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Comparative study of Wood Physical and Mechanical properties of *Melia dubia* with *Tectona grandis* at different Age Gradation

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Abstract

Study was carried out at Forest College and Research Institute, Mettupalayam, Tamil Nadu, India using different age gradation viz., three, four and five year of Melia dubia wood samples collected from the plantations raised at Kollegal, Samraj Nagar District, Karnataka to evaluate the Physical and mechanical properties. Five year-old M. dubia wood recorded maximum density (500.20 kg m^{-3}) and specific gravity (0.60). Among the age gradations five year old M. dubia registered maximum value for the parameters like static bending strength, modulus of rupture, modulus of elasticity, compression strength parallel to grain, Compression Strength perpendicular to grain, hardness, shearing stress parallel to grain, tensile stress parallel and perpendicular to grain, Nail-holding power, screw-holding power, brittleness, and cleavage strength parallel to grain. The current study confirmed the suitability of five year old wood as raw material for plywood, pencil, packing cases, and light furniture industry.

Keywords: Density, specific gravity, static bending strength, MOR, MOE, compression strength, stress.

Introduction

In India, forests are shrinking under acute socio economic pressure. India's forests till recently are being denuded at an alarming rate and has fortunately come down with the enactment of the Forest Conservation Act, 1980. Currently, the forest area in the country is around 23.81 per cent and in the state of Tamil Nadu it is around 17.59 per cent which is much low against the mandated requirement of 33.00 per cent. Not only is the forest wealth of the country is poor but its productivity in terms of MAI is also one of the lowest. The MAI of Indian Forest is a meager of 0.5 - 0.7 m^3 ha^{-1} compared to the global average of 2.1 m^3 ha^{-1} [1]. The less forest area coupled with the low productivity of Indian forest has ushered in a total mismatch between the demand and supply of both domestic and industrial wood requirement besides creating environmental disequilibrium and destability[2]. The current supply of raw materials for industries like pulpwood, plywood, furniture, and biomass energy in the state is far behind the demand. Hence, to meet the growing raw material requirement and also to sub serve the 1988 National Forest Policy Guidelines of Indian Government and to keep pace with these progressive developmental changes in the country, the industries must expand sharply its plantation programme. However, considering the acute shortage of suitable raw material, the industries have to establish plantation of suitable species with tree improvement programme to achieve maximum yield within a short rotation period. This besides choice of alternative tree species to meet the raw material requirement of industries is the need of the hour. *Melia dubia* is one such alternative species suitable for timber, pulpwood and also as fuelwood.

Melia dubia belonging to the family Meliaceae has its trade name as Malabar Neem and is locally called as Mala-veppu. Large deciduous and fast growing tree with wide spreading branches on a stout, straight, tall bole. Young shoots with inflorescence covered with mealy stellate hairs. It is indigenous to the Western Ghats of southern India and is common in moist deciduous forests of Kerala[3]. The tree is a light-demander and the seedlings suffer from drought and frost. Moist soil favours the growth of the tree. The tree grows to an average height of 35m and the bark is rough and peeling. Trees flower during February-April when the trees shed their leaves. And the fruits ripen during November-February in the next year. The fruit is a drupe which is ellipsoid in shape with 1-6 seeds, seeds are black, ovoid with long endocarp. Mature fruits weigh 130-140 per kilogram[4]. With the rapid increase in population, demand for timber by various sectors has increased considerably. Also supply of conventional timbers has reduced due to deforestation and depletion of natural forests. The growing demand for timber can be met to some extent by utilizing alternative species and increasing the timber production through intensive management. The demand for forest based products, particularly wood and fiber has increased many folds in the last few decades. India is likely to face severe shortage of supply of timber to meet its requirement from both domestic and international front. It is estimated that the demand for timber is likely to grow from 58 million cubic metres in 2005 to 153 million cubic meters in 2020. The supply of wood is projected to increase from 29 million cubic meters in 2000 to 60 million cubic meters in 2020. The shortfall of 93 million cubic meters should be met by import from international market. The productivity of timber in India is only 0.7 cu. m/ha/year whereas the world average is 2.1 cu.m/ha/year[5]. The supply of timber is mainly from forest plantations and wood production is showing a negative growth rate. In the absence of adequate supply from domestic sources, the nation has to depend heavily on imports to meet its demand for timber. This will increase the nation's forest footprint, particularly in South East Asia. In order to minimize the forest footprint, we need to encourage sustainable consumption of timber by promoting farm forestry. The demand gap should be bridged by increasing domestic production by introducing fast growing timber species with short rotation.

