

STRENGTH CHARACTERISTICS OF APA (*afzelia bipindensis*) TIMBER FOR STRUCTURAL USE (A CASE STUDY OF SPECIES GROWN IN KWARA STATE, NIGERIA)

A. A. Jimoh¹, I. A. Yahya², J. B. Adefemi³

^{1,3}Department of Civil Engineering, University of Ilorin, Kwara State, Nigeria.

²Department of Civil Engineering, Moddibo Adama
University of Technology, Yola, Adamawa State, Nigeria.
Corresponding Author: ismakola2012@gmail.com

ABSTRACT

This paper presents the results of experimental tests carried out on Apa (*Afzelia bipindensis*) to ascertain its structural performance. Fresh samples of Apa timber (*Afzelia bipindensis*) was collected from forest in *Ajase Ipo* town, in Irepodun Local Government Area of Kwara State, Nigeria. A log of Apa timber was obtained, air dried and 324 test specimens were prepared for strength properties determination. The strength characteristics tested were tensile, compression and bending parallel to grain alignment. The strength characteristics tests were conducted in accordance with BS 373. The mean and confidence limit were obtained through statistical analysis of the data obtained. The Tensile, Bending, Compressive, Modulus of Elasticity and Modulus of Rupture values of 26.90, 50.66, 2.58, 9274.62 (N/mm²) respectively were recorded at 18% moisture content. In comparison with other structurally viable timber, it was concluded that Apa timber (*Afzelia bipindensis*) is more structurally adaptable and reliable.

Keywords: Apa Timber, Structural performance, Strength Characteristics, Structural adaptable, Grain Alignment.

1. INTRODUCTION

Timber is one of the most frequently used building materials in the construction industry. Despite the discovery and availability of other materials, the relevance of timber for construction work remains significant due to its environmentally friendly nature and low handling cost. Nevertheless, insufficient information on the structural behaviour of timber member causes difficulties in adequate description and reliable design of timber structures (Eliska, 2013).

The use to which timber member is subjected determines its loading condition and this in effect constitutes its structural characteristic. There is need for sufficient information on the structural viability and market accessibility of timber species of interest, to ensure adequate use of the timber as construction material. It is a known fact that timber has a high strength to weight ratio, its strength and stiffness are dependent on the direction of load in relation to the grain alignment and it is strong and relatively stiff parallel to the grain alignment (Raji, 2013). The physical and mechanical properties of wood vary markedly, both with trees of the same species and among trees of different species (Okon, 2014). For evaluation of structural properties of timber, the determination of physical and mechanical properties of timber is important.

The main challenge to a reliable design of timber as structural member is to be acquainted with sufficient data about a given species of timber to ensure that the relevant performance criteria are met, as specified by relevant standards and codes. This implies that failure risk is reduced to the extent to which structural information about a given species of timber is readily available to timber designers, specifiers and construction regulators. A significant element of uncertainty is associated with lack of information on the physical variability as well as structural behaviour of material under load (Aguwa, 2012).

Afzelia bipindensis is grown in *Ajase Ipo*, in Kwara State, in North Central zone of Nigeria. It is readily available and extensively used in this area and many other part of Nigeria. The determination of strength characteristics of Nigerian grown species of Apa timber involves the evaluation of physical and mechanical properties and the establishment of the structural interrelationship of these properties. This study therefore, covers the evaluation of Nigerian grown Apa timber on the basis of its conformity to BS 373 specifications. The question of strength characteristic of Apa timber is therefore aimed at

reducing the structural risk of using the Apa timber for supporting and sustaining loads, in structural systems.

2. LITERATURE REVIEW

Timber being a natural composite material applicable in construction is relatively inexpensive building material used for a variety of structural applications ranging from building to transportation. Timber has inherent advantages that makes it especially attractive in specific structural applications (Afolayan and Adeyeye, 1998). Trees are classified into softwood and hardwood. The softwood is mostly conifers with needle – leaved evergreen trees like pines, cedar larches, araba, which comes from gymnosperms. The hardwoods are angiosperm with broad leaves and they range from Oak, Maple, Beech, Walnut, Mahogany, Teak, Balsa to Apa (*Afzelia bipindensis*), Iroko (*Meliaceae excelsa*), Lagos Mahogany (*Khaya ivorensis*), Obeche (*Triplochiton Scleroxylon*), Opepe (*Nauclea diderichii*) and Danta (*Nesogordonia papaverifera*) (Isiaka et al, 2013). The division of trees into hardwood and softwood refers to the botanical origin of timber and has no direct bearing on the actual softness or hardness of the wood (Jack and Abdy, 2007).

