Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 6 [9] August 2017: 11-15

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.533
Universal Impact Factor 0.9804

ORIGINAL ARTICLE **OPEN ACCESS**

Variation in physical and mechanical properties of *Pinus roxburghii* Sargent wood from different areas of Himachal Pradesh

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ABSTRACT

The wood of Pinus roxburghii is used in making furniture, packing cases, boxes, building construction, matchboxes etc. In the present studies wood samples of Pinus roxburghii were collected from different locations n Himachal Pradesh. These were evaluated for physical and mechanical properties viz. specific gravity, tensile and compression strength by following standard methods. In total 10 sites were evaluated and five samples were collected from each site which were considered as replicates. Teak wood was taken as a control for comparison.The results revealed highest specific gravity, bending strength and compression parallel to grain (0.5756, 0.0089 KN/mm² and 0.057 KN/mm², respectively) were recorded in Banethi. The maximum tensile strength and compressionperpendicular to grain were observed in Chabbal (0.043 KN/mm²) and Nurpur (0.00180 KN/mm²), respectively. The chir pine from Banethi location performed overall best among the studied sites.
***Keywords**: Pinus roxburghii*, tensile, bending, compressive strength and grain

Received 11.04.2017 Revised 16.06.2017 Accepted 17.07.2017

INTRODUCTION

Pinus roxburghii is one of the most widely used commercial timber species in the hills and northern plains of northern India. The sapwood is white to creamy white [1]. The mechanical properties of wood indicate the ability of wood to resist various types of external forces, static or dynamic. The type of deformation, whether in size or in shape, caused in wood when it is subjected to an external force, depends on such mechanical properties, as modulus of elasticity, ultimate stress, fibre stress at elastic limit, etc which are inherent in wood. The mechanical properties of wood varies with species to species and also with the moisture content, temperature and defects of the woods subjected to the forces [2].

Maximum wood production and their suitability for different uses depends on the crop density and wood properties, respectively. The wood properties vary from species to species, at different site qualities, within species and within individual trees. Specific gravity reflects the strength, load bearing capacity and hardness. It is an important parameter to determine the wood quality, pulp yield and strength of paper [3,4].

The chir pine populations growing in Himachal Pradesh show a good amount of variation. Hence, the chir pine populations under present work have been selected by scientist of HFRI Panthaghati Shimla for DUS characteristics. The present investigation was undertaken with the objective**,** to study the variation in the mechanical properties of wood from the different areas of Himachal Pradesh.

MATERIAL AND METHODS

The present investigation carried out in the Department of Forest Products, College of Forestry, Dr. Yashwant Singh Parmar University of Horticulture and Forestry Nauni, Solan (H.P). The mechanical strength testing and laboratory analysis of the collected samples was carried out in the wood workshop and laboratory of the department and experimental details are given in table 1.

Preparation of samples

The wooden logs were got converted to prepare the following sizes of wood samples for carrying out the different tests. Every care was taken for maintaining the symmetry of the samples. The sizes prepared were:

- **i)** 20mm ×20mm ×20mm (specific gravity of wood).
- **ii)** 300mm ×10mm ×10mm (for Tensile strength).
- **iii)** 300mm ×20mm ×20mm (for Bending strength).
- **iv)** 50mm ×20mm ×20mm (for compression parallel to grain).
- **v)** 50mm ×20mm ×20mm (for compression perpendicular to grain).

Parameter to be observed in the present study:

i) Specific gravity

Specific gravity of the samples was determined by the maximum moisture content method (5). The wood samples were submerged in water till saturation. The weight of the samples at this point was recorded as weight at maximum moisture content level. These samples were then oven dried at 102±1°C until a constant weight was attained. The specific gravity was calculated as per the formula given below:

$$\text{Specific gravity} = \frac{1}{\frac{M_m - M_o}{M_o} + \frac{1}{GS}}$$

Where,

Mm = Weight of the sample having maximum moisture (After submersion of wood samples in water for about 2 days)

