PRELIMINARY STUDY ON WOOD PROPERTIES OF PAULOWNIA SPECIES GROWN IN PESHAWAR

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Abstract

Anatomical, physical and mechanical properties of 3 species of (*Paulownia fortunei, P.elongata* and *P.tomentosa*) wood grown at Pakistan Forest Institute, Peshawar were studied under standard laboratory procedures. In all the studied species, vessels were found larger in size, the fibres were thin walled and wide lumened and frequency and size of wood rays was somewhat higher. The wood of all the three species could behave better in seasoning and preservation, chemical treatment may be necessary to enhance the durability of wood and can be used for pulp and paper due to favourable fiber morphological characteristics. On the basis of physical and mechanical properties, the wood is suitable for various purposes where high strength is not required. It has favourable relation between tangential and radial shrinkage and is suitable for framework where the stability is of high importance. The wood can also be used for making various kinds of boxes, cases, cupboards, tables, crates, handicrafts, rural house construction, posts and poles etc.

Introduction

Paulownia is one of the fast growing species. It has a wide range of distribution in China and can be found up to and around 2,400 m elevation. It is extremely fast growing species (Anon., 1986) and can adapt to a wide range of temperatures and humidity conditions.

Paulownia wood is considered as the light wood in China with acceptable physical and mechanical properties. Co-efficient of shrinkage is very small and hardness is low, hardly subject to split or crack and easily worked (Zhu Zhoa-hua,1987). In China it is widely used in furniture, plywood, paper pulp, agriculture implements, sculpture, handicrafts, house construction, musical instruments, sail plane and model air plane etc. (Anon, 1986, Zhu Zhoa-Hua, 1987).

In Pakistan different species of paulownia were introduced and growing well at the Silvicultural Research Garden of the Pakistan Forest Institute, Peshawar. At the same age, *P.fortunei* has shown the best growth (12.1 m height and 26.3 cm diameter) followed by *P.elongata* (11 m height and 23.7 cm diameter) and *P.tomentosa* (9.9 m height and 23.2 cm diameter) (Haq, 1999). However, these have not been tested for their

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wood properties. This study was carried out to collect data on the anatomical, physical and mechanical properties of some paulownia species grown at the Pakistan Forest Institute (PFI), Peshawar to provide technical information and to assess their suitability for different end uses.

Materials and Methods

Two, 8 years old trees of *Paulownia fortunei, P.elongata* and *P.tomentosa* having a diameter of 25-30 cm were logged in the PFI Research Garden. To study the anatomical properties, the wood samples were removed at breast height from the butt log of each species. Permanent slides of cross, radial and tangential sections of each species were prepared by standard laboratory procedure (Anon., 1971) and studied under the microscope for the occurrence, arrangement, shape, frequency, and size of different wood elements/structures. Small pieces of wood from each species were macerated in a mixture of 10% nitric acid and potassium chlorate for fibre length measurement. Observations were taken for the following microscopic features.

- Number of early and latewood vessels per mm^2
- Diameter of early and latewood vessels
- Number of rays per mm in cross section
- Number of rays in tangential section /mm^2
- Height and width of rays in cells and in microns
- Length, diameter and wall thickness of fibres

For physical and mechanical properties, the samples were prepared according to standards (ISO.1975, BSI.1957, ASTM.1954) as fallow:

Property	Size of test sample
- Shrinkage	3 × 2 × 2cm
- Density	6 × 2 × 2cm
- Static bending	30 × 2 × 2cm
- Impact bending	30 × 2 × 2cm
- Max. compression parallel to grain	6 × 2 × 2cm
- Tensile strength Per-pendicular to grain	7 × 2 × 2cm
- Cleavage	4.5 × 2 × 2cm
- Hardness	10 × 2 × 2cm

Mechanical tests were performed on Amsler Universal Wood Testing Machine. The data collected for anatomical, physical and mechanical properties were analyzed for average values, standard deviation and co-efficient of variation and given in tables 1-3.

Results and Discussion

Anatomical Properties

Gross features of wood:

The wood *Paulownia* species studied is pale yellow to pale red in colour. It is light and soft, odourless, streight grained, fine to rather coarse textured and lustrous after planning. The wood is semi-ring porous to ring porous as the size of vessels gradually decreases outwards but they do not form a clear early wood stripe in the beginning of the growth ring.

Microscopic structure

The occurrence, arrangement and shape of different wood elements/structures in *Paulownia fortunei, P.elongata* and *P.tomentosa* were observed almost similar however, variations in their frequency and size were different.