Wood and wood products appeal readily to structural and non - structural application. Lucas et al, (2006) stated that wood are currently being employed in building construction in Nigeria as: Poles used as studs, columns, beams, wall plates, rafters, and purlins largely in farm structures and rural residential buildings, and for scaffolding in multi-storey building construction sites; Posts in forms of round, hewn, squared or split wood, used principally for scaffolding, rafting and as columns and wall plates for farm houses, sheds, livestock buildings, storage structures, beams for drying platforms, and generally for fencing.

The multipurpose applications of timber are due to the fact that timber and other wood products have, for ages, remained one of the major structural materials for building construction worldwide due to their renewable nature, availability in various sizes, shapes and colours, affordability, relatively high fatigue resistance and specific strength, ease of joining, durability, and aesthetic appeal.

Along with the superior properties of timber, there are some undesirable properties, including its susceptibility to damage by fungus and beetles due to its organic structure. Its hygroscopic property and its flammability make it changes size due to moisture content and temperature (Kaygin and Akgun, 2008). These adverse effects can be addressed in the presence of adequate information on the structural or mechanical behaviour of timber. Unfortunately, there is lack of sufficient information on most structural timber in Nigeria and this remain the tenable excuse on the part of timber designer, handlers, suppliers and regulators of timber structure in the construction industry.

In Nigeria, however, the major area of structural utilization of timber is in roof construction, with the building industry alone consuming about 80% of the country's estimated 20 million cubic meters of annual lumber production (Alade and Lucas, (1982), Lucas and Olorunnisola 2002). According to Aguwa (2012) Structural timber is the timber used in framing and load-bearing structures, in which strength is the major factor in its selection and use. Properly processed softwoods can still be used in the building construction but in structures like bridges and railway sleepers, hardwoods are specially used (Karlsen and Slitskouhov, 1989).

The interest in Apa timber is born out of the fact that Apa (*Afzelia bipindensis*) is a very durable hardwood, has excellent resistance to attack by termites and available commonly in savannah and high forests. It is referred to as African wood because it is found in tropical Africa or Asia with origin from Cameroon. It is a hardy, fast – growing evergreen tree with a straight trunk. It remains smooth under friction and it shows only small movement with time. Apa timber has good machining qualities, it sands to a smooth surface and its uses include flooring, furniture, decking, stair rails and other common construction. (Aguwa, 2012). Despite its structural, commercial and manufacturing importance, its ecological, design and regulation options need to be improved upon for sustainable production, processing, design and application of Nigerian grown Apa timber.

Timber quality assessment involves the consideration of a large number of anatomical, physical and mechanical properties of wood. Most wood properties differ along different axes most especially between the radial and tangential axes which are relatively minor when compared to differences between the radial or tangential axis and the longitudinal axis (Amtzen and Charles, 1994). The most commonly measured physical properties includes, density, water absorption, swelling and water losing capacity etc. while the strength properties for design includes, compression, tensile, torsion, modulus of rupture impact loading capacity and flexure.

3. MATERIAL AND METHODOLOGY

Fresh log of Apa timber (*Azelia bipindensis*) was collected from forest in Ajase Ipo town, in Irepodun Local Government Area of Kwara State, Nigeria. The area lies within latitude $8^{\circ} 13' 60''$ N and longitude $4^{\circ} 49' 0''$ E. (Google map). The log as shown in plate 1 was transported to Irewolede estates sawmill for processing. The processing involved sawing, seasoning (open air method) and stock piling. Figure 1 shows typical sampling process for test specimen.



Figure1: Typical cross section of Apa log

Specimens for properties tests were prepared following the procedure of specified dimensions as contained in standard codes BS 373, in relation to each test.