Global demand for wood is increasing at an annual rate of 1.7 per cent[6]. At the same time, planted forest resources are insufficient to meet current demands. The scope for expansion of forested areas is limited[7]. This trend creates economic pressure that encourages the commercial exploitation of natural forests unless supply can be increased through the establishment of high yielding plantations. The use of fast growing, elite trees enable early harvest and so it helps to improve yield. *Melia dubia* is one such fast growing tree species. However, wood property data is not available. Wood property profile is helpful for the identification of this species and rational utilization of wood. This is of great importance in the case of indigenous forestry and the information in this aspect with respect to this species is entirely lacking. Recently this species has become popular among both public and private-sector planters. As the planting has been a pioneering effort, there is not much scientific information available about the tree's performance in this region. Information on growth rate and wood properties which is helpful in evaluating its potential for various end-use is essential for informed investment in extensive plantation programs. An understanding of the wood properties and their variation with age provides a basis for assessing opportunities for value-added uses. However such information are not available in this species and there is no planned research attempt to characterize wood properties which demands intensive investigation. Against this backdrop, the current study for Genetic evaluation and wood characterization for pulp, anatomical, mechanical and energy properties of *Melia dubia* genetic resources is conceived and designed with the objective to determine the mechanical properties of *Melia dubia* at different age gradation.

Material and Methods

Sample collection: Destructive method of sampling was adopted to collect the wood samples. For this, the trees of third, fourthand fifth year were felled and converted into logs of one meter length which are used for preparation of samples for mechanical properties analysis (figure-2). The basal billets of one metre length were converted into scantlings of 40 × 5 x 5 cm cross section to prepare test samples from pith to periphery in one radial direction selected randomly just below breast height for the study of mechanical properties after air drying of the wood. Mechanical tests were conducted as per the Indian Standard Specification IS 1708 (Part 5-17)[8] by Universal Testing Machine (Shimadzu AG-100kNG) as shown in Figure 1.

Static bending test t: Test method: IS 1708 part-5:1986 (Sample size-30x2x2cm): The strength and stiffness of wood samples were tested by using static bending test. Here applied force is increased very slowly and gradually until the specimen broken. From the stress strain graph, load at proportional limit and corresponding deflection were noted. Modulus of elasticity (MOR), Fiber stress at proportional limit (FS at LP), Modulus of rupture (MOR), Maximum load were also analyzed. These values are useful to derive the application of this timber as beams, planks, scantlings, furniture, packing cases etc.

Compressive strength parallel to grain test: Test method: IS 1708 part-8:1986 (Sample size-8x2x2cm): Here the usefulness of the timber under purpose where forces and reactions act towards each other either along the grain or across the grain likes furniture legs and athletic goods. Here compressive stress at proportional limit and compressive stress at maximum load, Modulus of elasticity are measured for this wood sample.

Compressive strength perpendicular to grain test: Test method: IS 1708 part-9:1986 (Sample size-10x2x2cm): The compressive stress at proportional limit and compressive stress at a compression of 2.5mm deflection is measured.

Tensile strength parallel to grain test:-Test method: IS 1708 part-12:1986 (Sample size-32.5x5x1.5cm): The properties of timber differ in three principal directions. These properties are determined by applying forces and reactions which pull apart from each along the grain. Tensile stress at proportional limit and tensile stress at maximum load are measured.

Tensile strength perpendicular to grain test:-Test method: IS 1708 part-13:1986 (Radial, Tangential) (**Sample size-5x2cm area**): The load required for failure of sample perpendicular to grain was recorded. The load divided by the area gave the maximum tensile stress perpendicular to grain in the radial and tangential plane. The maximum load / area of stress gives an indication of splitting characteristic of the material in radial or tangential plane. The maximum tensile stress in perpendicular direction is also an indication of tensile strength of the timber in that direction.

