PHYSICAL AND STRENGTH PROPERTIES OF *AZADIRACHTA INDICA,* (A. Juss) GROWING IN MOROGORO, TANZANIA

Gillah, P.R., Augustino, S., Ishengoma, R.C. & Nkomulwa, H.O.

Department of Wood Utilization, Faculty of Forestry & Nature Conservation, Sokoine university of Agriculture, P.O Box 3014, Morogoro, Tanzania

Corresponding Author: pgillah@suanet.ac.tz

ABSTRACT

Physical and strength properties of *Azadirachta indica* growing in Morogoro, Tanzania were determined and the results compared with already known properties of timber of the same family. The properties determined included basic density, bending strength, stiffness, work to maximum load, total work, compression and shear parallel to the grain and cleavage strength. A total of 160 test samples were used from three trees randomly selected from the study area. Preparations of test samples, actual testing and determination of different properties were carried out following standard methods. All strength property values were adjusted to 12% moisture content. Results showed *A. indica* to have a mean basic density of 646 kg m^{-3}, classified as high density timber, comparable to that of *Khaya anthotheca* and *Trichilia emetica* from the same family. The overall strength properties of *A. indica* are lower compared to those of *K. anthotheca* and *T. emetica*, however, superior in terms of cleavage strength. Based on the studied properties, the species can successfully substitute *K. anthotheca* and *T. emetica* in uses which require high bending, cleavage and shear parallel to the grain strengths. *A. indica* wood is therefore recommended for uses other than fuel wood and poles such as making furniture, tool handles, artificial limbs, joinery and plywood.

Keywords**:** Physical properties - strength properties - *Azadirachta indica* - Tanzania.

INTRODUCTION

Azadirachta indica A. Juss (Neem), a cousin of Mahogany family, Meliaceae, is a small to medium-sized tree, usually evergreen, up to 25 m tall, with a round, large crown up to 10 (20 max.) m in diameter; spreading branches; branchless bole for up to 7.5 m, up to 90 cm in diameter, sometimes fluted at base; moderately thick bark, with small, scattered tubercles, deeply fissured and flaking in old trees, dark grey outside and reddish inside. Leaves are alternate, crowded near the end of branches, light green, with 2 pairs of glands at the base, otherwise glabrous. Flowers are white, bisexual or male on same tree, actinomorphic, small and slightly sweet scented. The fruit 1 (max. 2)-seeded drupe, greenish, greenish-yellow to yellow or purple when ripe (Kaale, 1984; ICRAF, 1992; Mbuya *et al*., 1994; Katende *et al*. 1995).

Neem tree grows well in low land tropics and is thought to be native to India and Myanmar but recently was introduced to many countries including Tanzania. The species is synonymous to *Melia azadirachta* and *Anteleae azadirachta*. *Melia azadirachta* has sometimes been confused with *Melia azadirach*, a west Asian tree commonly known as Persian lilac, Bakain, Dharak or Chinaberry (NRC, 1992). *A. indica* is thought to have been introduced in East Africa in the 19th century by Arab immigrants, however, there is scanty information describing the exact date and the introducer. According to Mugasha *et al.* (2001), Tanzania's interest in community forestry in the 1970s led to the planting of Neem trees in wood lots for fuel wood and poles in the country. According to Kaale (1984), the trees are distributed throughout the country in water logged and semi arid areas and used as an amenity in urban areas and for afforestation in the driest parts such as Dodoma.

The species has several uses ranging from products and services such as food for humans and fodder for animals, charcoal, timber, gum or resin, oil and medicinal as well as for shade and ornament in urban areas (Kaale, 1984; ICRAF, 1992). The species is said to be poisonous due to Azadirachtin which has been identified as *A. indica*'s principal active compound. Extracts can be made from leaves and other tissues, but the seeds contain the highest concentrations of the compound (ICRAF, 1992). People use the twigs as toothbrushes, and dentists find twigs effective in preventing periodontal disease. Neem oil is a powerful spermicidal and can therefore be used as an inexpensive birth control method. A Neem oil-based product, Sensal, is being marketed in India as an intravaginal contraceptive. Neem oil has been used traditionally as a topical treatment for skin symptoms in both humans and livestock, but it should not be ingested orally (NRC, 1992).

