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Analysis of Wood Anatomical Features of Shisham (*Dalbergia sissoo*) from Rajasthan

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Abstract: In this study Shisham (*Dalbergia sissoo*) wood samples were collected from twelve districts of Rajasthan -Baran, Barmer, Bhilwara, Bikaner, Jaipur, Jhalawar, Kota, Nagaur, Rajsamand, Sikar, Sri Ganganagar and Tonk for analyzing anatomical features. The results revealed that the vessel length (0.195 mm), vessel diameter (0.153 mm), fibre length (1.017 mm) and fibre diameter (20.237 µm) in the Shisham wood were significantly highest from Jhalawar district of Rajasthan. Among different locations, the vessel frequency in Shisham wood was highest (7 per mm^2) from Nagaur district of Rajasthan. Among different districts of Rajasthan, wood samples obtained from Jhalawar district showed desirable anatomical properties that may be best suited for the wood industry.

Keywords: Shisham, Fibre length, Fibre diameter, Vessel length, Vessel diameter

Shisham (*Dalbergia sissoo* Roxb. ex DC.) is an important and substantial forest species distributed in tropical and subtropical regions of Africa and Asia. In addition to these regions, it is also found in Java, Nigeria, Mauritius, Sri Lanka, Kenya, northern Zimbabwe, Palestine, and South Africa. This deciduous tree is native to the foothills of the Himalayas, where it mainly grows along canal banks, roadsides, railway lines, and water canals in agricultural fields. The height of the trees ranges from 30 to 80 feet. Shisham is well-known in the international market for its lumber. On average, the heartwood is golden to dark brown and the sapwood is white to brown, which is durable, tough, and resilient. It can be grown in a variety of soils (Orwa et al 2009).

Wood consists of a matrix of fiber walls and air spaces. From the pith to the bark, from the trunk to the top and from the trunk to the branches and roots, its structural properties vary. The tracheids or fiber cells are the primary structural component of wood. There are wide range of sizes and lengths of these cells, from 16 to 42 microns in diameter and 870 to 4000 microns in length. The properties of a wood vary with the distribution patterns of its microstructures, the arrangement of its component cells, and the size and dimension of its components. Anatomically, hardwood consists of vessels, fibers, parenchyma cells, and rays that make up its anatomical structure. Fiber is the main component responsible for the strength of wood (Sinha et al 2019). Ocloo and Laing (2003) observed that these anatomical properties correlate positively with the strength properties of the wood. Fiber length is one of the quality parameters for sawn timber, plywood, pulpwood (Jorge et al 2000, Dhaka et al 2020). Anatomical properties of wood included studies of vessel, ray and axial parenchyma properties and their derived values. The study of wood fiber determines its use in the industries, such as making the pulp and paper, carbonated wood, and bioethanol (Adi et al 2011, Chaudhary et al 2017). The importance of the Shisham can be characterized as being a fast-growing and multi-purpose tree. It can fix nitrogen, is easy to propagate, and offers a high economic return to the stakeholders. It is one of the most demanding tree species in timber industry. This multipurpose tree is economically significant as it is used as a medicinal tree to treat various diseases (Qurashi 2004). Shisham is a money-making tree because farmers earn good economic return by selling wood which is used in the manufacture of furniture, plywood industries, construction, and fuel. It is an inexpensive source of indigenous medicines to treat various ailments (Azaizeh et al 2003). It is perfect for railroad ties, but is rarely used for sleepers due to its usefulness in construction and furniture making. Shisham, like teak and rosewood, is considered one of the best cabinet and furniture wood in India, due to its rich brown color, attractive shape, good grain. The wood properties vary from species to species and according to edaphoclimatic conditions. Therefore, it is important to study wood properties of one species according to the climatic conditions of its place of occurrence. Therefore, present study was undertaken to ascertain the wood properties of wood from different regions of Rajasthan, India.

MATERIAL AND METHODS

The *D. sissoo* (Shisham) wood samples (n=3) were collected from twelve districts (taken as treatments) of Rajasthan Baran, Barmer, Bhilwara, Bikaner, Jaipur, Jhalawar, Kota, Nagaur, Rajsamand, Sikar, Sri Ganganagar and Tonk from tree of similar diameter class. The recorded data were subjected to one way ANOVA for statistical analysis.

D. sissoo logs were converted into different sample sizes according to the test specifications. The samples were properly planed and sanded to maintain smoothness. The size of the specimens prepared for anatomical studies was 20 mm x 20 mm x 20 mm. Wood samples were preserved in 100 ml formalin-acetic acid (FAA) solution consisting of 90 ml 70% ethyl alcohol, 5 ml glacial acetic acid and 5 ml formaldehyde (Johanson 1940). The wood sections were macerated by dipping the wood shavings in Jefferys solution (10% chromic acid and 10% nitric acid) for 48 hours (Pandey et al 1968). The anatomical parameters like vessel parameters (Vessel length, Vessel diameter and number of vessel) and fibre dimensions (fibre length and Fibre diameter) were studied under the microscope.