3.1 Physical Properties

3.1.1 Moisture Content Determination

Moisture content is the amount of water contained in the wood, usually expressed as a percentage of the mass of the oven-dried wood. The percentage of moisture in each sample was determined before the test as described in BS 373. Six samples of sizes 50x50x50mm were collected from three different sections A, B and C, representing the bottom, middle and top section of the log, for each of the physical properties test. The moisture content of the samples was determined by weighing the test pieces at green state and after they were oven dried repeatedly in an oven at constant temperature of 103°C until constant values were obtained. The Moisture Content was calculated as expressed in Equation (1)

$$\text{M.C.} = \frac{\text{original mass} - \text{oven-dry mass}}{\text{oven-dry mass}} \times 100 \quad (1)$$

3.1.2 Density Determination

The density property of wood provides an index of wood quality to which end users can determine and differentiate wood (Walker, 2006). In wood science, oven-dry density and density at 12% MC are most frequently used (Kuklik, 2008). Timbers which are high in density have high compression strength across the grain (Akpan, 2006). Density is a measure of the wood substance contained in a given volume in accordance to BS 373. The expression for density is as given in Eq. (2)

$$\text{Density } \rho = \frac{\text{Mass}}{\text{Volume}} \quad (2)$$

3.1.3 Specific Gravity

Specific gravity of wood is the weight of any given volume of a substance divided by the weight of an equal volume of water in accordance to BS 373. The specific gravity of the samples is as given in Eq. (3):

$$\text{S. G.} = \frac{\text{weight of sample}}{\text{weight of equal volume of water}} \quad (3)$$

3.1.4 Volume Shrinkage

Volumetric shrinkage represents changes in dimension due to decrease in moisture contents. For this test, six samples of 20x20x60mm each from section A, B and C as specified in ASTM D143. $V_A = L_A \times W_A \times t_A$ = air dry volume $V_B = L_B \times W_B \times t_B$ = oven-dry volume. Equation for volumetric shrinkage is as given in Eq. (4) and the rate of shrinkage is provided in Eq. (5)

$$\text{Volume Shrinkage (\%)} = \frac{V_A - V_B}{V_B} \times 100 \quad (4)$$

$$\text{Shrinkage Rate} = \frac{\text{Average \% shrinkage}}{\text{Average \% moisture content}} \quad (5)$$

3.1.5 Swelling Test

Swelling property of timber is measured in terms of changes in dimension due to increase in moisture contents. For this test five specimen A, B and C of sizes 20x20x60mm were used. The initial weight and dimension of sample were taken and recorded. They were soaked in water and their weight checked at 3-day interval until no significant change was recorded. Then the dimension of the specimens measured at the end of the test is as given in Eq. (6):

$$\text{Swelling (\%)} = \frac{V_B - V_A}{V_A} \times 100 \quad (6)$$

Where V_A = Initial volume of test sample = $L_A \times W_A \times t_A$ V_B = Final volume of test sample = $L_B \times W_B \times t_B$

3.2 Mechanical Properties

3.2.1 Tensile Test

The strength test was carried out with the aid of a Universal Testing Machine. The arrangement of the test piece is as shown in Figure 2. The machine was capable of measuring the stress – strain to the required accuracy of 1% of the applied load. Tensile strength parallel-to-grain was calculated using the relation in Eq. (7):

$$\text{Tensile strength} = \frac{\text{Load at failure (N)}}{\text{Minimum Cross-sectional area (mm}^2\text{)}} \quad (7)$$



(a) Tensile test set up



(b) Failure of specimen

3.2.2 Compression Test

In evaluating the compressive property of wood, it is necessary to ensure that the specimen does not buckle during loading thereby subjecting it to bending rather than a compressive stress (Desch, 1992). This is because, unlike other materials, timber is significantly weaker in longitudinal compression than in longitudinal tension with value as low as one quarter (Porter 2001). For some selected end uses such as railway sleepers, rollers, wedges, bearing blocks and bolted timbers, resistance to crushing is an important property.

The compressive strength test was carried out with the aid of a Universal Testing Machine. The arrangement of the test piece is as shown in Plate 3. The maximum compressive strength parallel-to-grain was read directly from the recorded machine's chart. Maximum compressive strength parallel-to-grain was calculated using Eq. (8):

$$\text{Compressive Strength} = \frac{\text{Load at failure (N)}}{\text{Cross-sectional area (mm}^2\text{)}} \quad (8)$$

3.2.3 Bending Strength Test

Statics bending is one of the important properties for end use, because it is the measure of the load carrying capacity of a piece of wood when used as a beam rafters, bridges, stringers and flooring joists. Bending properties of timber increase from pith to bark in a tree (Ogunsanwo and Akinlade, 2011).