Despite all the mentioned uses of Neem wood, in Tanzania the wood is mainly used for fuel wood, charcoal and provides poles (Mugasha *et al*. 2001). According to Kaale (1984) the timber from the species has good resistance to termites and decay. Neem trees however, are among the wood species in Tanzania which are not explored in terms of their physical and strength properties. The species is not included even in the list of commercial timber of Tanzania (Bryce, 1967), a book which gives a summary of properties and uses of most timber species growing in Tanzania. If the properties were well studied, known, publicized and used, a great volume of prime timber such as *Khaya anthotheca* and others valuable timber species which are currently threatened by over exploitation (Ishengoma and Chihongo, 1995) would probably be available for high quality utilization. There's thus, a need to investigate and provide understanding on the physical and mechanical properties of *A. indica* grown in Morogoro District.

MATERIALS AND METHODS

The study area

Logs for test samples preparation were collected from Maseyu village in Morogoro Rural District, located at 6°34' - 6°45' South and 37°53' - 38°04' East of Greenwich. The area is about 50 km East of Morogoro and 150 km West of Dar es Salaam along Dar es Salaam - Morogoro highway. The climate is hot and humid. The area lies on the 700 - 1000 rainfall belt per year with a mean rainfall of 900 mm and at least two months with surplus rainfall over potential evaporation. A wet period is dominant between November to May. The driest months are August to October. The annual mean temperature is 24.3°C (Luoga, 2000). The soils are related to topography, mostly alfisols soils occurring on the undulating to rolling convex slopes on the piedmont of Kitulangalo hill. Mollisols and Inceptisols are also found on the gentle undulating concave valley bottom. The vegetation of the area is mostly covered with Miombo woodlands with dominant species being *Julbernadia, Brachystegia, Combretum* and *Acacia* trees (Luoga, 2000).

Collection of sample materials

Sampling

Three straight and tall mature trees, free from visible defects with a clear cylindrical bole and minimum branching were randomly selected from the study area and marked. Before felling, diameter at breast height (Dbh) was measured using a calliper. The sample trees were then felled and for each felled sample tree, the length from the bottom to where branching starts and the total tree height were measured using a measuring tape. Two 1.5m long logs of were cut from breast height of each tree upwards and marked accordingly. The measurements sampled trees are as shown in Table 1.

Table 1 Sample trees measurements

Tree number	DBH (cm)	Height to branching above DBH (m)	Total tree height (m)
1	28	3.2	7.3
2	24	3.0	5.2
3	32	3.6	8.0

Sawing

The 1.5m long logs were carried to a nearby sawmill for sawing. Sawing was done according to standard procedures described by Lavers (1969); whereby each of the 1.5 m log was rough sawn through and through making a centre plank of 65 mm thickness. The centre planks of 65 mm thickness were transported to Sokoine University of Agriculture, Wood Utilization Laboratory where they were stacked in the laboratory to air dry.

Laboratory procedures

Test samples preparation.

The centre cants were re-sawn to 30 x 65 x 1500 mm planks from the pith left right towards the bark. The planks were numbered and labelled sequentially to identify point of extraction from the pith towards east and west directions. The planks were then reduced to 1 m lengths, and the portions removed (0.5 m) were used for determination of basic density.

Determination of physical properties of wood

Determination of physical properties involved the preparation of test samples, determination of their moisture content and basic density.

Moisture content

Moisture content of each test sample for each strength test was determined at the time of test. During moisture content determination, initial weights of the test samples were measured before testing and placed in the oven at 103 ± 2 ^{o}C. Drying continued until when a constant weight was reached. To ascertain that a constant weight was reached, test samples were reweighed at regular intervals until when there was no appreciable difference between the last two readings. Time required for drying varied depending on the initial moisture content and size of test samples. Two readings for each test sample were recorded and the moisture content determined using a formula by ISO 3131 (1975).

Basic density

Wood basic density is based on oven dry weight and volume at specified moisture content. Wood test samples of 10 x 20 x 20 mm sizes for determination of basic density were extracted from 0.5 m length portion of cants. Test samples were first soaked in water until they sunk indicating that they were fully saturated with water or had attained maximum swollen or green volume. The green volumes of each test sample were obtained by displacement method according to Archimedes principle (Lavers, 1969). The test sample weights were obtained by first placing a graduated beaker on weighing balance half filled with distilled water. The balance was reset to zero. Test sample clamped in a needle was then immersed in water. Assuming the density of water is one, the weight of water displaced will then be equal to the volume of that test sample. Basic density (g cm^{-3}) was calculated using a formula by ISO 3131 (1975).

Determination of strength properties

Test sample preparations for different strength tests were done following standard methods (BS 373, 1957, 1976; Lavers, 1969; Ishengoma *et al.* 1997). The procedure involved air drying the 30 x 65 x 1000 mm planks until when the moisture content reached below 15%. This was followed by re-sawing the planks to 30 x 30 x 1000 mm scantlings and planning to 20 x 20 x 1000 mm size. Finally, from the scantlings, clear small test samples of different dimensions for different strength tests (Table 2) were extracted.

