WOOD QUALITY EVALUATION FOR RATIONALE UTILIZATION OF PAULOWNIA WOOD SPECIES GROWN IN PESHAWAR

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ABSTRACT

Evaluation of various wood species for their physico-mechanical properties and further recommendations for rationale utilization of studied wood species on the bases of strength (physico-mechanical) properties was accomplished in this research study. ASTM international standards of wood testing were followed for physico-mechanical tests, i.e. Density, MoR, MoE, cleavage, tensile, compression parallel to grains, compression perpendicular to grains, End hardness and Side hardness. Results revealed that *Papular deltiodes* has low-very low strength wood species with moderate hardness; *Papular euphratica* were a high-density species having high elasticity, low bending and compression, with medium hardness; *Eucalyptus citridora* was hard with medium to very high strength properties, *Eucalyptus camaldulensis* was high in both density and compression strength, low and very low in bending and elasticity respectively having medium hardness. *Paulownia catalpifolia* and *Paulownia fortunei* both were low in strength. Furthermore, *Eucalyptus citridora was* the highest density among the studied wood species. *Eucalyptus citridora* wood was in the highest strength as per results. It may be used for furniture, bearing blocks, bowls, beams, columns, posts & struts, flooring, paving blocks, rollers, sleepers, wedges, wheelwrights work, and bolted timbers joints, nailed timbers, notched timber, mallets and others. *Eucalyptus camaldulensis* may be used in bearing blocks, bolted timbers, carving, furniture, patterns, pencil, paving blocks, rollers, sheaves, shuttles, wedges, etc. *Popular euphratica* may be used for bearing blocks, bolted timber, carving, columns and poles, posts, furniture, mallets, nailed timber, panelling, wedges and others. *Papular deltoides* may be used for bowls, carving, mallets, panelling, patterns, pencil, shuttles, toys work, matchsticks etc. *Paulownia catalpifolia* and *Paulownia fortunei* have very low strength and may be used in toys, matchsticks, articles and woodworking, where low strength properties are required.

Keywords: Physicomechanical properties, Modulus of rupture (MoR), Modulus of Elasticity (MoE)

INTRODUCTION

Poplar wood is mainly used in the pulp and paper industry as fiber and composite wood product, i.e. orientated fiber board, sheet veneer wood, and constructive composite engineered wood. (Balatinecz and Kretschmann, 2001). Specific gravity is an essential factor for deciding the choice of wood, due to most

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of the mechanical properties of wood are nearly related to specific gravity. (Haygreen & Bowyer, 1996). *Paulownia* is a very adaptable and rapidly growing hardwood tree species compared to most conventional and softwood tree plant species. If it grows in an artificial plantation, it may be a harvest for the wood purpose at the age of 04 – 07 years. As a comparison, this tree plant took 60–80 years to attain maturity level. The mean annual diameter increments of *P. elongata* could be 03– 04 cm at breast height (DBH), with a max. of 08 – 09 cm in a few years with an annual mean growth of wood volumes of about 0.05 – 0.06 m^3. The hardwood tree has a significantly extinct increment rate than that of *Paulownia elongata*. For instance; annual increment of beech (*Fagus grandifolia* Ehrh) of pole average around 1.8 - 2.3 mm in undisturbed 2^{nd} growth stands to 3.8 – 4.8 mm in tree release by partial cutting diameter at DBH of a 10-year tree can be measured approximately 30 – 40 cm and its volumes about of 0.3 – 0.5 m^3. Each paulownia woody species could reach a growth of cubic meters of timber at the age of 05 – 07 years; can develop intense plantation at approximately 2000 tree / hac (Akyildiz and Kol, 2010).

Fast-growing tree species are planted all over the globe to meet the growth supply (high yield) for pulp fiber, paper and wood products (Espinoza, 2004). An important factor in using poplars is to understand the changes in the characteristics of the wood in the stem. For illustration, the density of pulped and machined wood and the shrinkage of machined. This leads to finer chemical optimizations; for example, high density wood is essential for chemical pulp production, while medium density wood is most appropriate for plywood production (Udoakpan, 2013).The United States is currently the world's largest producer and importer of timber products. However, like most manufacturing in the United States, the wood products industry is also affected by low-cost producers in other countries and steadily loses its import base. From 1995 to 2005, imports of wood products increased by 60% (McRoberts *et al.,* 2005).

Poplar (*Populus deltoides*) is a widely planted agroforestry tree in India and Pakistan. Its industrial and household wood can be purchased from Chahim and Kashmir, Himalayas, Punjab, Haryana, Uttarakhand and Uttar Pradesh whereas in Pakistan it can be purchased from Khyber Pakhtunkhwa (KPK) and Punjab. After eucalyptus, poplar is the main source of wood raw materials in plantations. Research organizations in India have been studying its utilization. They have obtained a large amount of data, from strength characteristics to flavouring characteristics, anti-corrosion, ammonia fumigation, wood processing and finishing quality, as well as peeling characteristics and panel product manufacturing. These species are the main source of raw materials for industries and household fuelwood (Kothiyal, 2012). In Pakistan no study was conducted in the past to evaluate and compare the properties and its subsequent rationale utilization of the exotic fast growing wood species with special emphasis on Paulownia species. The study aimed to demonstrate the potential of some

important tree species of Paulownia growing in Peshawar valley in terms of wood quality. The specific objectives were: 1) to quantify the comparison of various wood species with Paulownia for their physicomechanical properties and 2) to rationale utilization of the studied wood species based on their strength properties.

MATERIAL AND METHODS

Study area

This research has been conducted in the Pakistan Forest Institute, Peshawar (PFI). It is situated in the arid geographic region of Khyber Pakhtunkhwa. Six (06) tree species samples have been collected for their analysis as non-commercial timbers from PFI research Area.