Hardness test under static indentation:-Test method: IS 1708 part-10:1986 (Sample size-15x5x5cm): Here load in required to penetrate a steel ball of 1.128 cm to half of its diameter i.e, 0.564cm either radial, tangential or end surfaces of the wood sample is measured.

Oven dry Density: Test method: IS 1708 part-2:1986 (Sample size-6x2x2cm): Volume of the samples is calculated using vernier caliper then it is oven dried and weight of samples at oven dried condition was also noted. Basic density at oven dry was calculated using the following formula.
Basic density = (Oven dry weight / Volume at test)
Amount of wood substances, wood quality, easy of transportation etc can be found out.

Shear strength parallel to grain test:-Test method: IS 1708 part-12:1986 (Sample size-6.25x5x5cm): This property shows the behavior of timber under forces which slide one portion of the material over the adjoining portion of the same.

Nail and screw holding power test:-Test method: IS 1708 part-15:1986 (Sample size-15x5x5cm): Predicts the utility of timber under joinery uses, packing cases where nail and screw are used. Load required pulling out nail and screwing from radial, tangential and end surface measured.

Cleavage strength parallel to grain:-Test method: IS 1708 part-14:1986 (Sample size-9.3x5x5cm): Cleavage resistance parallel to grain measured. The maximum load required for failure was recorded. The load divided by the width gives the maximum cleavage resistance kg/cm in radial and tangential plane.

Brittleness by Izodimpact:-Test method: IS 1708 part-16:1986 tested by Impact machine (Sample size-12.5x2x2 cm): The specimen held vertically clamped in a cantilever in a swinging pendulum machine such that 50 mm length of the specimen was under the clamp. The machine had a calibrated dial so as to give direct reading of energy absorbed in breaking the specimen in a single blow. The specimen clamped that the blow was given in the radial face on the side of notch. The pendulum of the machine adjusted that on release from the initial position it strikes the specimen at the lowest point of swing (horizontally) at a distance of 10mm from the upper end. The impact blow was given by releasing the pendulum and the reading on the calibrated dial in kg.cm was noted.

Brittleness by Charpy impact:-Test method: IS 1708 part-17:1986 (Sample size-12.5x1.25x1.25 cm): The specimen freely supported horizontally with the notch vertical on the base of a swinging pendulum machine up to 10mm on both ends. The machine had a calibrated dial so as to give direct reading of energy absorbed in breaking to specimen on a single blow. The blow should be given on the opposite side of the notch at the centre of specimen. The pendulum of the machine arranged so as on released from the initial position it may stroked the specimen at the lowest point of owing (horizontally). The impact blow was given by releasing the pendulum and the reading on calibrated dial in kg.cm was recorded.

Results and Discussion

The mean values of the physical and mechanical properties as determined in air-dry conditions are presented in table-1 and figure 3,4,5,6,7,and 8 for third, fourth and fifth year old trees, along with the corresponding values for 'standard teak', *Tectona grandis*[9], for the purpose of comparison.

Density: The mean density values based on air dry weight was 418.70, 485.60 and 500.20 kg m^{-3} for three, four and five year old *Melia dubia* wood samples respectively. Therefore wood density increased with increase in age. These findings are in accordance with the report of Akachuku[10] for wood density of *Gmelina arborea*. Fuwape and Fabiyi[11] also reported similar observation for wood density of plantation grown *Nauclea diderichii* wood. Similar result was recorded in *Acacia auriculiformis* wood[12]. In comparison with *Tectona grandis*, wood density of fifth year *Melia dubia* recorded 74 per cent value of teak wood density[9].

Specific gravity: The specific gravity of *Melia dubia* ranged from 0.47 (third year) to 0.60 (fifth year). Current study recorded that the specific gravity increases with age in *Melia dubia* wood which is in concurrence with the results of *Acacia auriculiformis* wood[12]. Similarily Verghese *et al.*[13] reported that specific gravity was 0.59 for 15-y-old plantations from Wada, Maharashtra. Keating and Bolza[14] reported that the specific gravity of timber obtained from Indonesia was 0.58–0.64. Mohd Noor Mahat[15] reported variation in specific gravity (0.53–0.61) of different provenances tested in Malaysia. Thus specific gravity appears to be widely influenced by age, environmental factors and seed origin. The fifth year specific gravity value of *Melia dubia* wood is equivalent to the specific gravity of *Tectona grandis*[9].