Table 2 Dimensions of different samples for strength tests

Test	Sample size (mm)	Number of test samples
Static bending	20 x 20 x 300	40
Compression parallel to the grain	15 x 15 x 45	40
Shear parallel to grain	20 x 20 x 20	40
Cleavage	20 x 20 x 45	40

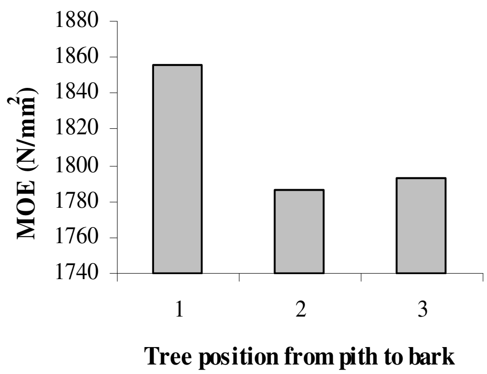
Determination of strength properties followed standard laboratory procedure for testing clear wood specimens as ascribed by BS 373 (1975), Lavers (1969), ISO 3131 (1975), ISO 3349 (1975) and Ishengoma and Nagoda (1991). Testing was done using Monsanto Tensiometer Wood Testing Machine. All strength properties were adjusted to 12% moisture content using a formula by Desch (1981). Microsoft Excel Computer software was used for analyzing data. The results were summarized and presented in tables and histograms. Regression analysis was performed to establish existence of relationships among properties.

RESULTS AND DISCUSSION

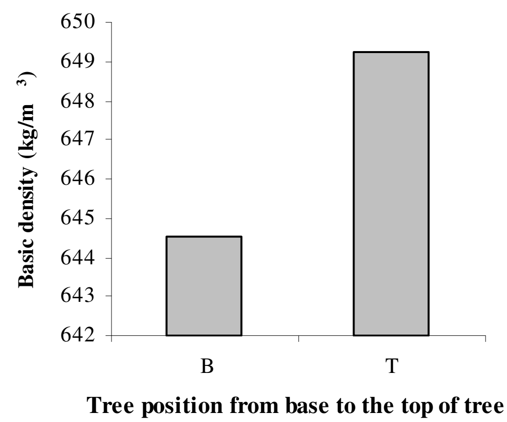
Wood colour and basic density

The wood colour of *A. indica* varies from greyish-white sapwood to brownish heartwood. Results indicated *A. indica* to have an average basic density of 646 kg/m^3, close to that of *K. anthotheca*, which is 657 kg/m^3 and *T. emetica* of 596 kg/m^3. The timber of *A. indica* can therefore be grouped or classified as a high density timber species, following a system used by Panshin and de Zeeuw (1970). The high density of *A. indica* wood observed could be attributed by some factors which are reported to affect the density of wood including genetic factors and modified environmental conditions (Hakan, 1996), site quality and climate (Elliot, 1970). Wood with high-density value is usually recommended for high tension works like bridge construction, housing, boat building and furniture (Desch and Dinwoodie, 1996).

Variations in basic density of sampled *A. indica* trees in radial and axial direction were also observed. Basic density increased from the pith to the bark (Figure 1a) and from the base to the top (Figure 1b).



(a)



(b)

Figure 1 Basic density variation in radial (a) and axial (b) directions for *A. indica* trees

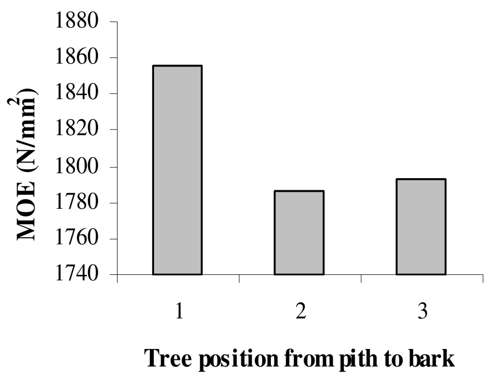
This trend is in agreement with Ishengoma and Gillah (1992) who reported that, core wood or juvenile wood is significantly lower in density than mature wood and hence the reduction in density as you move away from the butt end. This implies that the high-density wood from butt end logs should be used for structural purposes where high strength is required. However, according to Zziwa *et al.*, (2006), enforcement might be difficult because timber sawyers are usually after profit maximization and separation of timber on basis of location in a tree may have cost implications.

