COMPARISON OF WOOD ANATOMY OF DIFFERENT PAULOWNIA SPECIES GROWN IN PAKISTAN

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ABSTRACT

Imperative analysis of ring growth rate, heartwood percentage and anatomical properties of locally grown species *Paulownia catalpifolia, Paulownia elongata*, *Paulownia fortunei* and *Paulownia tomentosa* was carried out in order to observe the extent of variations. Discs were cut off from the butt log of each species at breast height and data were collected for the growth rate and heartwood percentage. To observe variations in anatomical properties, the sample blocks were removed from the disc of each species and permanent slides of cross, radial and tangential sections were prepared and examined under the microscope. Data were collected for ring growth rate, heartwood and sapwood percentage along with different dimensions of fiber, vessel and wood rays of each species. Results showed that maximum average ring growth rate was found in *Paulownia catalpifolia* and the highest heartwood percentage was observed in *Paulownia tomentosa.* Maximum fiber length and fiber diameter was measured in *P. catalpifolia* and the lowest in *Paulownia fortunei.* Greatest fiber wall thickness was determined in *P. tomentosa* while the lowest in *P. fortunei.* The largest diameter of earlywood vessel was observed in *P. elongata* and that of latewood vessel in *P. catalpifolia.* The highest frequency of earlywood vessel per unit area was found in *P. tomentosa* and that of latewood vessel in *P. fortunei.* Maximum ray height at tangential side was measured in *P. catalpifolia* whereas the ray width was found in *P. tomentosa.* The highest frequency of wood rays at tangential side was observed in *P. fortunei* whereas *at* cross side it was found in *P. tomentosa.*

INTRODUCTION

Pakistan has insufficient and declined forest resources due to deforestation, growth in population and increase in demand of wood resources to meet the requirements. It is therefore necessary to introduce new wood species in the market that may be used as substitute of the commercial wood species to fulfill the wood requirements. This will be helpful to reduce pressure on the commercially important timber species and forests as well.

Paulownia is a deciduous tree of the family Paulowniaceae (www.wikipedia.org/Paulownia). It is a genus of about 20 native species in China and South-East Asia cultivated since as early as 1000 BC. The species *Paulownia tomentosa* once occurred in North America, and is now considered an introduced species (Smiley, 1961). Paulownia is also called princess tree, royal Paulownia or empress tree (Carpenter & Smith, 1979).

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Paulownia species is extremely fast growing species and can be harvested in the age of 15 years for valuable timber (James *et al*, 2000). The tree species can be characterized by a fast development and a uniform and regular growth (Caparros *et al*., 2008).

The bark of the tree is brownish gray with shallow fissures (Jeff Stringer, 2009)**.**The wood is soft, lightweight, straight grained with a satiny luster and mostly knot free, which greatly reduces wastage (Kalaycıoglu, Deniz & Hiziroglu, 2005; www.ipaulownia.co.uk).

Paulownia wood is low in strength and thus not suitable for using as building components that require high strength. However, products made from Paulownia wood do not easily warp, crack and deform and is highly rot resistant**.** Due to good sound conduction, the sound musical instruments are made of *Paulownia*. The wood is easy to plane, saw or carve with low dulling effects and very easy to drive nails. It is good in absorption of glue and dyes and it has a beautiful colour and no odour. Silvery-grey wood used veneers for special visiting cards (Bergmann (1998); www.ipaulownia.co.uk, Anon 1986). In China the wood is widely used in furniture, plywood, paper pulp, agriculture equipment, sculpture, handicrafts, house construction, sail plane and model air plane etc. (Zhu Zhoa-hua, 1987, James Flynn, Charles 2001, Rai, P.; Solanki, Singh, 2000).

In Pakistan different species of *Paulownia* have also been introduced and are growing well. Among the species *P. fortunei* has shown the best growth (Haq, 1999).

The wood is pale yellow to pale in colour, 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 growth ring (G.M Nasir and Iqbal Mahmood, 2000).

The proposed study was carried out with the objective to observe the extent of variation in ring growth rate, heartwood percentage and anatomical properties of the wood of locally grown different *Paulownia* species to provide the technical information and to evaluate suitability of some *Paulownia* species for various end uses.

MATERIAL AND METHODS

To conduct the research work, wood material of *P. tomentosa*, *P. elongata*, *P. catalpifolia* and *P. fortunei* were collected from the Research Garden at PFI in 2016 in the form of discs at breast height from the butt log of each species. Observations were taken for the average ring width, ring growth

rate and heartwood percentage in each species. For the preparation of permanent slides of cross and tangential sections, a strip of full radial length was cut off from the disc of each species and sample blocks of about 13mm cube in size were prepared for sectioning.