Six sample of length 300mmx25mmx25mm were used for this test which was conducted in accordance to BS 373. The load was applied centrally to each specimen and deflection obtained from the machine's chart as shown in Plate IV. Bending strength was calculated using Eq. (9):

$$\text{Bending Strength} = \frac{3Fa}{bd^2} \quad (9)$$



Figure 3: Compression test set up

F = Maximum Load, a = Distance between load and the nearest support. b = Width of cross-section, d = Depth of cross-section.



Figure 4: (a) Bending test set up (b) Failure mode

4. ANALYSIS AND DISCUSSION

4.1 Strength Properties at Standard Moisture Content

The moisture content for the determination of physio-mechanical properties of timber is stipulated at 12%. Conversion of the ultimate strength of timber at a given moisture content (between 8% and 23%) to the ultimate strength at a standard moisture content of 12% is given as Eq. (10):

$$F_{12} = F_w (1 + \alpha(W - 12)) \quad (10)$$

Where F_{12} is the ultimate strength at 12% moisture content, W is the moisture content at the time of testing, F_w is the ultimate strength, α is the correction factor. Table 3 gives various values of α . This equation can be adapted to convert strength values of timber from 12% moisture to the 18% moisture content approved in Northern Nigeria.

Table 3: Correction factor (α)

Stress state	α (for all wood species)
Compression parallel to the grain	0.05
Static bending	0.04
Shearing parallel to the grain	0.03

Source: Karlsen and Slitskouhov (1989)

4.2 Basic Tensile, Compressive and Bending Strength Determination

The basic tensile stress was determined from the experimental tensile stress at failure as provided in Eq. (11)

$$t_{b\ par} = \frac{f_m - 2.33\sigma}{2.25} \quad (11)$$

The basic compressive stresses parallel to the grain for the species were determined using the failure stresses from tests by

$$c_{b\ par} = \frac{f_m - 2.33\sigma}{1.4} \quad (12)$$

The basic bending stress were determined from the experimental bending stress at failure as given in Eq. (13):

$$f_{b\ par} = \frac{f_m - 2.33\sigma}{2.25} \quad (13)$$

Where $t_{b\ par}$, $c_{b\ par}$, $f_{b\ par}$ = Basic tensile, compressive and bending stress parallel to the grain respectively, f_m = Mean value of the failure stresses, σ = Standard deviation of the failure stresses

4.3 Modulus of Elasticity

Equation (xiv) formula below gives the relationship between the mean of modulus of elasticity (E_{mean}) and the statistical minimum value of modulus of elasticity (E_N) is given as Eq. (14).

$$E_N = E_{mean} - \frac{2.33\sigma}{\sqrt{N}} \quad (14)$$

Where E_N is the statistical minimum value of E appropriate to the number of pieces N acting together (where $N=1$, E_N becomes the value for E_{min}) and σ is the standard deviation.

4.4 Physical Properties

Table 4 in appendix shows the results of the physical properties of Nigerian species of Apa timber.

Table 4: Physical Properties of Apa timber from Kwara State, Nigeria

Properties	Bottom	Middle	Top	Average @ 12% M.C	Average @ 18% M.C
Moisture Content	14.95	11.01	10.33	12.1	18
Density	0.74	0.68	0.63	0.68	1.01
Specific Gravity	0.98	0.97	0.94	0.96	1.43
Swelling Test	9.68	8.95	8.16	8.93	13.28
Volumetric Shrinkage	7.53	9.27	12.10	9.60	14.28

4.5 Mechanical Properties

Table 5 in appendix shows the results of the mechanical properties of Kwara state's species of Apa timber in Nigeria.

Table 5: Mechanical properties of Apa timber from Kwara State, Nigeria

Mechanical Property (N/mm ²)	Mean Stress @ 12% (N/mm ²)	Mean Stress @ 18% (N/mm ²)	Standard Deviation	Basic Stress (N/mm ²)
Tensile Stress	69.61	104.41	18.83	26.90
Bending Stress	114.61	171.92	24.86	50.66
Compressive Stress	28.77	43.11	16.91	2.58
Modulus of Elasticity	10748.02	16122.03	24.86	9274.62

4.5 Confidence Limit

Statistical analysis of confidence limit was done for mean failure of stress at 18% moisture content and the result is as shown in Table 6. The upper limit of 99% and lower limit of 95% was adopted.