Though statistically results were not significantly different in radial direction ($p > 0.05$), the variation of wood density within a tree are thought to be attributed by age (Mendoza, 1988) a factor which could apply for sampled *A. indica* trees. As a general rule however, there is a gradual decrease in wood density in samples from successively higher levels in the trunk as heaviest wood is found at the base of the tree. Also at any given height in the trunk there is usually a general increase in density outwards from the pith, fairly marked in the rings near the pith as the effect of growth rate (Desch and Dinwoodie, 1996).

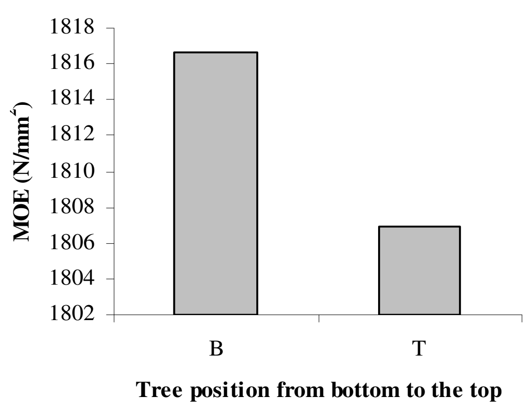
Strength properties

Modulus of elasticity (MOE)
A. indica was found to have MOE of 1812 N/mm^2, which is lower compared to other members of Meliaceae (Table 3). The MOE did not vary significantly ($p > 0.05$) in the radial direction. According to Ishengoma and Nagoda (1991), MOE expresses the relationship existing between stress-strain of wood. It is an important factor in determining the deflection of a beam under load and a measure of stiffness of a timber which controls the load bearing capacity of long columns. Normally, the greater the MOE, the stiffer the wood. From the results it implies that, for the uses of wood where stiffness is considered, the species is not as suitable as *K. anthotheca and T. emetica*.

Despite the lower value of MOE in *A. indica*, variations within a tree in radial and axial directions were observed for sampled trees. In radial direction, the wood showed high MOE at the pith, decreasing towards the bark (Figure 2a). The radial variation could probably be explained by the effect of microfibril angle which has been reported to decrease from pith to bark (Cowdrey & Preston, 1966; Bendtsen & Senft, 1986; Donaldson 1992; Butterfield & Pal, 1998). In axial direction MOE was high at the bottom decreasing toward the top (Figure 2b) probably due to the growing presence of juvenile wood caused by tree taper and its vicinity close to crown (Machado and Cruz, 2005).



(a)

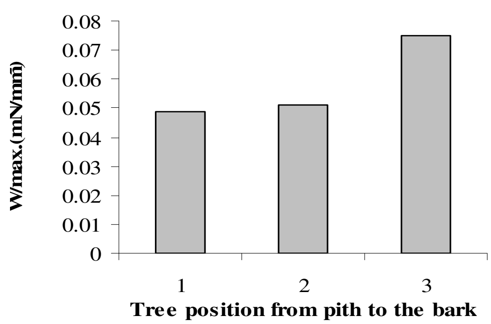


(b)

Figure 2 Modulus of elasticity variation in radial (a) and axial (b) directions for *A. indica*

Modulus of rupture
The Modulus of rupture (MOR) for *A. indica* was found to be 62 Nmm^{-2}, almost similar to

that of *T. emetica* (61N mm^{-2}) and lower than that of *K. anthotheca* (66N mm^{-2}). MOR is important where toughness and shock resistance is required (Lavers, 1969; Dick, 1972). From the results, the species can be used for example in making tool handles, sporting goods and other uses where toughness and shock resistance are required. The wood of sampled *A. indica* trees on the other hand showed high MOR at the pith, decreasing towards the bark (Figure 3a), despite lack of statistical difference ($p > 0.05$). This could be explained by the effect of microfibril angle which has been reported to decrease from pith to bark (Cowdrey & Preston, 1966; Bendtsen & Senft, 1986; Donaldson 1992; Butterfield & Pal, 1998).The trend was different in axial direction, where a great variation from the bottom to the top was observed (Figure 3b) probably due to the growing presence of juvenile wood caused by tree taper and its vicinity close to crown (Machado and Cruz, 2005).