Mo = Oven dried constant weight of the sample

GS = Average density of wood substance, a constant, having value 1.53

ii) Compression strength parallel to grain (KN/mm²)

This test was done in the direction along or parallel to grain. The standard size of specimens for this compression test was 50mm×10mm×10 mm. These samples were tested for compression on (UTN-10). In this case also a proper care was taken such that each specimen faced similar type of test measures.

iii) Compression strength perpendicular to grain (KN/mm²)

The size of the specimens taken was 50mm×10mm×10mm across or perpendicular to the direction of grain and the data were recorded after subjecting to compression test on Universal Testing Machine (model: UTN-10). Every care was taken such that each specimen faced similar type of test measures.

iv) Bending strength (KN/mm²)

The standard size of the specimen taken was 300mm × 20mm × 20mm. These specimens were dried to almost similar moisture content at 102±1°C and tested for bending strength on Universal Testing Machine (model: UTN-10). Every care was taken such that each specimen faced similar type of test measures.

v) Tensile strength (KN/mm²)

The standard size of the specimens for conducting this test was 300mm×10mm×10mm. The properly dried samples having almost similar moisture content were tested as per the procedure followed for testing on Universal Testing Machine (UTN-10). The computer generated data and graph was obtained to derive the values of maximum load, maximum displacement and breaking pattern for all the samples. Proper care was taken such that each specimen faced similar type of test measures.

RESULTS AND DISCUSSION

The results of present study has been described under the following sub heads:

Specific gravity of wood

There is significant variation in specific gravity of wood samples of *Pinus roxburghii* populations as shown in table 2. The highest specific gravity of 0.6127 was recorded in control (Teak). Among chir pine populations, the highestspecific gravity of 0.5756 was recorded in Banethi, which wasstatistically at par with Nurpur (0.5602) and Chabbal (0.5552). The lowest specific gravity (0.5277) was recorded in Ghanahatti which was statistically at par with Nihari (0.5296) and Swarghat (0.5370).

Specific gravity is the parameter which determines the strength of wood. It shows the level of compactness and also the porosity of wood. Extractives are located mainly in the cell lumen. So they fill vacant spaces in the wood and thus decrease the porosity and thereby increase the specific gravity. Similar findings by Cox et al. [6] in *Shorea acuminata, S. ovalis,* S, *leprosula and Dryobalanops aromatica*. Significant variation in specific gravity of wood among different sites of *Pinus roxburghii* and has also been reported by Nimkar and Sharma [7]. The variation in specific gravity of wood has also been reported by Wittman et al. [8] in *Hevea spruceana* and *Tabebuia barbata,* Verma et al. [9] in hybrids of *Eucalyptus citriodora* and *E. torelliana* and Dhillon and Sidhu [10] in poplars.

Tensile strength (KN/mm²)

A critical analysis of the data on tensile strength presented in table 2 showed significant variation in wood samples of *Pinus roxburghii* populations. The maximum tensile strength was noticed in Teak (0.089kN/mm²) and among chir pine populations it was maximum in Chabbal (0.043 KN/mm²) which was statistically at par with Nurpur (0.037 KN/mm²) and Ghanahatti (0.036 KN/mm²). The minimum tensile strength was observed in Malan (0.022 KN/mm²) which was statistically at par with Swarghat (0.023 KN/mm²) and Sarahan (0.025KN/mm²).

Tensile strength is the ability of any material to resist the stretching forces. Wood when used for construction and other purposes is ought to face these forces. Hence, study of this parameter tells the ability of wood to work under such stresses [11]. Significant variation has been observed in tensile strength among different sites of *Pinus roxburghii*. Similar findings for tensile strength in *Ostrya carpinifolia* wood by Korkut and Guller (12). Awan et al. [13] have studied the tensile strengthand other mechanical properties in *Eucalyptus camaldulensis* and have reported variation. The variation in strength properties of a species is mainly attributed to its genetic parameters. However, variation in wood structure due to growth and presence of defects also affects the strength properties in wood.