Vessels

The vessels were rounded to oval shaped in out line, solitary or in radial rows of 2-3, or in irregular clusters, sometimes paired tangentially, with simple perforation filled with tylosis, mostly in earlywood vessels. In *P.fortunei* earlywood vessels were found 136μ-252μ in diameter and 4-8/mm^2 in number whereas, the latewood vessels 19μ-106μ in size and 2-9/mm^2 in number. In *P.elongata* earlywood vessels were 274μ-422μ in size and 2-5/mm^2 in number, whereas the latewood vessels 48.5μ-184μ in diameter and 2-7/mm^2 in number. In *P.tomentosa* earlywood vessels were found 160-349μ in diameter and 2-5/mm^2 in number, whereas the latewood vessels 53μ-150μ in size and 2-8/mm^2 in number.

Wood Parenchyma

Paratracheal parenchyma was observed forming wing-like structure around the vessels or in broad bands joining the vessels tangentially and was mostly clear in latewood portion.

Wood Rays

The rays were multiseriate, with a few uniseriation, generally straight in cross section tending to bow due to larger size of earlywood vessels, mostly homogeneous and rarely heterogenous. In *P.fortunei* the rays were found up to 6 cells and 19μ-97μ in

Table 1. Frequency and dimensional measurements of different wood elements/structures in *P.fortunei, P.elongata* and *P.tomentosa*

Microscopic feature	Unit	*P.fortunei*			*P.elongata*			*P.tomentosa*		
		AV	S.D±	C.V%	AV	S.D±	C.V%	AV	S.D±	C.V%
No. of earlywood vessels	/mm²	6	1.07	17.60	4	1.06	29.18	4	1.12	30.43
No. of latewood vessels	/mm²	5	1.69	33.66	5	1.24	26.10	5	1.32	25.43
Diameter of earlywood vessels	μ	202	32.59	16.13	307	54.70	17.84	284	52.76	18.56
Diameter of latewood vessels	μ	66	24.22	36.52	115	40.06	34.82	102	28.22	27.70
No. of rays in cross section	/mm	4	–	–	4	–	–	4	–	–
No. of rays in tang. section	/mm²	18	1.86	10.42	16	2.22	13.56	14	1.78	12.85
Height of ray	cells	17	7.58	43.43	14	9.02	64.42	10	5.21	51.33
	μ	231	95.17	41.12	253	119.31	47.19	266	109.90	41.34
Width of ray	cells	4	0.98	25.15	3	1.13	40.35	3	0.814	27.59
	μ	55	20.27	36.79	33	12.16	36.49	32	9.05	28.07
Fibre length	mm	1.04	0.25	24.30	1.03	0.19	19.32	0.959	0.26	27.94
Fibre diameter	μ	33	9.16	27.77	35	6.50	18.51	39	6.01	15.37
Fibre wall thickness	μ	3.69	1.23	33.33	2.75	0.57	21.01	4.05	1.04	25.67
Fibre lumen width	μ	26	–	–	30	–	–	31	–	–

Table 2. Physical and mechanical properties of paulownia species (**in green condition**)

Properties	*Paulownia tomentosa*			*Paulownia fortunei*			*Paulownia elongata*		
	$\bar{X}$	S.D	C.V%	$\bar{X}$	S.D	C.V%	$\bar{X}$	S.D	C.V%
Basic density	257	10.0	3.9	325	12.0	3.7	275	20.0	7.3
Volumetric shrinkage (%)	5.69	–	–	4.87	–	–	5.81	–	–
Modulus of rupture (kg/sq.cm)	358	21.5	6.0	456	51.0	11.2	473	75.1	15.9
Mod. of elasticity (kg/sq.cm)	23439	4928	21.0	33771	5822	17.2	27341	5080	18.6
Max. comp. 11 to grain (kg/sq.cm)	131	13.2	10.1	162	21.5	13.3	141	15.3	10.9
Max. comp. 11 to grain at E.L (kg/sq.cm)	72	11.2	15.6	110	11.7	10.6	91	11.8	13.0
Tensile strength 1 to grain (kg/sq.cm)	19	3.1	16.3	21	1.3	6.2	20	2.5	12.5
Cleavage (kg/cm)	16	1.6	10.0	18	1.5	8.3	17	1.7	10.0
Impact bending (m-kg/4sq.cm)	1.52	0.4	26.3	2.1	0.3	14.3	2.0	0.6	30.0
Hardness side (kg)	116	7.6	6.6	198	13.7	6.9	156	6.8	4.4
end	171	14.4	8.4	253	27.0	10.7	183	10.4	5.7

Table 3. Physical and mechanical properties of paulownia species (**in air-dry condition**)