Location and climate of Peshawar district

Peshawar district is geographically situated in Khyber Pakhtunkhwa. It has been surrounded by Charsadda city in the north, Nowshera city in the east. Mohmand in the south and Khyber agencies in the west of Peshawar. The climatic conditions in Peshawar range from mild in winter too severe in summer. Summer rain is brought by the southwest monsoon and covers the eastern part of Peshawar valley. Rainfall occurs in two different crop growing seasons: Rabe (Winter, December, March) and Kharif (Summer, June, September). The main rainfall ranges from 1100 mm in the province's northwest to as low as 100 mm in the south.

Targeted Species

The PFI research garden Peshawar collected ten defect-free logs of targeted tree species. Details have been provided in the following Table 1.

Table 1. Target Wood Species and their Coordinates

S.No.	Targeted wood species		
	Common name	Botanical name	Coordinates in decimal degree
1	Papular	*Papular euphratica*	34.020422° 71.486411°
2	Papular	*Papular deltoides*	34.016766° 71.487490°
3	Eucalyptus	*Eucalyptus citridora*	34.018980° 71.489156°
4	Eucalyptus	*Eucalyptus camaldulensis*	34.019878° 71.489342°
5	Paulownia	*Paulownia catapifolia*	34.018867° 71.485513°
6	Paulownia	*Paulownia fortunei*	34.019163° 71.484804°

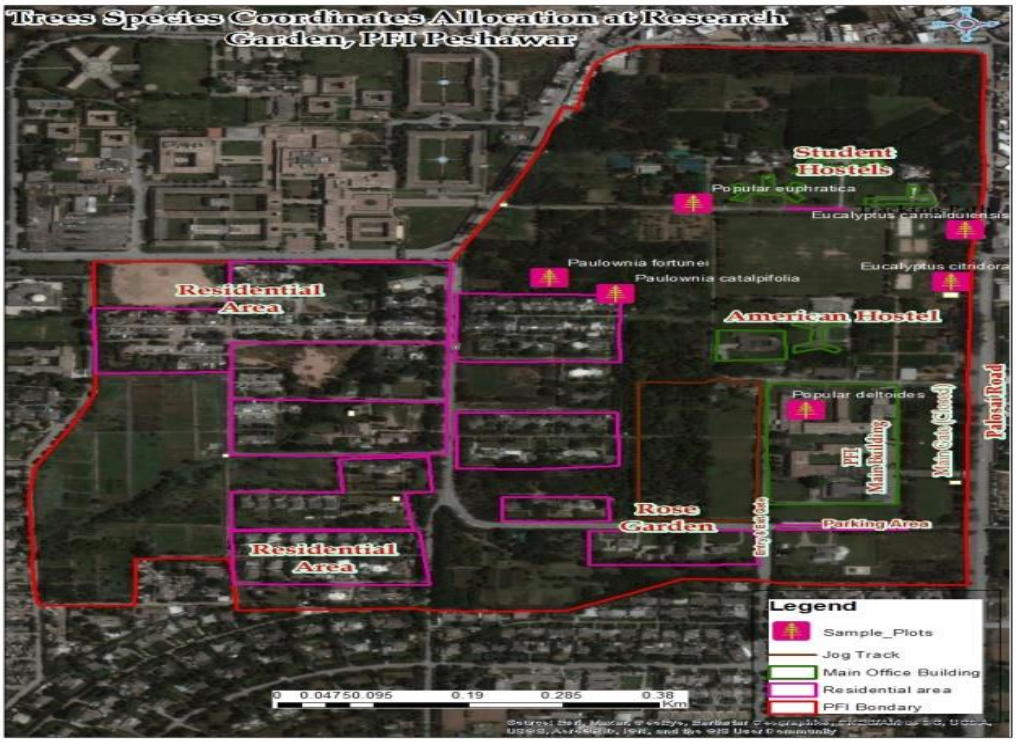

Fig. 1. Coordinates of research tree species

Sampling and conditioning

Ten defect-free logs were being collected from the Pakistan Forest Institute research garden. Wherein half of the research material was converted into planks of 2.5 cm thickness, and reaming were stacked in seasoning kiln to attain moisture content equilibrium. Further, wood material was utilized and selected for physico-mechanical tests to determine its various properties. The air-dried samples were being conditioned at a prevalent temperature of the atmosphere and observed at relative humidity, ranging from 62-68%. The samples were allowed to attain moisture content at a level of 12 ± 2%. After conditioning, the test pieces were stored in the controlled condition in wood testing laboratories of the forest products research division (FPRD) at PFI, Peshawar.

Physicomechanical property

For the determining of mechanical property, ISO was being followed for each mechanical test specimen, and test samples were being prepared:

S. No.	Wood property	Specimen size
1.	Density	6 cm x 2 cm x 2 cm
2.	MoR and MoE	30 cm x 2 cm x 2 cm
3.	Compression parallel to grain	6 cm x 2 cm x 2 cm
4.	Compression perpendicular to grain	30 cm x 2 cm x 2 cm
5.	Tensile	7 cm x 2 cm x 2 cm
6.	Cleavage	4.5 cm x 2 cm x 2 cm
7.	Hardness End	10 m x 2 cm x 2 cm
8.	Hardness Side	10 cm x 2 cm x 2 cm

All the tests were performed on a Wood Testing Machine, i.e. Amsler, at a 400 - 4,000 kg total loading capacity. It has been ensured that specimens are used defect-free to find out accurate strength properties of wood throughout the study.

Statistical analysis

One way analysis of variance (ANOVA) was used to determine the physicomechanical properties of target species. These statistical analyses were conducted using SPSS statistics version 25 (IBM USA). While graphs were processed in Microsoft Excel 2007.

