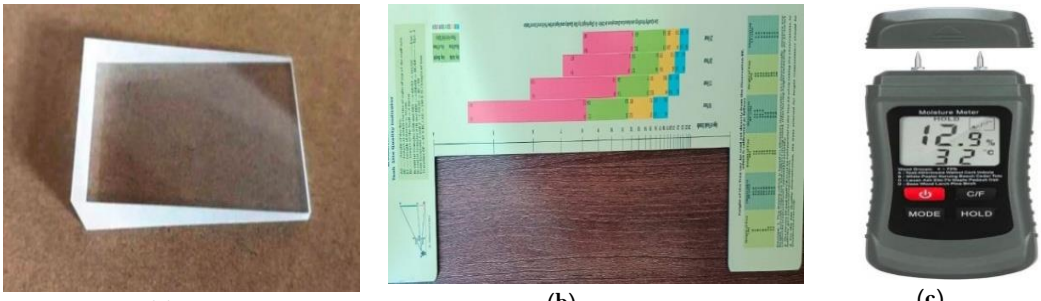
Teak is widely spread over the Vidarbha region; accordingly, five representative divisions are selected for examination, wherein teak plantations are distributed, namely Nagpur, Bhandara, Gondia, Yawatmal, and Chandrapur.

Materials and Methods

In this study, various *Tectona grandis* plantation areas of five divisions of Vidarbha region, i.e., Nagpur, Bhandara, Gondia, Yawatmal, and Chandrapur, were examined, and various properties of this species were studied. To ensure the objective of the present study, a detailed literature survey has been completed to address these challenges, and the implementation of established protocols is vital for achieving reliable and consistent results, free from any personal bias. Key measurements, such as morphology, Height Class, Girth Class, Diameter at Breast Height (DBH) and Green Moisture Content (GMC), are studied by laying representative sample plots. With the 5 m long graduated measuring tape, DBH, is measured, height and girth class are measured using the wedge prism and Christens Hypsometer. Green Moisture Content (GMC) is measured with the help of KERRO-KT-10 moisture meter (Figure 2. a, b, c)



(a) (b) (c)

Figure 2. (a) Wedge Prism, (b) Hypsometer and (c) Moisture Meter used for the study.

Laying of sample plots:

The areas that are representative of that division are identified, and the boundaries of plantations are vindicated. When there is a large plantation then it is divided into different sections. There is a substantial difference between the rate of growth of *Teak* . at different sites selected in this study, so the area is studied from stock maps of that particular plantation. 20 X 20 meters representative sample plots are laid. Site qualities are determined with the help of the top height by site quality and age table of Maharashtra Forest Records No.III, Silviculture Manual.

Enumeration survey:

After laying the representative sample plots, 100% enumeration of the trees in the sample plots is carried out during the enumeration of physical characteristics, morphology, DBH, Height Class, and Girth Class of Teak is studied. The enumeration is done as follows: (Figure 3)

1. The enumeration is followed in a successive narrow strips, with each strip being observed once and in the opposite direction to the previous strip.
2. Visible, shallow blazes are used to mark trees, facilitating the identification of completed survey areas. By placing the blazes on the side of the trees that face away from the remaining survey, researchers can easily determine the extent of the previous survey work during ongoing surveying. Serial numbers are given on the blaze by pencil.
3. Morphology, DBH, Height Class, and Girth Class of each tree are studied and calculated.
4. The Wedge Prism of a suitable Basal Area Factor (BAF) is to be used to measure the Existing Average Basal Area per hectare in each sample plot.
5. After the computation of the volume of growing stock with the help of measurements taken from the sample plot by using the quarter girth formula. *(Maharashtra Forest Records No.III, Silviculture Manual.2022)*

Figure 3. Representative Sample Plot

Determination of Physical Properties of Teak

Morphology

Morphological characteristics, i.e., leaf characteristics of leaf and crown, as well as fruits and seed pattern, crown surface area, are studied for morphological determination. (Figure 4. (a), (b), (c), (d), (Table 1).