Vessel parameters (length, diameter and frequency) were measured by macerating the wood in Jefferys solution (10% chromic acid and 10% nitric acid) for 48 hours (Pandey et al 1968). The macerated woods havings were then thoroughly washed, stained with safranine, and roughened with a needle in 10% glycerine before mounting on slides. Straight and complete fibers were selected and measured under a stereomicroscope fitted with a 10X eyepiece. Vessel element length was observed from the macerated wood samples by using ocular and stage micrometer. Vessel element was observed on the macerated wood samples using an eyepiece and a stage micrometer. Vessel frequency was observed under the microscope in transverse sections of the wood. The number of vessels was counted at 10x magnification in a microscopic field. The diameter of the microscopic field was measured using a bench top micrometer, and then the area of the microscopic field was calculated using the formula: $A = \pi r^2$, Where, π=3.143, r=radius of microscopic field standardized with stage micrometer. Fiber length (mm) and diameter (µm) were measured after maceration using Jeffery's method determined by placing the wood chips in Jefferys solution, i.e.10% chromic acid and 10% nitric acid, were soaked (Pandey et al 1968). The shavings were then thoroughly washed, stained with safranine and roughened with a needle in 10% glycerine before mounting on slides. Straight and complete fibers were selected and measured under a trinocular microscope fitted with a 10X eyepiece. The fiber measurements (7-10 readings for each replication) were made in each slide using an ocular micrometer attached to the eyepiece of a microscope at 10X magnification and standardized using a micrometer.

RESULTS AND DISCUSSION

Vessel parameters: Significant variation for vessel length of Shisham wood collected from different districts of Rajasthan were observed (Table 2). Vessel element length of Shisham wood from Jhalawar district was maximum (0.195 mm) followed by wood from Kota (0.186 mm), whereas the minimum (0.162 mm) was in Rajsamand was statistically at par with vessel element length of wood (0.164 mm) from Tonk region. On contrary to the present study, Pandey and Singh (2005) observed that variation in anatomical features such as vessel length, vessel diameter, and wall thickness of wood in a tree in vertical or radial and axial direction and at different locations were not significant in *Shorea robusta*. Similar results were also reported by Sunny (2017) in *D. sissoo.* Vessel diameter showed significant differences in Shisham wood from different districts of Rajasthan (Table 1). The vessel diameter of Shisham wood from Jhalawar district was maximum (0.153 mm) followed by wood from Sikar (0.150 mm), whereas the minimum vessel diameter was observed in wood samples from Bikaner and Barmer districts (0.128 mm). Karimanisha et al (2020) reported a radial variation in vessel diameter from pith to periphery region of *D. sissoo*. As regards vessel frequency, highest number of vessels were in the wood samples of Nagaur which was statistically equivalent to Bhilwara, Jaipur, Rajsamand, Sikar and Sri Ganganagar wood samples. The lowest number of vessels (2 mm^2) was in the wood samples from the Kota area, which was statistically equal to the samples from Barmer (3 mm^2).

Table 1. Geographic location of collected *D. sissoo* (Shisham) wood samples

Location	Latitude	Longitude
Baran	25° 6'4.1220"N	76° 30'47.3796"E
Barmer	25° 45' 11.3580"N	71° 25'5.0160"E
Bhilwara	25° 19' 36.7536"N	74° 36'49.2948"E
Bikaner	28° 1'37.6968"N	73° 18'7.7580"E
Jaipur	26° 55' 19.4520"N	75° 46'43.9860"E
Jhalawar	24° 35' 50.4564"N	76° 9'39.5280"E
Kota	25° 9'46.7928"N	75° 50'43.1592"E
Nagaur	27° 12' 25.2216"N	73° 44'32.2584"E
Rajsamand	25° 4'0.1200"N	73° 52'59.8836"E
Sikar	27°36'55.4616"N	75° 7'33.1860"E
Sri Ganganagar	29°54'13.8204"N	73° 52'37.8840"E
Tonk	26°13'45.7536"N	75° 46'51.4020"E