Static bending strength: The static bending strength values recorded were 616.30, 524.30 and 312.80 kg cm^{-2} for fifth, fourth and third year *Melia dubia* woods respectively (figure-7). It showed that the static bending strength improves with age of the tree (table-1). Similar observation was made in *Acacia auriculiformis* wood at 8^{th}, 12^{th} and 13^{th} year wood samples[12]. Fifth year *Melia dubia* wood recorded lower static bending strength value compared to *Tectona grandis*[9].

Modulus of Rupture: The mean MOR value obtained in the study were 492.60 to 851.90 kg cm^{-2} for three, four and five year old *Melia dubia* woods respectively (table-1). The results proved that MOR values increased with the age of tree. The present study is in accordance with the research of Bhat and Priya[16] in *Tectona grandis* and Shukla *et al.*[12] in *Acacia auriculiformis*. MOR values increased with age, a situation which may be due to increment of annual rings, addition of more mature wood and the increasing age of cambium as the tree grow in girth[17]. The increased in MOR as age increase appears to agree with the report of Fuwape and Fabiyi[11] on *Nauclea diderichii* wood and Izekor and Fuwape[18] in *Tectona grandis*. The increased trend in MOR was also associated to the variations in some morphological features such as fibre length, fibre diameter, lumen width and fibre wall thickness[19]. Fifth year *Melia dubia* wood recorded lower MOR values compared to *Tectona grandis* (959.00 kg cm^{-2})[9].

Modulus of Elasticity: The mean values for MOE of third, fourth and fifth year *Melia dubia* woods were 52872.20, 63212.50 and 68384.50 kg cm^{-2} respectively (table-1). But fifth year *Melia dubia* wood recorded lower MOE than *Tectona grandis*[9]. This observation showed that MOE increases with age, which may be attributed to increments of growth rings, and the addition of more mature wood and the increasing age of cambium as the tree grow in girth. Similar trend of increase in MOE has been reported in Slash pine [20]. Also Fuwape and Fabiyi[11] reported similar observations in MOE for plantation grown *Nauclea diderichii* wood. Comparable result was reported by Shukla *et al.*[12] in *Acacia auriculiformis*.

Compression strength parallel to grain: The mean values of CS of *Melia dubia* wood were 241.00, 250.60 and 283.30 kg cm^{-2} for age of three, four and five year trees respectively (table-1). The compression strength was lower compared to *Tectona grandis* for fifth year *Melia dubia* wood. The current study showed that CS increases with age which was in accordance with the findings of Shukla *et al.*[12] in *Acacia auriculiformis*. The increase in CS according to age may be as a result of variation in some morphological factor such as fibre length, wall thickness and fibre diameter[18].

Compression strength perpendicular to grain: The mean values for Compression strength perpendicular to grain of *Melia dubia* woods were ranged from 31.80 kg cm^{-2} (third year) to 104.20 kg cm^{-2} (fifth year) respectively (table-1 and figure-3). Fifth year *Melia dubia* wood recorded slightly higher value for compression strength perpendicular to grain than *Tectona grandis* wood. Similar results were observed by Shukla *et al.*[12] in *Acacia auriculiformis*.

Hardness: Hardness in radial, tangential planes, and end surface hardness of fifth year *Melia dubia* wood was higher than that of fourth and third year (table-1 and figure 5 & 6). Fifth year *Melia dubia* wood recorded comparatively lower value that of *Tectona grandis* wood. This result showed that the hardness of *Melia dubia* wood increased with age of the tree, which may be attributed to increments of growth rings, and the addition of more mature wood and the increasing age of cambium as the tree grow in girth[17].