Bending Strength (KN/mm²)

The data on bending strength exhibited significant variation in wood samples of *Pinus roxburghii* populations as shown in table 2. The highest bending strength was noticed in Banethi (0.0089KN/mm²) followed by statistically different values for Nurpur (KN/mm²) and Chabbal (0.0064 KN/mm²) populations. The lowest bending strength (0.0033KN/mm²) was observed in Niharisite followed by statistically significant values for Swarghat (0.0055 KN/mm²) and Platu (0.0059 KN/mm²). In standard Teak wood samples, a bending strength value of 0.0070 KN/mm² was observed.

Bending strength of wood reveals its capacity to use as a beam or similar type of situations for other uses [11]. The significant variation is observed in bending strength among different sites of *Pinus roxburghii*. Aleinikovas and Grigaliunas [14] have estimated significant variation in wood of *Pinus sylvestris* in bending strength and have found that distribution of wood properties is related to tree growth rate. Guler et al. [15] reported that the mechanical properties of black pine (*Pinus nigra)* juvenile wood has been observed to be lesser as compared to black pine mature wood and the bending strength of pine juvenile wood were measured as 50-85 Nmm^{-2}. Olufemi and Malami [16] have also concluded that *Eucalyptus camaldulensis* has an average density of 977.58 kg/m³ and static bending strength of 133.33 N/mm².

Compressive strength parallel to grain (KN/mm²)

The data on compressive strength parallel to grain showed significant variation in wood samples of *Pinus roxburghii* populations as depicted in table 3. The maximum compressive strength parallel to grain (0.057 KN/mm²) was noticed in Teak and also in Banethi site and the value for minimum compressive strength parallel to grain was noticed in Platu (0.034 KN/mm²).

Wood is an important raw material used for different purposes and may be subjected to compressive forces during its use. Hence, determination of maximum compressive stress bearing ability is an important factor for its end use [11]. Getahun et al. [17] while working on mechanical properties of *Pinus patula* have found direct relationship with basic density. Elzaki and Khider [18] in their studies on *Pinus radiate* have found that average values for compression strength parallel to the grain for Western Sudan pine and Southern Sudan pine as well as for the North American pine expressed maximum crushing stress. This is governed by the average angle of the helical layers in the secondary wall of pine tracheids and the longitudinal orientation of micro fibrils as well as the effect of site and environmental conditions on the anatomical structure and strength properties of wood.

Compressive strength perpendicular to grain (KN/mm²)

The perusal of data, shown in table 3 have revealed significant variation in compressive strength perpendicular to grain in wood samples of *Pinus roxburghii* populations. Teak showed a compressive strength of 0.0194 KN/mm² which was highest as compared to *Pinus roxburghii.* The data for chir pine populations revealed highest compressive strength perpendicular to grain in Nurpur (0.0180 KN/mm²) site and the lowest compressive strength perpendicular to grain (0.0062 KN/mm²) was noticed in Swarghat site. The determination of compressive strength perpendicular to grain is generally required for its use for sports goods. The cellular orientation perpendicular to the grain makes the wood weaker in compression as cell layers in this direction may have variable cell types. Similar findings by Awan et al. [13] for the mechanical properties of farm-grown *Eucalyptus camaldulensis* in comparison to conventional timbers i.e. *Dalbergia sissoo, Acacia nilotica* and *Cedrus deodara.* Aydin and Yardimci [19] in mechanical properties of Four timber species have found that compressive strength parallel to the grain is much greater than that perpendicular to the grain. About 90 per cent of the cells are aligned vertically (known as grain) and the remaining percentage is present in bands (known as rays). This means that there is a different distribution of cells on the 3 principle axes, the main reason for the anisotropy present in timber. This is due to the fact that the resistance of wood perpendicular to the grain is simply a matter of the resistance offered by the wood elements to being crushed or flattened. Therefore, the strength of wood under forces perpendicular to the grain is relatively small [20]. Rosner and Karlsson, [21] have also evaluated compression strength perpendicular to the grain in Norway spruce *(Picea abies* (L.) Karst).