Diameter Breast Height (DBH) Measurement

Breast Height is marked using a measuring tape on standing trees at 1.37 m (4 ft 6 in) above the ground level, and measurements of diameter (girth) are taken as per standard rules for different types of trees such as straight tree, leaning tree, forked tree, and buttress formed tree by using 5 m long graduated measuring tape with hook. *(A.N Chaturvedi et.el (2013)*

Volume measurement by quarter girth formula

$V = (G/4^2) \times L$.

Volume of a tree

G, in this case, is the girth of a tree

L- Tree length/height

Measurement of Height

The height of trees is measured with the help of a Christens Hypsometer.

Green Moisture Content (GMC),

Green moisture content is measured with the moisture meter.

(a) **(b)**

(c) **(d)**

Figure 4. (a) Leaf, (b) Fruits, (c) Crown, and (d) Seeds of *Teak* .

Determination of Chemical Properties

For the determination of chemical properties of teak, samples were taken from the teak plantation, specifically collecting twenty samples from each of five divisions. Trees were chosen based on specific criteria that they had to be free from defects, straight boles, and good vigor. Trees that were dead, dying, or diseased were excluded. The logs from these selected trees were then processed using a band saw in a live sawing pattern to produce pieces with a set thickness. Finally, these pieces were re-sawn into timber measuring 20mm x 100mm x 200mm. The following properties are determined.

Green Density

Freshly cut (green) teak wood is selected, and then the mass and volume of the wood sample are calculated in grams. The green density is then calculated using the following formula.

Green Density = Mass / Volume.

Basic Density

To calculate the basic density of teak wood, the green volume of the wood and dry weight after the sample is oven dried at 103 °C is measured. The basic density is then calculated by using the following formula.

Basic Density = Dry Weight / Green Volume

Shrinkage Percentage

Teak wood shrinkage is calculated by measuring the change in dimensions of a wood sample before and after drying and then dividing that change by the original dimension. Shrinkage percentage is calculated by using the following formula.

Shrinkage (%) = ((Initial Dimension - Dried Dimension) / Initial Dimension) * 100

Growth Pattern

The growth pattern, including heartwood formation and radial growth, is assessed by analysing tree rings and their characteristics.

Thermal Conductivity (k):

The thermal conductivity is determined by the steady-state heat flow method.

Thermal conductivity (k) is calculated using Fourier's law: $k = (Q*L) / (A*\Delta T)$

Where Q is the heat flow rate, L is the sample thickness, A is the cross-sectional area, and ΔT is the temperature difference.

Specific Heat Capacity (Cp):

Specific heat capacity is determined using a differential scanning calorimeter (DSC).

Elemental carbon,

To calculate the elemental carbon content of teak wood, the dry weight of the teak wood is determined and then multiply that weight by 0.5 (or 50%).

Ash content percentage,

To determine the ash content of teak wood, the initial weight of the sample wood is taken, and then a sample is heated at 500-800°C in a muffle furnace until ash formation. The ash content is calculated as follows.

Ash content (%) = [(Weight of ash) / (Initial weight of wood sample)] * 100

Temperature,

The temperature of teak wood is measured by using a digital thermometer.

Results and discussions

Physical Properties:

Girth Class

After enumeration of different sample plots in the above five divisions, the height class and girth class were calculated/determined. With the help of the height and girth of the tree, the volume of the tree is calculated by using the quarter girth formula, and accordingly average volume is calculated for each plantation site. In Teak, the minimum girth of trees is 18-25 cm, and the maximum girth is observed 262 cm. The maximum species found in all five divisions is between 64 cm to 79 cm, and 94-109 cm girth classes. From the above girth class, it is observed that the crop/ plantation has having uneven age group of trees, and most of the trees of middle age. (Figure 5)