Shearing stress parallel to grain: The fifth year *Melia dubia* recorded higher shearing stress value at radial and tangential position compared to the fourth and third year which recorded slightly lower values (table-1 and figure-4). The fifth year *Melia dubia* reported higher radial shearing stress than *Tectona grandis* while lower tangential shearing stress compared to *Tectona grandis*. This result established that the shearing stress increases with the age of the tree in *Melia dubia*.

Tensile stress parallel to grain: The tensile stress of *Melia dubia* increases with increase in tree age which was registered in fifth, fourth and third year wood samples at proportional limit. The same trend was observed for tensile stress at maximum load (table-1 and figure-8).

Tensile stress perpendicular to grain: The maximum tensile stress recorded for fifth, fourth and third year *Melia dubia* wood were 48.30, 44.40 and 34.40 kg cm^{-2} respectively. The fifth year wood recorded lower than *Tectona grandis* wood. Current study showed that the tensile stress perpendicular to grain increases with increase in age of the tree in *Melia dubia* wood (table-1).

Nail-holding power: Nail-holding power was maximum at fifth year *Melia dubia* wood sample followed by fourth and third year wood sample for side and end position (table-1). The fifth year wood had higher nail-holding power compared to *Tectona grandis* wood. Similar result was reported by Shukla *et al.*[12] in *Acacia auriculiformis* in green wood at end position for 8^{th}, 12^{th} and 13^{th} year wood samples.

Screw-holding power: The maximum screw-holding power was reported in fifth year *Melia dubia* wood and the lowest value is recorded in third year. The present study was in accordance with findings of Shukla *et al.*[12] in *Acacia auriculiformis* wood. The fifth year wood of *Melia dubia* recorded the lower screw-holding power than the *Tectona grandis* wood (table-1).

Brittleness by Izod impact: Izod impact test established that the brittleness of *Melia dubia* wood ranged from 158.30 kg cm^{-1} (fifth year) to 100.40 kg cm^{-1} (third year) (table-1). This result recorded that the brittleness of *Melia dubia* wood increases with age of the tree.

Brittleness by Charpy impact: Charpy impact test for brittleness of *Melia dubia* ranged from 59.90 to 81.80 kg cm^{-1} (table-1). This result also established that the brittleness of *Melia dubia* wood increases with age of the tree.

Cleavage strength parallel to grain: The maximum cleavage strength value of 59.30 kg cm^{-1} (fifth year) and minimum value of 54.00 kg cm^{-1} (third year) was recorded for *Melia dubia* wood and the result showed that cleavage strength of the *Melia dubia* wood increases with the age of the tree (table-1).

Conclusion

In a holistic perspective, the results of the current study apparently indicates that *Melia dubia* is amenable for pulp and paper industry due to superior pulp yield and quality, plywood industry due to acceptable mechanical properties and also for biomass based power generation industries due to their ideal energy value. The productivity also indicated that *Melia dubia* is fast growing tree with the growth rate of 41.54 m^3/ha/yr coupled with multifarious utility extend greater scope of its utility for various wood based industries.

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Reference

1. Srivastava M.B., Timber industries and non- timber forest products. CBS Publication, New Delhi, 518 **(2005)**

2. Parthiban K.T., R. Seenivasan1, S. Vennila, P.V. Anbu, P. Kumar, V. Saravanan, S. Umesh Kanna, P. Rajendran, V. Subbulakshmi and P. Durairasu, Designing and Augmenting Pulpwood Supply Chain through Contract Tree Farming, *Indian J. Ecol. 38 (Special Issue)*, 41-47 **(2011)**

3. Gamble S.J., A manual of Indian timbers, 145 **(1992)**

4. Nair K.K.N., C. Mohanan and George Mathew, Plantation technology for selected indigenous trees in the Indian Peninsula. *Bios Et Forets Des Tropiques, KFRI Research Report no.*, **285(3) (2005)**

5. Lal P., Clonal Agroforestry Plantations in India, *Indian J. Ecol*., **38 (Special Issue),** 6-10 **(2011)**

6. South D.B., How can we feign sustainability with an increasing population?, *New For.*, **17,** 193-212 (**1999)**

7. Gregory P.J., J.S.I. Ingram, R. Andersson, R.A. Betts, V. Brovkin and T.N. Chase, Environmental consequences of alternative practices for intensifying crop production, *Agric. Ecosystem Environ.*, **88**, 279-290 **(2002)**