Table 2. Mean value of Co-efficient of variation (CoV) for each wood property

Wood property	Co-efficient of variation (CoV) %
Number of growth rings in 1 cm	37
Percentage of latewood	28
Density	10
Equilibrium moisture content	5
Co-efficient of shrinkage (linear)	28
Co-efficient of shrinkage (volumetric)	16
Ultimate compressive strength parallel to the grain	13
Ultimate strength in static bending	15
Ultimate shearing strength parallel to the grain	20
Modulus of elasticity in static bending	20
Proportional limit in compression perpendicular to the grain	20

RESULTS AND DISCUSSIONS

Details of the results of strength properties were categorized according to physicomechanical properties of Chinese timber as mentioned in the following

Table 3 (Jiang and Peng, 2001).

Table 3. Classification of Physico-mechanical properties

Class	Description [1]	Density	Compression Strength Parallel	MoR	MoE	End Hardness [2]
I	Very low	≤ 0.35	≤ 29.0	≤ 54.0	≤ 7.4	≤ 2500
II	low	0.351- 0.55	29.1-44.0	54.1-88.0	7.5-10.3	2570-4000
III	medium	0.551- 0.75	44.1-59.0	88.1-118.0	10.4-13.2	4010-6500
IV	high	0.751- 0.95	59.1-73.0	118.1-142.0	13.3-16.2	6510-10000
V	Very high	≤ 0.95	>73.0	≥142.0	≥16.3	>10000

1. Classes are described density, compression, Modulus of rupture (MoR) and Modulus of elasticity (MoE).

2. End hardness is described as very soft, soft, moderately hard, hard and very hard.

Categorization of strength properties of studied species

Table 4. Physico-mechanical property and strength categorization of *Papular deltoids*

S. No.	Test Modules	Estimated Value	Class	Description
1	MoR	678 kg/cm^2 (66 mpa)	II	low
2	MoE	55271 kg/cm^2 (5.42gpa)	I	Very low
3	Cleavage	25 kg/cm		
4	Compression parallel	258 kg/cm^2 (25.30 mpa)	I	Very low
5	Compression perpendicular	48 kg/cm^2	-	-
6	Density	428 kg/cm^3 (0.428 g/cm^3)	II	low
7	Tensile	27.4 kg/cm^2	--	--
8	End Hardness	427 kg (4187.43 newtons)	III	Moderately hard
9	Side Hardness	348 kg	-	-

The properties of *Papular deltiodies a*re shown in Table 4. As for as the MoR and density of the wood are concerned, the wood can be categorized as low-value wood. It means that the wood is expected to have low strength properties in general based on wood density and has low bending capacity, i.e. it can be used in construction work where low bending value is required. The wood is of very low strength in terms of its compression parallel to grain and MoE, which means that it can't be used as posts, poles, wooden columns, etc. Similarly, other strength properties of wood are also low value. However, the wood is moderately hard, as depicted by its end hardness value.

Table 5. Physico- mechanical properties and strength categorization of *Papular euphratica*

S.No.	Test Modules	Estimated Value	Class	Description
1	MoR	890 Kg/cm^2 (87.27mpa)	II	low
2	MoE	152391 kg/cm^2 (gpa14.94)	IV	high
3	Cleavage	33.7 kg/cm	-	-
4	Compression parallel	429.2 kg/cm^2 (42mpa)	II	low
5	Compression perpendicular	143.43 kg/cm^2	-	-
6	Density	677 kg/cm^3 (0.677 g/cm^3)	IV	high
7	Tensile	32.9 kg/cm^2	-	-
8	End Hardness	641.3 kg(6289 newtons)	III	medium
9	Side Hardness	547.6 kg	-	-

The properties of *Papular euphratica* are shown in Table 5. As for as the density and MoE of the wood are concerned, the wood can be categorized as high-value wood. It means that the wood is expected to have high strength properties in general based on wood density and has low bending capacity, i.e. it can be used in construction work where low bending value is required. The wood is of low strength in terms of its compression parallel to grain and MoE, which means that it can't be used as posts, poles, wooden columns, etc. Similarly, other strength properties of wood are also medium value. However, the wood is moderately hard, as depicted by its end hardness value,

Table 6. Physico mechanical properties and strength categorization of *Eucalyptus citriodora*

S.No.	Test Modules	Estimated Value	Class	Description
1	MoR	1152 kg/cm^2 (112mpa)	III	Medium
2	MoE	268926 kg/cm^2 (26.37gpa)	V	Very high
3	cleavage	29.5 kg/cm	-	-
4	Compression parallel	638 kg/cm^2 (62.56mpa)	IV	high
5	Compression perpendiculars	135 kg/cm^2	-	-
6	Density	977kg/m^3 (0.977g/cm^3)	IV	high
7	Tensile	34.4 kg/cm^2	-	-
8	End Hardness	873 kg (8561newtones)	IV	hard
9	Side Hardness	348kg	-	-

The properties of *Eucalyptus citriodora* are shown in Table 6. As for as the density and MoE of the wood are concerned, the wood can be categorized as a high-value wood. It means that the wood is expected to have high strength properties in general based on wood density and has high bending capacity, i.e.

it can be used in construction work where high bending value is required. The wood is of high strength in terms of its compression parallel to grain and MoE, which means that it can be used as posts, poles, wooden columns, etc. Similarly, other strength properties of wood are high value. So that, the wood is hard as depicted by its end hardness value,

Table 7. Physico mechanical properties and strength categorization of *Eucalyptus amaldulensis*