Table 6: Confidence limit of Apa timber from Kwara State, Nigeria

Mechanical Properties	Lower Limit (95%)	Upper Limit (99%)	Mean
Tensile Stress (N/mm ²)	107.37 to 101.45	109.17 to 99.65	104.41
Compressive Stress (N/mm ²)	45.76 to 40.46	47.38 to 38.84	43.11
Bending Stress (N/mm ²)	175.82 to 168.02	178.20 to 165.64	171.92

5. DISCUSSION

Aguwa (2012) conducted study on the same hardwood (Apa) and reported basic tensile and bending stresses parallel to grain of 28.85 and 29.92 (N/mm²) respectively. The values tensile and bending stresses obtained in table 5 are greater than the reported values for the same mechanical properties of Abura timber of 19.78 and 20.62 (N/mm²) by Aguwa (2013). Aguwa and Sadiku (2011) reported bending stress of 37.45 (N/mm²) for Ekki timber which is lower than the bending stress obtained for Apa timber in this study.

CONCLUSION

The top section of sample timber showed highest Modulus of Rupture (MOR) of 138.801 N/mm² while the middle and bottom sections recorded 121.705 N/mm² and 81.608 N/mm² respectively. This is opposite to the reported MOR for other tree like *Pinus patula*. According to Zelalem et al., (2014), *Pinus patula* has MOR of 109.36, 87.55 and 83.74 N/mm² at the bottom, middle and top section respectively. Jamala et al. (2013) reported that timber for structural purpose should have MOR value of 39 to 132 N/mm² and should be durable. From the result obtained in this study, *Afzelia bipindensis* timber meet up with this requirement and therefore is suitable for structural use as tie beams, rafters and purlins in house construction.

In comparison with some other species of tree, *Afzelia bipindensis* timber is more structurally viable. Jamala et al., (2013), reported the Modulus of Rupture and Modulus of Elasticity of the following timbers: *Celtis mildbraedii* (149.94 and 7088.69) N/mm², *Afzelia Africana* (136.71 and 6313.58) N/mm², *Khaya ivorensis* (94.82 and 8192.54) N/mm², *Meliceae excels* (90.41 and 5765.63) N/mm² and *Triplochiton scleroxylon* (30.87 and 3937.50) N/mm². From this study it can be deduced that *Afzelia bipindensis* with MOR and MOE of 171.92 and 9274.62 N/mm² at 18% moisture content is more structurally adaptable and reliable.

The specie of Apa (*Afzelia bipindensis*) timber grown in Kwara State Nigeria has been successfully characterized for structural purpose. It has been established that there is little difference in properties at the bottom, middle and top section of the log. However, the higher strength values observed at the middle section will guide structural designers in their design decision in relation to the use of the timber.

REFERENCES

- Afolayan, J.O. and Adeyeye, A. (1998). Failure Analysis of a Glue-Jointed Roof Truss. *Journal of Engineering & Applied Science*, Vol. 17 No1, pp. 51-63
- Aguwa, J. I. (2012). Reliability Assessment of the Nigerian Apa (*Afzelia Bipindensis*) Timber Bridge Beam Subjected to Bending and Deflection Under the Ultimate Limit State of Loading. *International Journal of Engineering and Technology*, (IJET) UK Vol. 2, No. 6, pp. 1076-1088
- Aguwa, J. I. (2013). Structural Reliability of the Nigerian Grown Abura Timber Bridge Beam Subjected to Bending and Deflection Forces. *Nigerian Journal of Technology (NIJOTECH)*. Vol.32. No. 2, pp. 241-252.
- Aguwa, J. I. and Sadiku, S. (2011). Reliability Studies on the Nigerian Ekki Timber as Bridge Beam in Bending under the Ultimate Limit State of Loading. *Journal of Civil Engineering and Construction Technology*. Vol. 2(11), pp. 253-259.
- Akpan, M. (2006). Studies on Physical and Mechanical Properties of Neem (*Azadirachta indica*) Wood in Relation to Utilization as Timber in North Eastern Nigeria. Unpublished Ph.D. Thesis, Department of Forestry and Wildlife Management, Federal University of Technology, Yola, Nigeria., pp 213.
- Alade, G.A. and Lucas, E. B. (1982). Timber Connector: A Major Contributor to Structural Failure in Wooden Components in Nigeria". Paper presented at the 36th annual meeting of the Forest Products Research Society, mechanical fastening session, New Orleans, U.S.A., June 24, pp. 22.