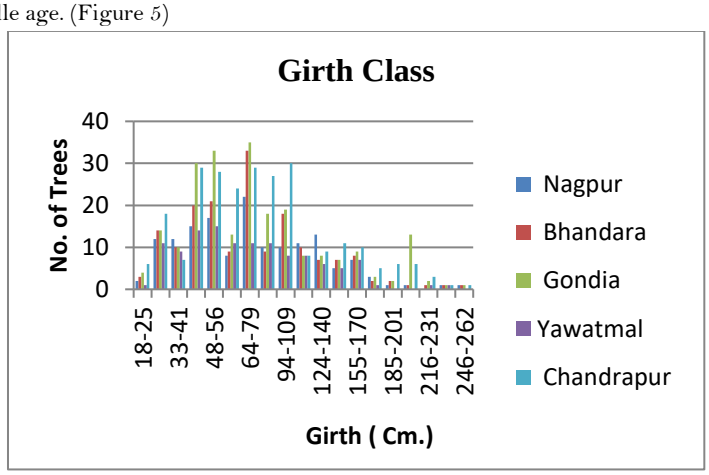


Figure 5. Girth class of Teak, at the selected region for this study.

Height Class

Height class ranges between 3.4 meters to 33.5 meters. After studying the height class, it is observed that the Gondia division has the maximum number of tall Teak compared to the Yawatmal and Nagpur divisions. Minimum height attained by Teak, in Yawatmal division is 3.4-9.1 meters, and maximum height is found in Gondia division is 27.4-33.5 meters. Average Age of plantations calculated by knowing height and girth class, plantation year, plantation history, and with the help of local volume table, and the average age of trees found in Nagpur Division is 30 years, Bhandara Division 45 years, Gondia Division 50 years, Yawatmal Division 40 years, and Chandrapur Division 55 years. Different height and girth classes observed in different divisions are due to different environmental and topographical conditions such as soil, climate, and intensity of light. (Figure 8).

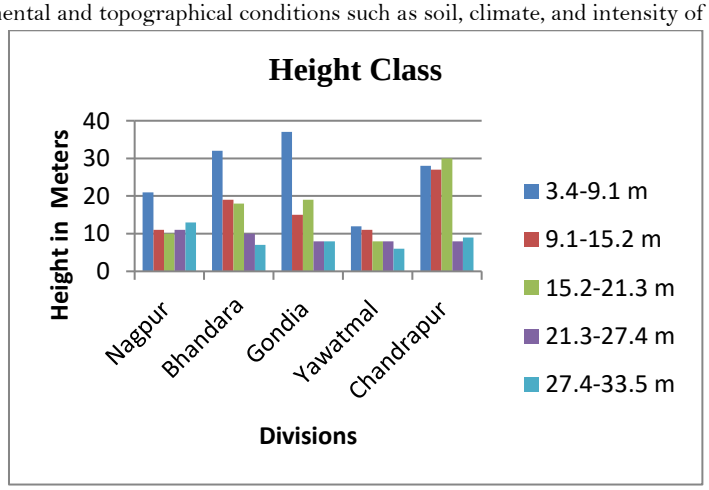


Figure 6. Height class of Teak, at the selected region for this study

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The details of Morphological Characteristics observed in Teak, at the selected region for these studies, are as follows:

Table 1. Morphological characteristics observed in Teak at the selected region.

Name of the Division	Location	Leaf Tip	Leaf Margin	Leaf Surface Texture	Leaf Venation	Flowering	Fruit	Seed	Inner Bark	Outer Bark	Shape of trees	Avg. Height (M)	Avg. Girth(Cm.)	Avg. Age (Years)	Avg. Green Moisture Content% %
Nagpur	21.31700N 79.20000E	Tapered	Flat	Rough	Pinnate	Profuse	Drupe, Globose	Brownish	Whitish	Brown	Tapered	7.95	7.947	30	40
Bhandara	21.07360N 79.82970E	Tapered	Flat	Rough	Pinnate	Profuse	Drupe, Globose	Brownish	Light green	Brown	Tapered	9.32	9.316	45	38
Gondia	20.390N 86.420E	Tapered	Flat	Rough	Pinnate	Profuse	Drupe, Globose	Brownish	Whitish	Brown	Tapered	12.11	12.105	50	36
Yawatmal	20.1170 N 78.11080E	Tapered	Flat	Rough	Pinnate	Profuse	Drupe, Globose	Brownish	Whitish	Brown	Tapered	6.32	6.316	40	39
Chandrapur	20.20950N 79.56030S	Tapered	Flat	Rough	Pinnate	Profuse	Drupe, Globose	Brownish	Whitish	Brown	Tapered	13.58	13.579	55	35

Outer Bark- Outer bark is brown or light brown.