S.No.	Test Modules	Estimated Value	Class	Description
1	MoR	767 kg/cm^2(75mpa)	II	low
2	MoE	74398 kg/cm^2 (7.29gpa)	I	Very low
3	cleavage	26.9 kg/cm	-	-
4	Compression parallel	356 kg/cm^2 (62.56mpa)	IV	high
5	Compression perpendicular	114kg/cm^2	-	-
6	Density	850 kg/m^3(0.850 g/cm^3)	IV	high
7	Tensile	26.02kg/cm^2	-	-
8	End Hardness	609kg (5972 newtons)	III	medium
9	Side Hardness	542kg	-	-

The properties of *Eucalyptus comadulensis* are shown in Table 7. As for as the density and MoE of the wood are concerned, the wood can be categorized as a high-value wood. It means that the wood is expected to have high strength properties in general based on wood density and has low bending capacity, i.e. it can be used in construction work where low bending value is required. The wood is of high strength in terms of its compression parallel to grain and MoE, which means that it can be used as posts, poles, wooden columns, etc. Similarly, other strength properties of wood are medium value. So that, the wood is moderately hard as depicted by its end hardness value,

Table 8. Physico mechanical properties and strength categorization of *Paulownia catalpifolia*

S.No.	Test Modules	Estimated Value	Class	Description
1	MoR	599kg/cm^2 (58mpa)	II	Low
2	MoE	55315kg/cm^2 (5.42gpa)	I	Very low
3	cleavage	16.9kg/cm	-	-
4	Compression parallel	206kg/cm^2 (20.1mpa)	I	Low
5	Compression perpendicular	30kg/cm^2(2.94mpa)	-	-
6	Density	305kg/m^3(0.305g/cm^3)	I	Very low
7	Tensile	15.7kg/cm^2	-	-
8	End Hardness	242 kg(2373 newtons)	I	Very low
9	Side Hardness	169kg	-	-

The properties of *Paulownia catalpifolia* are shown in Table 8. As for as the MoR and density of the wood are concerned, the wood can be categorized as low-value wood. It means that the wood is expected to have low strength properties in general based on wood density and has low bending capacity, i.e. it cannot be used in construction work due to low bending value. The wood is of very low strength in terms of its compression parallel to grain and MoE, which means that it can't be used as posts, poles, wooden columns, etc. Similarly, other strength properties of wood are also very low value. However, the wood is very soft, as depicted by its end hardness value,

Table 9. Physico mechanical properties and strength categorization of *Paulownia fortunei*

S.No.	Test Modules	Estimated Value	Class	Description
1	MoR	702kg/cm2(68mpa)	II	low
2	MoE	55464kg/cm2 (5.43gpa)	I	Very low
3	cleavage	22.18kg/cm2		
4	Compression parallel	252kg/cm2(24.71mpa)	I	Very low
5	Compression perpendicular	36kg/cm2(3.53mpa)	-	-
6	Density	395kg/m3(0.395g/cm3)	II	low
7	Tensile	16.4kg/cm2		
8	End Hardness	275 kg(2696newtons)	II	low
9	Side Hardness	176kg		

The properties of *Paulownia fortunei* are shown in Table 9. As for as the MoR and density of the wood are concerned, the wood can be categorized as low-value wood. It means that the wood is expected to have low strength properties in general based on wood density and has low bending capacity, i.e. it can be used in construction work due to the low bending value is required. The wood is of low strength in terms of its compression parallel to grain and MoE, which means that it can't be used as posts, poles, wooden columns, etc. Similarly, other strength properties of wood are also low value. However, the wood is soft, as depicted by its end hardness value.

Statistical analysis

Multivariate tests were applied on six targeted wood species to compare the strength properties. In this respect, Wilks' Lambda test results were considered for interpretation as shown in the result table 10, and there was found a significant difference among species. Further analysis was carried out by applying ANOVA to determine what properties differed significantly w.r.t. species, as shown in Table 10.

Table 10. ANOVA Test

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Species	Density	3686528.279	5	737305.656	1281.500	.000
	Cleavage	1702.997	5	340.599	18.791	.000
	Tensile	3164.294	5	632.859	12.647	.000
	Hardness End	2923844.333	5	584768.867	174.483	.000
	Hardness Side	3193768.283	5	638753.657	164.401	.000
	Compression Parallel	1280995.087	5	256199.017	250.092	.000
	Compression Perpendicular	134604.396	5	26920.879	1002.968	.000
	MoR	1978477.329	5	395695.466	54.163	.000
	MoE	381365293858.466	5	76273058771.69	207.317	.000

Density

The means for groups in homogeneous subsets of the density of 06 species studied are shown in Table 11; the results show a significant difference in the densities of all species. It means that no one species can be used as an alternative to all other species concerning their quality (density). Further, the studied wood species can be categorized (ordered) in the following descending manner, *Eucalyptus citridora* > *Eucalyptus camaldulensis* > *Papular euphratica* > *Papular deltoides* > *Papular euphratica* > *Paulownia fortune* > *Paulownia catalpifolia*. The above descending order clearly shows that *E. citridora* wood has the highest density (quality) values of 977 among the studied species, followed by *E. camaldulensis* and others.