- Amtzen, S.E. and Charles J. (1994). *Encyclopaedia of Agriculture Science*. Orlando, FL Academic Press: Vol. 4, pp.549- 561.
- BS 373. (1957). *Methods of Testing Small Clear Specimens of Timbers*. British Standards Institution, London
- Desch, H. E. (1992). *Timber: Its Structure, Properties and Utilization*. Macmillan Educational Publications, London, pp. 410.
- Eliska B. (2013). *Constitutive Model of Timber*. Master Thesis, Faculty of Engineering, Department of Mechanics, Czech Technical University in Prague.
- Isiaka, O. O., Joseph, A O. and Mayowa. P. B. (2013). Mechanical Properties of Mahogany (*Swietenia Macrophylla*) and Araba (*Ceiba Pentandra*) Dusts Reinforced Polyester Composites. *Leonardo Electronic Journal of Practices and Technologies*, pp. 1 – 18
- Jack P. and Abdy, K. (2007). *Structural Timber Design to Eurocode 5*. Blackwell Publishing, Company USA.
- Jamala, G.Y., Olubunmi, S. O., Mada, D.A. and Abraham, P. (2013). Physical and Mechanical Properties of Selected Wood Species in Tropical Rainforest Ecosystem, Ondo State, Nigeria. *IOSR Journal of Agriculture and Veterinary Science*. Vol. 5, pp 29-33.
- Karlsen, G. and Slitskouhov. Y. U. (1989). *Wooden and Plastic Structures*. Mir Publishers Moscow, USSR, 1st Edition, pp 400.
- Kaygin, B. and Akgun, E. A. (2008). Nano – Technological Product: An Innovative Varnish Type for Wooden Surfaces. *Scientific Research and Essay* ISSN: 1992 – 2248. Vol. 4(1), pp. 001 – 007.
- Kuklík, P. (2008). Fire Resistance of Timber Structures. Handbook 1 – Timber Structures, Chapter 17, Leonardo da Vinci Pilot Project, CZ/06/B/F/PP/168007, Educational Materials for Designing and Testing of Timber Structures – TEMTIS.
- Lucas, E. B. and Olorunnisola, A.O. (2002). Wood processing and utilization in Nigeria: The Present Situation and Future Prospects, *Agricultural Engineering in Nigeria: 30 Years of University of Ibadan Experience*. Department of Agricultural Engineering, University of Ibadan, Nigeria. pp. 98-109
- Lucas, E., Olorunisola, A. and Adewole, N. (2006). Preliminary Evaluation of Guava (*Psidium Gujava L.*) Tree Branches for Truss Fabrication in Nigeria, *Agricultural Engineering International: CIGR Ejournal*.
- Ogunsanwo, O. Y. and Akinlade. A. S. (2011). Effects of Age and Sampling Position on Wood Property Variations in Nigeria grown *Gmelina Arborea*. *Journal of Agriculture and Social Research (JASR)* Vol. 11, No. 2.
- Okon, K. E. (2014). Variation in Specific Gravity and Shrinkage in wood of a 25 – year old (*Gmelina arborea*) in Oluwa Forest Reserve, South West Nigeria”, *Scholar Research Library* 6(4): ISSN: 0975 – 508X, pp 271 – 276.
- Perera, P.K.P. Amarasekera, H.S. and Weerawardena, N.D.R. (2012). Effect of Growth Rate on Wood Specific Gravity of Three Alternative Timber Species in Sri Lanka. *Swietenia macrophylla*, *Khaya senegalensis* and *Paulownia fortune*. *Journal of Tropical Forestry and Environment*. Vol. 2. No. 01. pp. 26 - 35
- Porter, B. (2001). *Carpentry and Joinery 3*. Butterworth Heinemann Publications, Oxford. pp. 288
- Raji, M.A. (2013). *Architecture and Emerging Cities: The Impact of Technological Change in Building Material, A Study of Minna, Nigeria*.
- Walker, J. C. F. (2006). *Primary Wood Processing: Principles and Practice*”. University of Canterbury, Christchurch, Springer, New Zealand.
- Zelalem, G. Pradeep, P. and Omprakash, S. (2014). The Influence of Physical and Mechanical Properties on Quality of Wood Produced from *Pinus patula* Tree Grown at Arsi Forest. *Advanced Research Journal of Plant and Animal Science* ISSN-2360-7947: Vol. 2(4): pp. 032-041