8. ISI (Indian Standards Institution). Indian standards method of testing small clear specimens of timber. IS: 1708, Bureau of Indian Standards (BIS), New Delhi. **36**, 6-10 **(1986)**

9. Sekhar A.C. and B.S. Rawat, Studies on effect of specific gravity on strength considerations of Indian timbers, *J. Inst. Engg., India,* **39(8),** 865-870 **(1966)**

10. Akachuku A.E., University of Ibadan, Nigeria, *Agric. Research Bulletin*, **1(2),** 5-6 **(1980)**

11. Fuwape J.A. and J.S. Fabiyi, study on wood density of plantation grown *Nauclea diderichii* wood *J. Trop. For. Prod.*, **9(1and2)**, 45-53 **(2003)**

12. Shukla, S.R., R.V. Rao, S.K. Sharma, P. Kumar, R. Sudheendra and S. Shashikala, Physical and mechanical properties of plantation-grown *Acacia auriculiformis* of three different ages, *Australian Forestry,* **70(2)**: 86-92 **(2007)**

13. Verghese M., A. Nicodemus and K. Subramanian, Growth and wood traits of plantation-grown *Acacia mangium*, *A. auriculiformis* and *A. crassicarpa* from Thane, Maharashtra, *Indian Forester***, 125(3),** 923-928 **(1999)**

14. Mohd Noor Mahat, Genetic variation of growth and selected wood properties of four-year-old *Acacia auriculiformis* provenances of Serdang, Malaysia, Institute of Wood Science and Technology, Bangalore **(1999)**

15. Bhat, K.M. and P.B. Priya, Influence of provenance variation on wood properties of teak from the Western Ghat region in India, *IAWA Journal* **25(3),** 273-282 **(2004)**

16. Izekor D.N., J.A. Fuwape and A.O. Oluyege, Effects of density on variations in the mechanical properties of plantation grown *Tectona grandis* wood. Scholars Research Library, *Arch. App. Sci. Res.*, **2(6)**: 113-120 **(2010)**

17. Izekor D.N. and J.A. Fuwape, Variations in mechanical properties among trees of the same and different age classes of Teak (*Tectona grandis* L.F.) wood, *J. App. Sci. Res.*, **6(4),** 562-567 **(2010)**

18. Roos K.D., J.E. Shottafer and R.K. Shepard, The relationship between selected mechanical properties and age in quaking aspen, *Forest Products Journal*, **40(7and8)**, 54-56 **(1990)**

19. Macpeak M.D., L.F. Burker and D. Weldon, *Forest Product Journal***, 40(1)**, 11-14 **(1990)**

Table-1
Comparative profile of wood mechanical properties of *Melia dubia* at different ages at 12 per cent moisture content with *Tectona grandis*

Mechanical Properties	**Age in years**			**Teak**
	3	**4**	**5**	
Density (kg m^{-3})	418.70	485.60	500.20	676.00
Specific gravity	0.45	0.47	0.60	0.60
Static bending strength (FS at LP) (kg cm^{-2})	312.80	524.30	616.30	651.00
MOR (kg cm^{-2})	492.60	808.30	851.90	959.00
MOE (kg cm^{-2})	52872.20	63212.50	68384.50	119060
Compression strength parallel to grain at LP (CS at LP) (kg cm^{-2})	241.00	250.60	283.30	376.00
Compression strength perpendicular to grain at LP(CS at LP) (kg cm^{-2})	31.80	68.80	104.20	101.00
Hardness (static indentation)				
Radial (kg)	112.40	172.30	279.00	502.00
Tangential (kg)	234.90	355.90	369.30	524.00
End (kg)	234.90	270.40	400.40	488.00
Shearing stress parallel to grain (MSS)				
Radial (kg cm^{-2})	96.50	97.60	104.40	96.87
Tangential (kg cm^{-2})	66.60	72.80	98.20	108.09
Tensile stress parallel to grain (TS)				
Tensile stress at proportional limit ((kg cm^{-2})	238.90	273.40	293.50	-
Tensile stress at maximum load ((kg cm^{-2})	752.30	908.40	1020.30	-
Tensile stress perpendicular to grain (TS)				
Maximum Tensile Stress ((kg cm^{-2})	34.40	44.40	48.30	66.28
Nail-holding power				
Radial (kg)	70.60	155.10	195.90	93.00
Tangential (kg)	84.30	120.50	148.00	93.00
End (kg)	59.40	65.40	91.90	85.00
Screw-holding power				
Radial (kg)	249.40	295.90	371.30	388.00
Tangential (kg)	246.90	355.20	361.40	410.00
End (kg)	223.00	231.20	270.00	283.00
Brittleness by Izod impact (kg cm^{-1})	100.40	157.80	158.30	-
Brittleness by Charpy impact (kg cm^{-1})	59.90	81.60	81.80	-
Cleavage strength parallel to grain (kg cm^{-1})	54.00	54.30	59.30	-