Table 1: Experimental details

S. No.	Sites	District	Longitude	Latitude
i.	Platu	Hamirpur	76^0 30 E	31^0 36 N
ii.	Nihari	Bilaspur	76^0 31 E	30^0 53 N
iii.	Swarghat	Bilaspur	76^0 31 E	30^0 53 N
iv.	Nurpur	Kangra	75^0 53 E	32^0 17 N
v.	Malan	Kangra	76^0 25 E	32^0 06 N
vi.	Ghanahatti	Shimla	77^0 17 E	31^0 10 N
vii.	Banetthi	Sirmour	$76^0$48 E	$30^0$51 N
viii.	Chabbal	Solan	76^0 57 E	30^0 56 N
ix.	Rajgarh	Sirmour	77^0 18 E	30^0 51 N
x.	Sarahan	Sirmour	77^0 11 E	30^0 43 N
xi.	Control (Teak) from market			

Replications = 5
Design = Randomized Block Design (RBD)

Table 2: Variation in Specific gravity, tensile strength and bending strength for wood of *Pinus roxburghii*

Sites	Specific Gravity	Tensile Strength (KN/mm²)	Bending Strength (KN/mm²)
Platu	0.5499	0.031	0.0059
Nihari	0.5296	0.034	0.0033
Swarghat	0.5370	0.023	0.0055
Nurpur	0.5602	0.037	0.0068
Malan	0.5445	0.022	0.0061
Ghanahatti	0.5277	0.036	0.0060
Banethi	0.5756	0.034	0.0089
Chabbal	0.5552	0.043	0.0064
Rajgarh	0.5376	0.032	0.0062
Sarahan	0.5491	0.025	0.0060
Control (Teak)	0.6127	0.089	0.0070
Mean	15.88	0.036	0.0062
SE(d)	1.24	0.0055	0.00062
$CD_{0.05}$	2.52	0.011	0.0012

Table 3: Variation in compressive strength parallel and perpendicular to grain for wood of *Pinus roxburghii*

Sites	Compression parallel to grain (KN/mm²)	Compression Perpendicular to grain (KN/mm²)
Platu	0.034	0.0168
Nihari	0.035	0.0075
Swarghat	0.044	0.0062
Nurpur	0.051	0.0180
Malan	0.041	0.0120
Ghanahatti	0.037	0.0095
Banethi	0.057	0.0179
Chabbal	0.048	0.0109
Rajgarh	0.051	0.0106
Sarahan	0.046	0.0179
Control (Teak)	0.057	0.0194
Mean	0.045	0.0133
SE(d)	0.006	0.0039
$CD_{0.05}$	0.013	0.0079

CONCLUSION

In Himachal Pradesh, *Pinus roxburghii* Sargent, is distributed in Shimla, Kunihar, Solan, Rajgarh, Chopal, Nahan, Dalhousie, Bilaspur, Hamirpur, Palampur, Dharamshala and Nurpur divisions covering an area of 1.36 lac hectares. Out of these divisions, 10 sites were selected which shows the good amount of variations. From the present study, it was concluded that different physicaland mechanical properties viz. specific gravity, bending strength. Tensile strength, compression parallel and perpendicular to grain were varied from 0.5277 to 0.5756, 0.0033 to 0.0089 KN/mm^2, 0.022 to 0.043 KN/mm^2, 0.034 to 0.057 KN/mm^2, 0.0062 to 0.0180 KN/mm^2, respectively among selected chir pine populations. Physical and mechanical properties of Chabbal, Nurpur and Banethi sites was recorded maximum, so it is recommended that chir pine wood of respective sites are suitable raw material for making pulp in India for paper manufactures. The timber obtained from these sites is also used for furniture, packing cases, boxes, building construction, matchboxes etc.

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CITATION OF THIS ARTICLE

V Kumar, K R Sharma and Jujhar Singh. Variation in physical and mechanical properties of *Pinus roxburghii* Sargent wood from different areas of Himachal Pradesh. Bull. Env. Pharmacol. Life Sci., Vol 6 [9] August 2017: 11-15