Table 11. The result of means for groups in homogeneous subsets of the density of species

Density

Test	Species	N	Subset					
			1	2	3	4	5	6
Tukey HSD[a,b,c]	Pulownia catalpifolia	10	305.40					
	Paulownia fortunei	10		395.50				
	Papular deltoides	10			428.30			
	Papular euphratica	10				677.95		
	Eucalyptus camaldulensis	10					850.10	
	Eucalyptus citridora	10						977.00
	Sig.		1.000	1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) = 575.346.

a. Uses Harmonic Mean Sample Size = 10.000.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

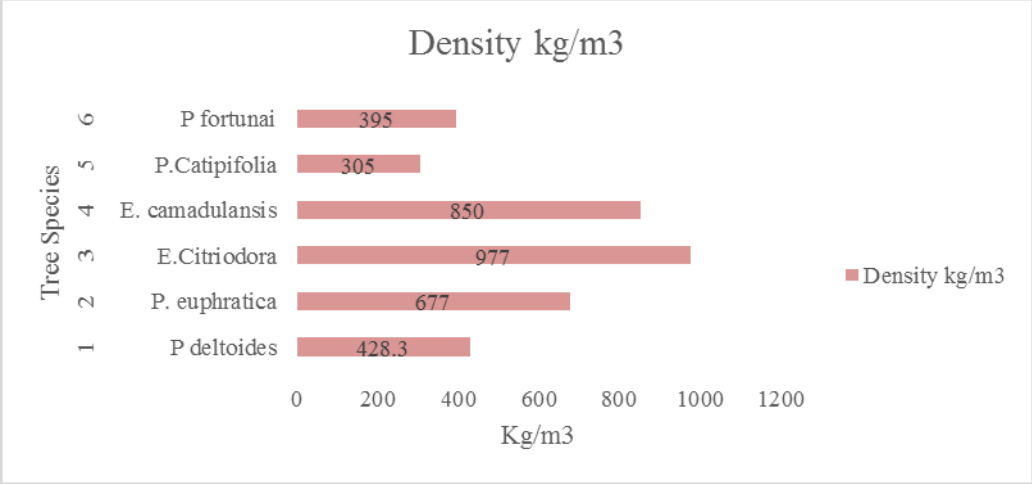

Fig. 3. The density of the species

Cleavage

Table 12 shows the results of means groups in homogeneous subsets of cleavage of studied wood species. It is evident from the results that *Paulownia catalpifolia* wood differed significantly in terms of its cleavage with all the other wood species except *Paulownia fortunei,* whose cleavage value has a significant difference from *Eucalyptus citridora* and *Papular euphratica. Papular deltoides* and E. camaldulensis are significantly different from *Paulownia catalpifolia and Papular euphratica,* E. citridora differed significantly from both *Paulownia* species. In contrast, *Papular euphratica* has a significant difference with all wood species except *E. citridora*.

Table 12. The results of groups of means in homogeneous subsets of cleavage

Cleavage

Test	Species	N	Subset			
			1	2	3	4
Tukey HSD[a,b,c]	*Paulownia catalpifolia*	10	16.94			
	Paulownia fortunei	10	22.18	22.18		
	Papular deltoides	10		25.00	25.00	
	Eucalyptus camaldulensis	10		26.90	26.90	
	Eucalyptus citridora	10			29.50	29.50
	Papular euphratica	10				33.75
	Sig.		.081	.149	.188	.240

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) = 18.126.
a. Uses Harmonic Mean Sample Size = 10.000.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

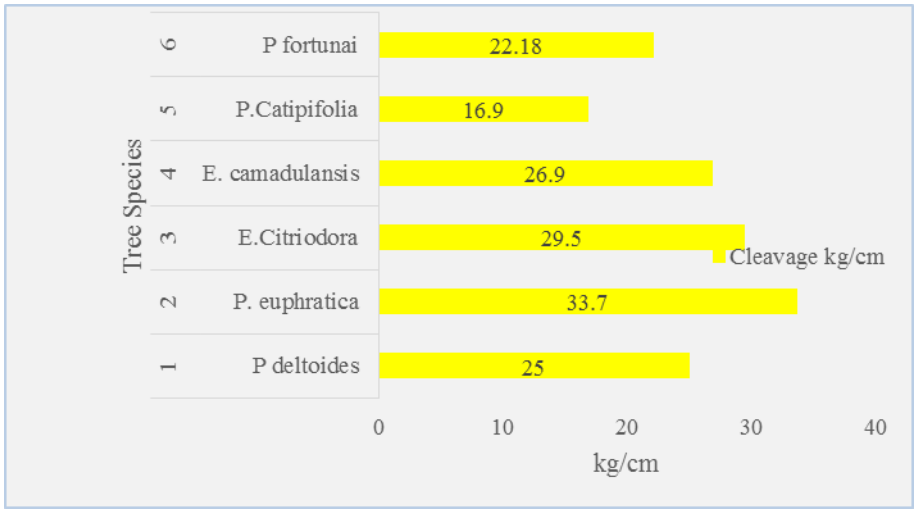

Fig. 4. Cleavage of the research species

Tensile

As well as the tensile strength of studied wood species is concerned, it is evident from the values of means from groups in homogeneous subsets displayed in Table 13 that *Paulownia catalpifolia* and *Paulownia fortunei* are differed significantly from all other wood species in terms of their tensile strength while the difference between themselves is non-significant it means that tensile

strength values of *Paulownia catalpifolia* and *Paulownia fortunei* lower than other wood species and the other wood species (*Eucalyptus camaldulensis, Papular deltoides, Papular euphratica* and *Eucalyptus citridora*) can be used interchangeably where the tensile property of wood is of prime concern.