Figure 1. Universal Timber Testing Machine

Figure 2. Sample Preparation

Figure 3. Compression strength

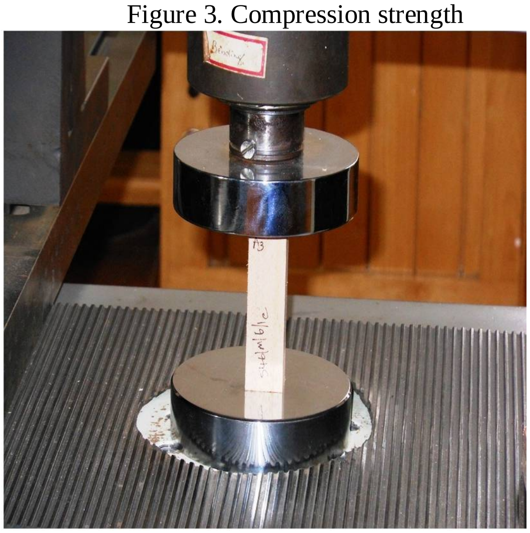

Figure 4. Shearing stress

Figure 5. Shearing stress

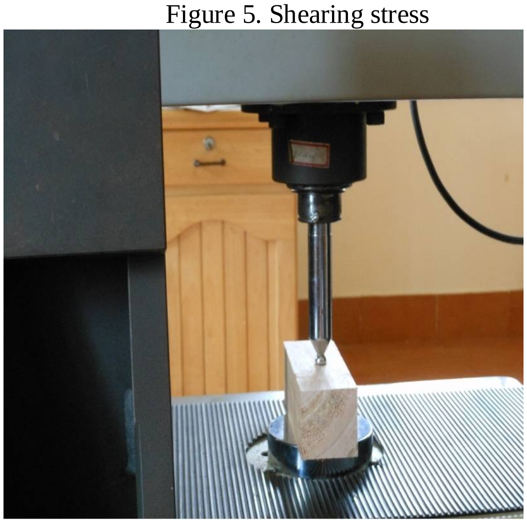

Figure 6. Radial hardness

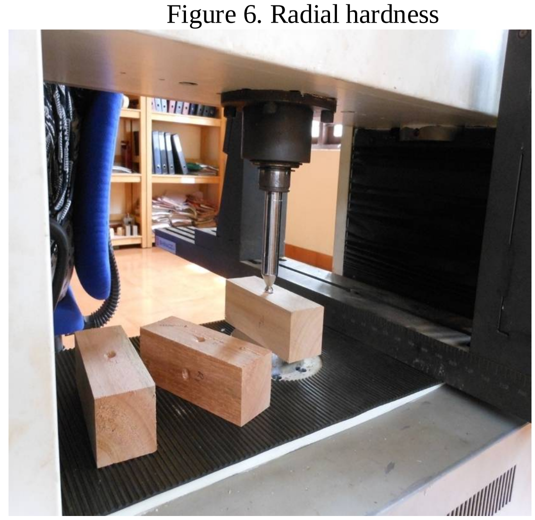

Figure 7. Tangential hardness

Figure 8. Static bending strength

Figure-1 to 8
Testing of Mechanical Properties of *Melia dubia* by Universal Timber Testing Machine