Small portion of wood from the each species was macerated in Schulze's mixture (20% Nitric Acid and Potassium chlorate) to separate the fibers and observe fiber length (Anon. 1971). Data were collected for the following macro and microscopic features in each species and analyzed for statistical variables:

S. No.	Parameters
1	Ring growth rate
2	Annual rings width
3	Percentage of heart wood
4	Percentage of sapwood
5	Fiber length (µ)
6	Fiber diameter (µ)
7	Fiber wall thickness(µ)
8	Vessel diameter(µ)
9	Vessel frequency per unit area
10	Ray length and width (in microns and cells)
11	Ray frequency in tang and transverse sections

RESULTS AND DISCUSSION

From the results shown in figure 1, ring growth rate was found over all very high in almost all of the four studied species of *Paulownia*. By mean value *P. catalpifolia* was found with maximum annual ring growth of 16.875mm followed by *P. fortunei* with 16.5mm, *P. elongata* with 10.111mm and *P. tomentosa* with lowest average ring growth of 6.65mm.

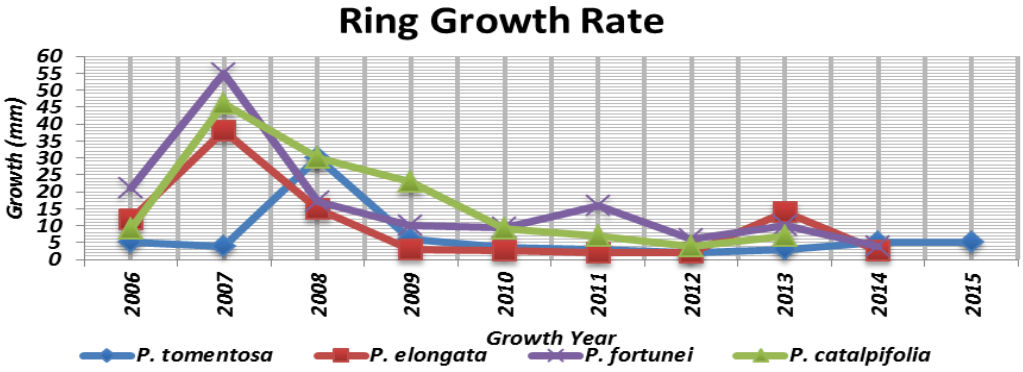

Fig 1. Comparative analysis of ring growth rate in Paulownia species

The *heartwood percentage* was observed with highest ratio of 91.79% of total wood in *P. tomentosa* followed by *P. catalpifolia* 83.01%, *P. fortunei* 80.47% and *P. elongata* observed with 70.61%. Results are shown in fig. 2.

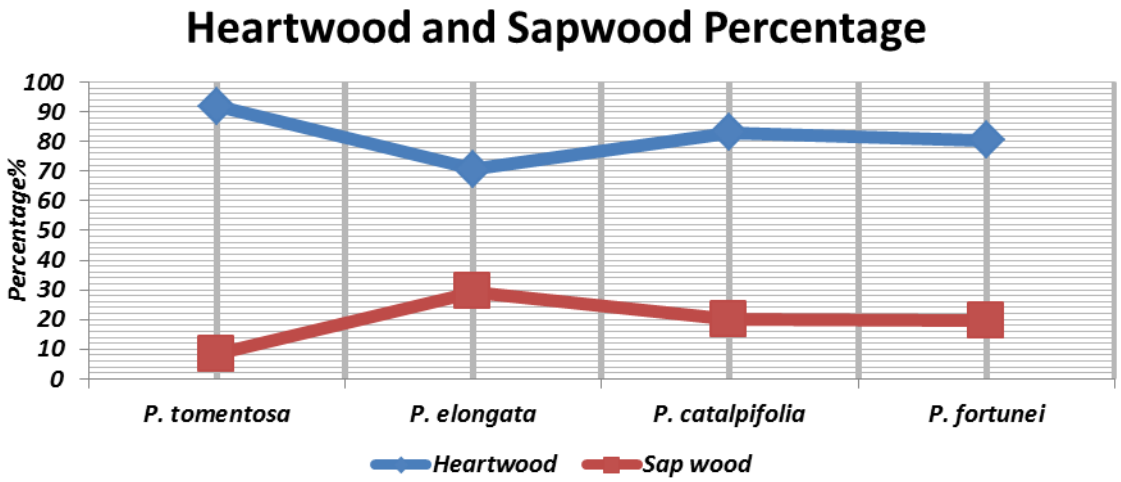

Fig.2 Comparative analysis of heartwood & sapwood percentage in Paulownia species

COMPARISON OF MICROSCOPIC STRUCTURE

Basic wood anatomy of different Paulownia species is almost similar however, the frequency and dimensional measurements of different wood elements/structures is different in different species.

Results given in the following table show that in Paulownia species, the ***Fibers*** were mostly thin-walled, wide lumened and septate. *P. catalpifolia* was found with longest fibers with average length 1269.6µ followed by *P. tomentosa* (1214µ), *P. elongata* (1068.11µ) and *P. fortunei* (825.76µ). *P. catalpifolia* was observed with wider fibers with 39.41µ diameter followed by *P. tomentosa* (37.20µ), *P. elongata* (35.96µ) and *P. fortunei* (33.97µ) in diameter. In *P. tomentosa* the fibers were found comparatively thick-walled (3.96µ) followed by *P. elongata* (3.37µ), *P. catalpifolia (*3.24µ) and *P. fortunei* (2.94µ). *P. catalpifolia* was found with maximum average lumen width of 32.93µ followed by *P. tomentosa* (29.28 µ), *P. elongata* (29.22 µ) and *P. fortunei* (28.09µ).