Table 13. The results of groups of means in homogeneous subsets of Tensile

Tensile

Test	Species	N	Subset	
			1	2
Tukey HSD[a,b,c]	*Paulownia catalpifolia*	10	15.74	
	Paulownia fortunei	10	16.44	
	Eucalyptus camaldulensis	10		26.02
	Papular deltoides	10		27.40
	Papular euphratica	10		32.98
	Eucalyptus citridora	10		34.40
	Sig.		1.000	.103

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 50.039.
a. Uses Harmonic Mean Sample Size = 10.000.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

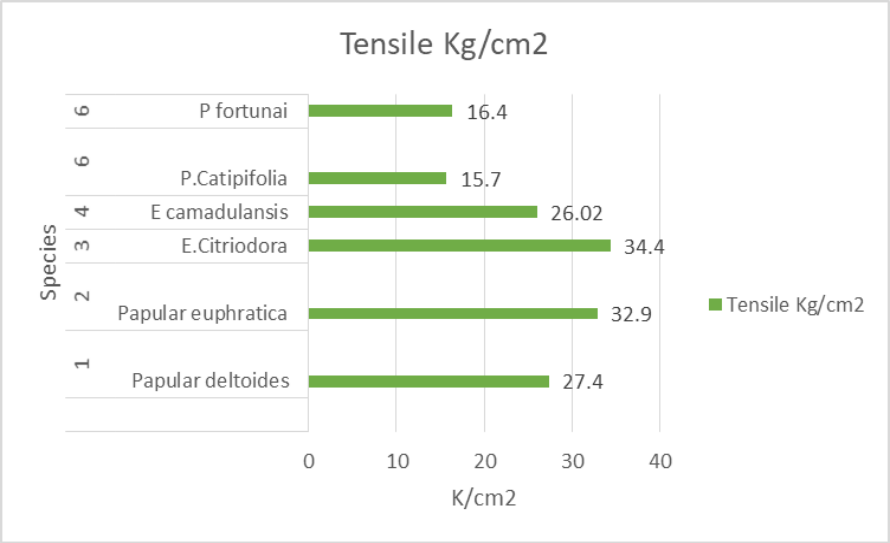

Fig. 5. Tensile of the research species

Hardness end

Hardness end values are depicted in Table 14 results showed that *Paulownia catalpifolia* and *Paulownia fortunei* have a significant difference from all other species. *Papular deltoides* significantly differed from all studied wood species, while *Eucalyptus camaldulensis* and *Papular euphratica* have a non-significant difference between themselves and a significant difference from all other species. *Eucalyptus citridora* has the highest hardness end value and differs significantly from other wood species.

Table 14. The results of groups of means in homogeneous subsets of Hardness end

Hardness End

Test	Species	N	Subset			
			1	2	3	4
Tukey HSD[a,b,c]	*Paulownia catalpifolia*	10	242.10			
	Paulownia fortunei	10	275.40			
	Papular deltoides	10		427.20		
	Eucalyptus camaldulensis	10			608.60	
	Papular euphratica	10			641.30	
	Eucalyptus citridora	10				873.00
	Sig.		.791	1.000	.803	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) = 3351.433.
a. Uses Harmonic Mean Sample Size = 10.000.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

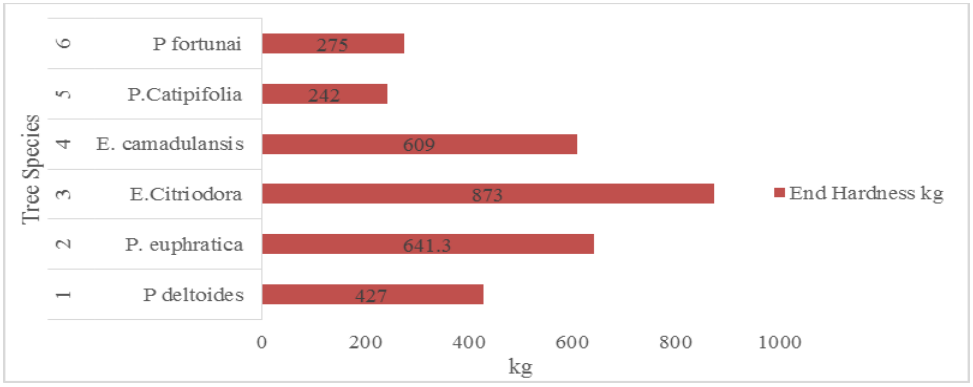

Fig. 6. Hardness End of the research species

Hardness side

Table 15 shows the side hardness value for the group is homogeneous subsets. The results show that the hardness values of both paulownia species have a significant difference from all other species. *Papular detiodes* differ significantly from all other wood species in terms of its hardness side. Similarly, *Eucalyptus camaldulensis* and *Papular euphratica* have significant variance with all other species. However, these differed significantly, and *Eucalyptus citridora* showed a significant difference with all other wood species concerning its side hardness.

Table 15. The results of groups of means in homogeneous subsets of Hardness side

Hardness Side

Test	Species	N	Subset			
			1	2	3	4
Tukey HSD[a,b,c]	*Paulownia catalpifolia*	10	169.30			
	Paulownia fortunei	10	176.40			
	Papular deltoides	10		348.20		
	Eucalyptus camaldulensis	10			541.70	
	Papular euphratica	10			547.60	
	Eucalyptus citridora	10				822.70
	Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 3885.346.
a. Uses Harmonic Mean Sample Size = 10.000.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

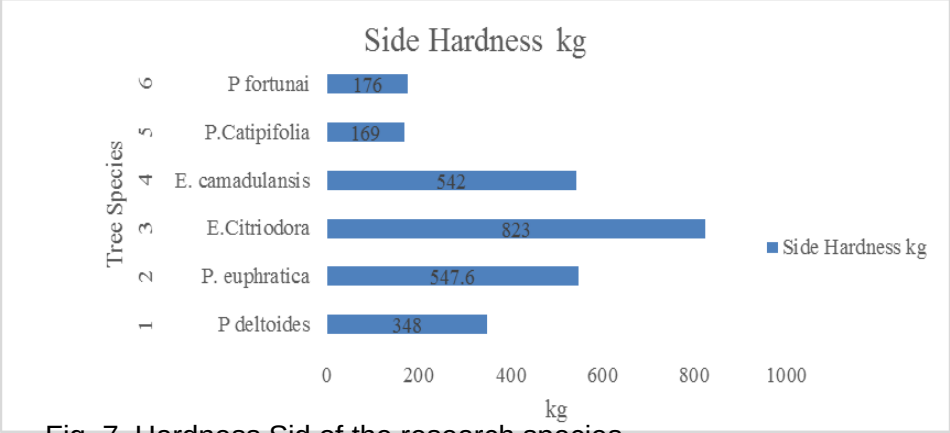

Fig. 7. Hardness Sid of the research species

Compression parallel

Results showed that the *Paulownia catalpifolia, Eucalyptus camaldulensis, Papular euphratica* and *Eucalyptus citridora* were found to have significant differences, individually, concerning all other wood species in terms of their respective compression parallel to grains property. In contrast, *Paulownia fortunei* and *Papular deltoides* differed significantly from all other wood species and insignificantly from each other in terms of their compression Parallel to grain (Table 16).