Properties	*Paulownia tomentosa*			*Paulownia fortunei*			*Paulownia elongata*		
	$\bar{X}$	S.D	C.V%	$\bar{X}$	S.D	C.V%	$\bar{X}$	S.D	C.V%
Density (kg/m^3)	337	19.0	5.6	391	23	5.9	330	15	4.6
Modulus of rupture (kg/sq.cm)	555	45.3	8.2	623	47.4	7.6	572	52.5	9.18
Mod. of elasticity (kg/sq.cm)	45003	5433	12.1	49178	6490	13.2	45359	3557	7.8
Max. comp. 11 to grain (kg/sq.cm)	238	32.1	13.5	282	27.8	9.9	235	22.3	9.5
Max. comp. 11 to grain at E.L (kg/sq.cm)	158	21.4	13.5	191	18.9	9.9	143	23.5	16.4
Tensile strength 1 to grain (kg/sq.cm)	21	3.0	14.3	23	2.15	9.3	20	2.09	10.5
Cleavage (kg/cm)	16	1.2	7.5	17	2.7	15.9	16	1.46	9.1
Impact bending (m-kg/4sq.cm)	0.55	0.1	18.2	1.40	0.1	7.14	1.46	0.13	8.9
Hardness side (kg)	141	21.4	15.2	205	19.0	9.3	175	15.3	8.7
end	237	15.8	6.7	333	31.8	9.5	180	19.4	10.8

width, 6-32 cells, 78μ-398μ in height and 14-21/mm^2 in number in tangential section. In *P.elongata* rays were 1-5 cells, 10μ-56μ in width and 2-33 cells, 78μ-533μ in height and 11-20/mm^2 in number. In *P.tomentosa* 1-4 cells, 15μ-51μ in width and 2-23 cells, 97μ-504μ in height and 10-17/mm^2 in number.

Fibres

The fibres were thin-walled and wide lumened, and mostly septate. In *P.fortunei* fibres were 0.468mm-1.5mm long, 19μ-48.5μ in diameter and the walls were 1.78μ-5.1μ thick. In *P.elongata* 0.57mm-1.35mm long, 18.4-48.5μ in diameter and with a wall thickness of 2.04μ -4.33μ. In *P.tomentosa* the fibres were 0.41mm-1.40mm long, 27.16μ-58.2μ in diameter and the walls were 2.04μ-5.1μ thick.

On comparison of average values given in Table 1, maximum frequency of vessels (5-6/mm^2) was found in *P.fortunei* whereas, the largest diameter of vessels (307μ) was observed in *P.elongata* followed by *P.tomentosa* and *P.fortunei*.

Frequency of rays in tangential section was maximum in *P.fortunei* followed by *P.elongata* and *P.tomentosa*. Height of ray in cells was found maximum in *P.fortunei* followed by *P. elongata* and *P.tomentosa* whereas, in microns it was found maximum in *P.tomentosa* followed by *P.elongata* and *P.fortunei*. However, the width of ray both in cells and in microns was observed maximum in *P.fortunei*.

The longest fibres were found in *P.fortunei* followed by *P.elongata* and

P.tomentosa. Whereas, the maximum fibre diameter and lumen width were observed in *P.tomentosa* followed by *P.elongata* and *P.fortunei* and the most thin-walled fibres were observed in *P.elongata*.

Physical and Mechanical properties

Physical Properties

The moisture content of freshly felled wood was determined. *Paulownia tomentosa, P.fortunei* and *P.elongata* were found to have 221%, 209% and 134% moisture content respectively. The density (air dry) of these species was determined as 330-391 kg/m^3. Basic density (ratio of oven dry weight to green volume) was calculated as 257-325 kg/m^3. *P.elongata* was the lightest with an air-dry density of 330 kg/m^3.

The shrinkage data from green to oven dry condition of *Paulownia tomentosa, P.fortunei* and *P.elongata* were 3.58%, 3.30%, 3.86% (tangential) and 1.95%, 1.48%, 1.80% (radial) respectively. Volumetric shrinkage (longitudinal shrinkage negligible) of the species from green to oven dry, has been given in the Table 2.

Mechanical Properties

Paulownia fortunei was found of better density therefore, its strength values were found higher than the other studied species. Maximum compression parallel to grain, tensile strength perpendicular to grain, side hardness and end hardness values in *P.fortunei* were higher than *P.tomentosa* and *P.elongata*. However, the average values of strength values of *P.tomentosa* and *P.elongata* were found comparable. The results of mechanical properties of the three species (both in green and air dry condition) can be seen in Table 2 and 3.

Conclusions

The wood of *Paulownia fortunei, P.elongata* and *P.tomentosa* grown in Peshawar can be classified as very light. Paulownia wood is better in strength to weight ratio when compared with the wood of same density class and can be seasoned and preserved without difficulty. In order to increase the durability of paulownia wood, chemical treatment may be necessary. The wood can be used for making cases, cupboards, boxes, crates, posts and poles and handi-crafts. Due to less volumetric shrinkage it is suitable for frame work. It can also be used for pulp and paper manufacturing due to favourable fiber morphological characteristics.

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