Leaves- leaves are opposite, broadly elliptic to obvate, about 30-70 cm long and 20-40 cm broad, at the base rounded to acute and at apex obtuse to acute, and for petiole is stout and 5-6 cm long. Teak sheds its leaves from November to February and remains leafless for 2-3 months, and the new leaves appear from April to June, according to locality. Flowering Phenology- The Teak observed in the above five divisions generally flowers in trees with an age group of 6 – 40 years, but profuse flowering occurs in the trees that are having age more than 15 years. Flowering phase commences immediately after the new shoots and leaves flushing stage in late May and continues up to August or September, which coincides with the south-west monsoon. Fruit- Fruit is a drupe, globose, 5-20 mm in size, enclosed by an accrescent calyx with a thick shaggy exocarp of matted hairs, epicarp inflated, spongy, and stellate pubescent, endocarp stony, 4 celled seeds1-4, oblong and exalbuminous. The fruit ripens from November to January and fall gradually, some remaining on the trees throughout the hot season. The fruits are yellowish and brownish in color and the number varies from 1150 to 2800 per kg.

Chemical properties

Chemical parameters like green density, basic density, shrinkage percentage, thermal conductivity, specific heat capacity, elemental carbon, ash content, and temperature are calculated by using various methods and formulas. The figure illustrates the chemical characteristics of teak wood from the Nagpur, Bhandara, Gondiya, Yavatmal, and Chandrapur districts. The chemical characteristics, such as green moisture content and basic density, are the main parameters in determining wood quality since they determine the effectiveness in the log hauling and wood drying process. Wood shrinkage percentage calculations are important to study the wood's dimensional stability is an important property that determines how much wood shrinks or swells with changing moisture content, which shows its suitability for various applications They help to study quality standards for teak wood and identify factors influencing its characteristics, such as age, origin (plantation vs. natural), and silvicultural practices. From the study of the above parameters of Teak species in the above five districts, physico-chemically fit, strong and durable and suitable for all operations and viable with a satisfactory growth pattern.

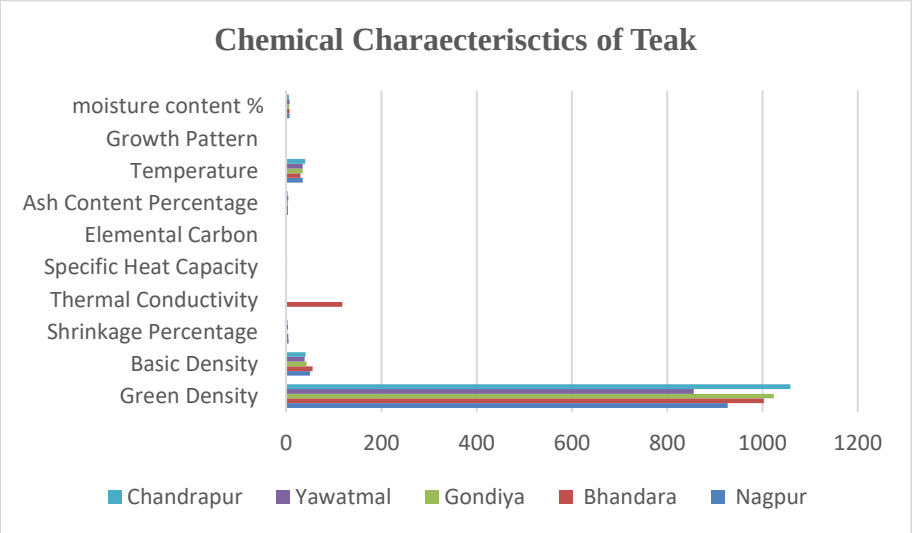

Figure 7. Chemical Characteristics of Teak

Conclusion

In conclusion, the chemical analysis of teak wood reveals a complex composition that contributes to its valuable properties, including natural durability, strength, and aesthetic appeal. Further research into the chemical components of teak wood can lead to a better understanding of its properties and potential applications, and mitigate erosion. They also play a role in land restoration and biodiversity enhancement, while simultaneously providing economic benefits.

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Conflict of interest

None

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