Table 16. The results of groups of means in homogeneous subsets of compression parallel

Compression Parallel

Test	Species	N	Subset				
			1	2	3	4	5
Tukey HSD[a,b,c]	*Paulownia catalpifolia*	10	206.04				
	Paulownia fortunei	10		251.91			
	Papular deltoides	10		258.01			
	Eucalyptus camaldulensis	10			355.60		
	Papular euphratica	10				429.29	
	Eucalyptus citridora	10					638.50
	Sig.		1.000	.998	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 1024.418.
a. Uses Harmonic Mean Sample Size = 10.000.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

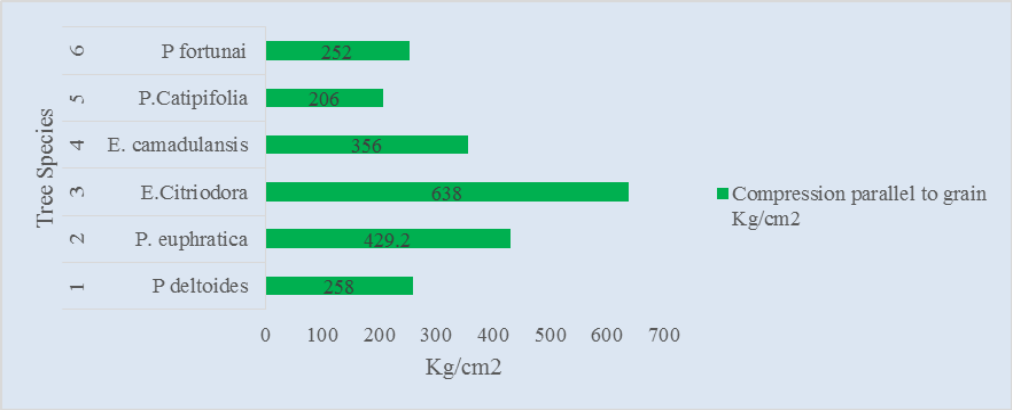

Fig. 8. Compression Parallel of the research species

Compression perpendicular

Table 17 shows the means results for the group in homogeneous subsets for compression perpendicular to the grain. Results showed that compression perpendicular to grain values of *Paulownia catalpifolia* and *Paulownia fortunei* had a significant from all other species. However, the difference between themselves was insignificant, while all other wood species showed significant differences with each other, individually, in terms of compression perpendicular to the grain.

Table 17. The results of groups of means in homogeneous subsets of compression perpendicular

Compression Perpendicular

Test	Species	N	Subset				
			1	2	3	4	5
Tukey HSD[a,b,c]	*Paulownia catalpifolia*	10	30.20				
	Paulownia fortunei	10	36.28				
	Papular deltoides	10		48.12			
	Eucalyptus camaldulensis	10			113.60		
	Eucalyptus citridora	10				134.94	
	Papular euphratica	10					143.43
	Sig.		.108	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) = 26.841.
a. Uses Harmonic Mean Sample Size = 10.000.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

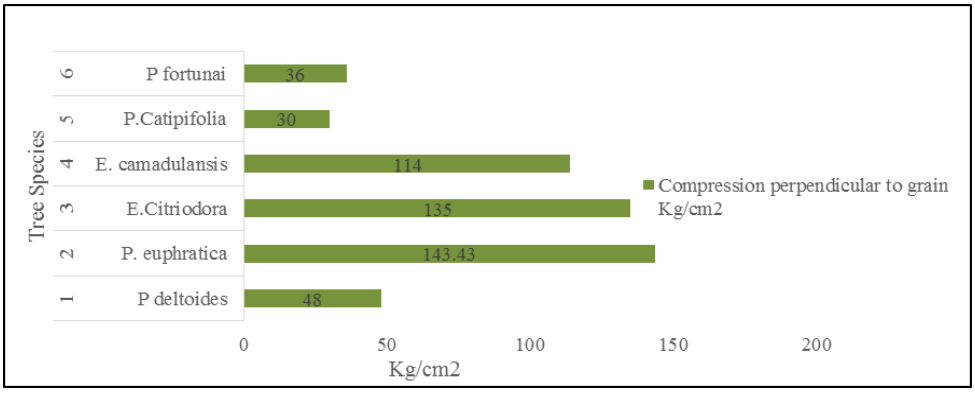

Fig. 9. Compression Perpendicular of the research species

Table 18 shows the results of MoR means for groups in homogeneous subsets. Results showed that *Paulownia catalpifolia* had significant difference from *Eucalyptus camaldulensis, Papular euphratica* and *Eucalyptus citridora; Papular deltoides* differed significantly with *Papular euphratica* and *Eucalyptus citridora; Paulownia fortunei* varied significantly from *Papular euphratica* and *Eucalyptus citridora; Eucalyptus camaldulensis* had significant variance with *Paulownia catalpifolia, Papular euphratica* and *Eucalyptus citridora*; and *Popular euphratica* and *Eucalyptus citridora* both differed significantly from all other wood species in terms of MoR property, individually, and from each other.