Variation in fibre dimensions: The significant difference was observed in fiber length of Shisham wood samples collected from different districts of Rajasthan (Table 3). Longest fiber length (1.017 mm) was recorded in samples collected from Jhalawar which was statistically at par with samples from Baran , Bhilwara, Kota, Rajsamand, Sri Ganganagar and Tonk. The shortest fiber length (0.877 mm) was recorded in samples collected from Sikar and Bikaner, which was statistically at par with specimens from Nagaur, Barmer and Jaipur. Sykes et al (2006) observed that fiber length is genetically controlled and not subject to the influence of the environmental fluctuations. Similar results in fiber length variation were reported by Krisdianto and Damayanti (2007) in *Acacia nilotica* and Saravanan et al (2014) and Sinha et al (2019) in *Melia dubia* wood. Mahmood et al (2016) also found the fiber length of 1470 mm in the samples of *A. nilotica* collected from Pakistan. Sunny (2017) reported large fiber length (1.66 mm) of *D. sissoo*. Karimanisha et al (2020) reported the variation in fiber morphology between different radial positions of the *D. sissoo* wood samples. Tavares et al (2011) observed that in *Eucalyptus* globule wood, fiber length decreases from the base to the top of the tree and increases from the pith to the bark. Similar results have been reported by Panda et al (2021) in Teak, Meghwal and Chauhan (2020) in *D. sissoo*.

Among the Shisham wood samples (Table 3), the maximum fiber diameter (20.23 µm) was from Jhalawar, which was statistically at par with samples from Kota and Tonk. Smallest fiber diameter (19.87 µm) was observed in the wood samples from Nagaur district, which was statistically at par with samples from Baran , Barmer , and Bikaner . Fibers are the main elements responsible for the strength of wood. In the present study, variations in fiber length and diameter may be due to genetic (chemical composition, age, elevation, location of trees, *etc*.) and environmental factors (soil composition, mean annual precipitation, seasonality, and temperature). David et al (2009) reported a decrease in fiber diameter in response to decreased water availability. Similarly, Karimanisha et al (2020) observed average fiber diameter of 24.23 µm in *D. sissoo* wood and fiber length and fiber diameter both increases from pith to the periphery. Wani

Table 3. Variation in fibre length (mm) and fibre diameter (µm) of *D. sissoo*

Treatment	Location	Fibre length (mm)	Fibre diameter (µm)
T_1	Baran	0.983	19.960
T_2	Barmer	0.890	19.953
T_3	Bhilwara	0.980	20.027
T_4	Bikaner	0.877	19.950
T_5	Jaipur	0.897	19.990
T_6	Jhalawar	1.017	20.237
T_7	Kota	0.973	20.233
T_8	Nagaur	0.887	19.870
T_9	Rajsamand	0.987	20.007
T_{10}	Sikar	0.877	20.087
T_{11}	Sri Ganganagar	0.977	20.063
T_{12}	Tonk	0.993	20.187
CD (p=0.05)		0.058	0.107
SE		0.028	0.052

Table 2. Variation in vessel length (mm), diameter (mm) & number of vessels per mm^2 of *D. sissoo*

Treatment	Location	Vessel element length (mm)	Vessel element diameter (mm)	Vessel frequency (No. of Vessels per mm^2)
T_1	Baran	0.168	0.131	4
T_2	Barmer	0.170	0.128	3
T_3	Bhilwara	0.178	0.149	6
T_4	Bikaner	0.168	0.128	5
T_5	Jaipur	0.173	0.132	6
T_6	Jhalawar	0.195	0.153	4
T_7	Kota	0.186	0.146	2
T_8	Nagaur	0.167	0.133	7
T_9	Rajsamand	0.162	0.140	6
T_{10}	Sikar	0.169	0.150	6
T_{11}	Sri Ganganagar	0.168	0.137	6
T_{12}	Tonk	0.164	0.145	5
CD (p=0.05)		0.005	0.005	1.376

and Khan (2010) reported significant differences in wood fiber diameter of *Populus nigra* from different locations. Similar results were also reported by Chauhan et al (2022) in Himalayan conifers.

CONCLUSION

The present research was conducted to evaluate the variation in some anatomical properties of Shisham wood from different regions of Rajasthan. Wood samples of *D. sissoo* collected from Jhalawar showed maximum fiber dimensions as compared to the samples from other sites of Rajasthan, which ensures the strength provided by the fibers to the wood. Results showed that the Shisham wood from Jhalawar, Baran and Kota sites has shown better performance as far as wood anatomical characteristics are concerned. The results of the present study may provide some insights for effective utilization of Shisham wood from different locations for different end uses.

AUTHOR CONTRIBUTIONS

Conceptualization, K.U.; Methodology, K.U. and S.C.; Data collection, S.C.; Validation and Formal Analysis, S.C.; Writing and Original Draft Preparation, S.C.; Rewriting, Review and Editing, K.U., A.V. and C.S.; Supervision, K.C. and A.V.

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