The *Vessels* were observed as round to oval shape in outline, solitary in radial rows of 2-3, or in irregular clusters, sometimes paired tangentially. Earlywood vessels were observed as filled with the tyloses. Average values of earlywood vessel diameter revealed that *P. elongata* have larger vessel diameter

of 232.24µ followed by *P. catalpifolia* (221.81µ), *P. fortunei* (208.31µ) and *P. tomentosa* (201.84µ). Whereas larger latewood vessel diameter was found in *P. catalpifolia* with an average diameter (104.9 µ) followed by *P. fortunei* (97.83µ), *P. elongata* (86.80 µ) and *P. tomentosa* (77.77µ). Maximum average frequency of earlywood vessels (12.3/mm²) was found in *P. tomentosa* followed by *P. fortunei* (10.64/mm²), *P. elongata* (9.26/mm²) and *P. catalpifolia* (6.80/mm²). Maximum frequency of latewood vessels (8.73/mm²) was found in *P. fortunei* followed by *P. tomentosa* (8.68/mm²), *P. elongata* (7.00/mm²) and *P. catalpifolia* (5.71/mm²).

The *Wood rays* were found multiseriate, with a few *uniseriation, generally straight in cross section* tending to bow due to larger size of early wood vessels, mostly homogenous and rarely heterogeneous. Maximum average ray length (290.07µ) in tangential section was observed in *P. catalpifolia* followed by *P. elongata* (247.03µ), *P. tomentosa* (247.3 µ) and *P. fortunei* (193.72 µ) while in number of cells maximum length of ray (13.33 cells) was found in *P. catalpifolia* followed by *P. elongata* (12.70 cells), *P. tomentosa* (12 cells) and *P. fortunei* (10.68 cells). Maximum average ray width (39.02 µ) was found in *P. tomentosa* followed by *P. elongata* (37.11 µ), *P. fortunei* (34.79 µ) and *P. catalpifolia* (30.37µ) while maximum width of ray by cells (3.82 cells) was found in *P. fortunei* followed by *P. elongate* (3.66 cells), *P. catalpifolia* (3.11 cells) and *P. tomentosa* (3.1 cells). Maximum ray frequency at tangential side (25.62/mm²) was found in *P. fortunei* followed by *P. elongata* (22.84/mm²), *P. catalpifolia* (17.66/mm²) and *P. tomentosa* (17.22mm²). However, in cross section, maximum frequency was found in *P. tomentosa* (4.90/mm²) followed by *P. elongata (2.87/mm²), P. fortunei (2.82/mm²) and P. catalpifolia (2.66/mm²).*

CONCLUSION

- Based on the results it can be concluded that *P. catalpifolia* is comparatively fast growing and may be planted extensively for wood resource production.

- *P. tomentosa* wood is relatively more durable i.e. resistant to borer, termites and fungus attack and qualitative than the other studied species due to low frequency of wood rays and higher percentage of heartwood portion.

- *P. catalpifolia, P. tomentosa and P. elongata* wood are comparatively better in strength properties due to longer or thick-walled fibers than *P. fortunei*.

- *P. elongata* and *P. tomentosa* are relatively easy to season and preserve due to larger diameter or higher frequency of vessels.

Table 1. Frequency and dimensional measurement of various wood elements/ structures in some low value timbers grown in AJK (average values)

Microscopic features	Unit	Kao *(Olea cuspidata)*	Lasura *(Cordia myxa)*	Shreen *(Albizzia lebbek)*	Anjir *(Ficus palmata)*	Dhak *(Butea frondosa)*	Tun *(Cedrela toona)*	Ritha *(Sapindus mukrossi)*
Vessel diameter	Microns	70.82	171.20	168.22	108.03	205.88	E.W 160.53	E.W 177.26
							L.W 109.28	L.W 49.34
Vessel frequency	/mm^2	75.56	4.18	3.15	9.15	8.9	E.W 7.98	E.W 7.60
							L.W 5.38	L.W 3.46
Ray frequency in tangential section	/mm^2	48.24	4.45	16.80	17.92	3.58	19.73	30.63
Ray frequency in cross section	/mm	10.28	3.29	4.00	6.03	4.00	4.33	5.47
Ray width	Cells	1.75	4.6	2.56	3.43	7	3.16	3.00
	Microns	25.16	111.30	30.15	49.95	165.1	74.69	31.87
Ray height	Cells	8.67	19.2	19.05	46.32	25.32	11.27	13.27
	Microns	177.99	548.08	200.54	574.62	626.6	343.13	175.81
Fiber length	mm	0.859	1.81	1.08	0.92	1.405	1.08	1.09
Fiber diameter	Microns	19.96	22.29	22.69	18.78	23.71	24.31	19.80
Fiber wall thickness	Microns	2.56	4.87	3.72	2.69	3.13	3.73	3.39
Fiber lumen width	Microns	14.84	12.55	15.25	13.4	17.45	16.85	13.02

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