Table 18. The results of groups of means in homogeneous subsets of MoR

Test	Species	N	Subset			
			1	2	3	4
Tukey HSD[a,b,c]	*Paulownia catalpifolia*	10	599.85			
	Papular deltoides	10	678.43	678.43		
	Paulownia fortunei	10	702.07	702.07		
	Eucalyptus camaldulensis	10		766.80		
	Papular euphratica	10			890.16	
	Eucalyptus citridora	10				1152.43
	Sig.		.097	.207	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square(Error) = 7305.642.
a. Uses Harmonic Mean Sample Size = 10.000.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

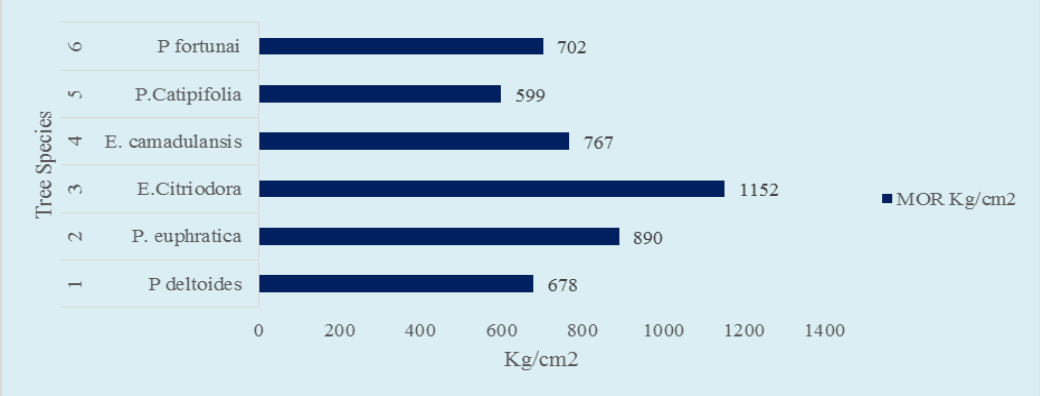

Fig. 10. MoR of the research species

Table 19 shows the results of MoE means for groups in homogeneous subsets. Results showed that *Papular deltoides* had a significant difference from *Eucalyptus camaldulensis, Papular euphratica* and *Eucalyptus citridora; Paulownia catalpifolia* differed significantly with *Papular euphratica* and *Eucalyptus citridora; Paulownia fortunei* varied greatly from *Papular euphratica* and *Eucalyptus citridora; Eucalyptus camaldulensis* had significant variance with *Popular deltoids, Papular euphratica* and *Eucalyptus citridora*; and *Popular euphratica* and *Eucalyptus citridora* both differed significantly from all other wood species in terms of MoE property, and from each other, individually.

Table 19. The results of groups of means in homogeneous subsets of MoE

Test	Species	N	Subset			
			1	2	3	4
Tukey HSD[a,b,c]	*Papular deltoides*	10	47911.74			
	Paulownia catalpifolia	10	55314.66	55314.66		
	Paulownia fortunei	10	55464.30	55464.30		
	Eucalyptus camaldulensis	10		74397.80		
	Papular euphratica	10			152391.40	
	Eucalyptus citridora	10				268926.45
	Sig.		.950	.244	1.000	1.000

Means for groups in homogeneous subsets are displayed.
Based on observed means.
The error term is Mean Square (Error) = 367906355.306.
a. Uses Harmonic Mean Sample Size = 10.000.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

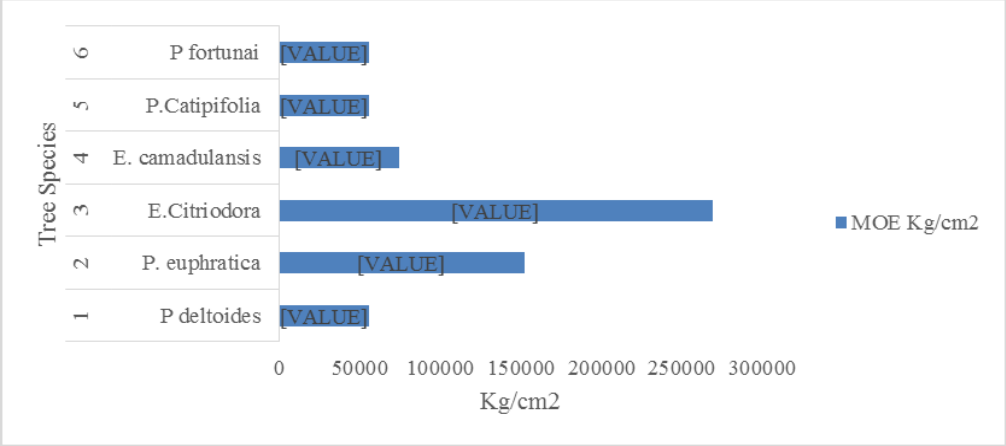

Fig. 11. MoE of the research species

CONCLUSIONS

When operating in a highly competitive business environment, finding new ways to differentiate oneself from the competition is vital. Globalization's effects on the corporate environment and rising demand for energy and raw materials put pressure on their cost-effectiveness. Targeted wood species were tested to conclude that *P. catalpifolia* and *P. fortunei* have very low strength and may be used in toys, matchsticks, articles and woodworking, where low strength wood properties are required. However, while in comparison with *Paulownia* species, the rest of the studied species like *E.citridora, E. camaldulensis, P. euphratica* and *P. deltoides* could be used for furniture, bearing blocks, bowls, beams, column, posts & struts, flooring, paving blocks, patterns, rollers, sleepers, wedges, wheelwrights work, bolted timbers, joints, nailed timbers, notched timber, mallets and others.

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