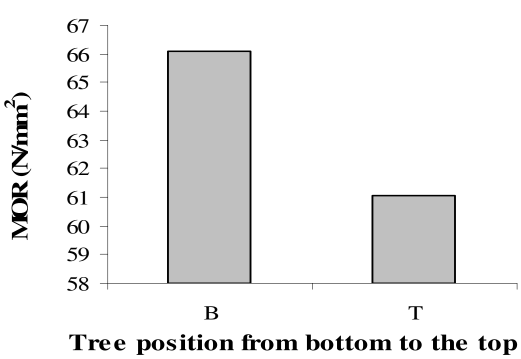
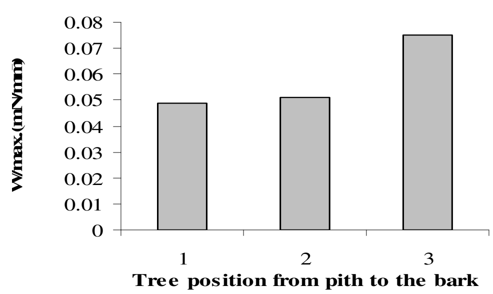


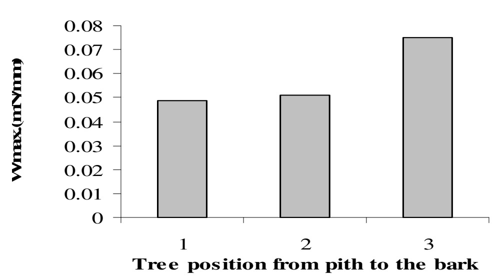
Figure 3 Modulus of rupture variation in radial (a) and axial (b) directions for *A. indica*

Work to Maximum load and total fracture

Results have indicated that the work to maximum load (W_{max}) for *A. indica* is 0.05mmN/mm^2 closer to the values for *K. anthotheca and T. emetica*, timber from the same family Meliaceae (Table 3). Nevertheless, despite lack of statistical difference in radial direction ($p > 0.05$), work to maximum load increased from the pith to the bark (Figure 4a), in agreement with (Desch, 1981) who noted that often the heartwood comprises of juvenile wood that is very weak. In axial direction the value of work to maximum load decreased from the bottom toward the top (Figure 4b) probably due to the growing presence of juvenile wood caused by tree taper and its vicinity close to crown (Machado and Cruz, 2005). Toughness (W_{max} and W_{total}) has been reported by Ishengoma and Nagoda (1991) to be important in timber subjected to shock load such as hummer handles, shunting poles, shuttles and sporting goods. This indicates that *A. indica* wood has the ability to absorb shock as *T. emetica* and thus be used to substitute that species for uses subjected to shock load**.**



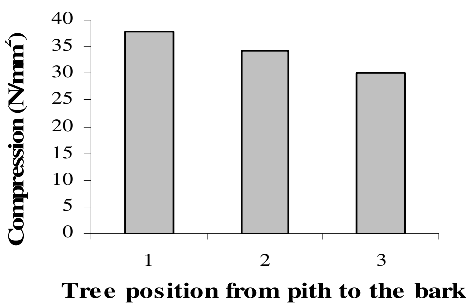
(a)



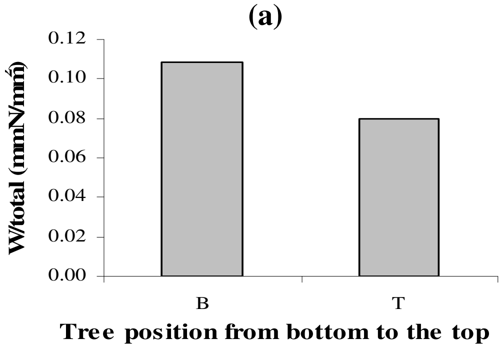
(b)

Figure 4 Work to maximum load variation in radial (a) and axial (b) directions for *A. indica*

Results also indicated that the total work (W_{total}) fracture of *A. indica* was 0.09mmNmm^{-2}. This value is slight higher than that of *T. emetica* (Table 3) and slight lower than that of *K. anthotheca*. Nevertheless, despite lack of statistical difference in radial direction ($p > 0.05$), a slight variation of total work to fracture within sampled *A. indica* tree was also observed to increased from the pith to the bark in radial direction (Figure 5a) in agreement with (Desch, 1981) who noted that often the heartwood comprises of juvenile wood that is very weak. Total work to fracture also decreased from bottom towards the top in axial direction (Figure 5b) probably due to the growing presence of juvenile wood caused by tree taper and its vicinity close to crown (Machado and Cruz, 2005). All in all results imply that the species can best be applied to uses in which the timber is subjected to shock load such as hammer handles and in many sporting goods compared to other two timber species of the same family Meliaceae.



(a)



(b)

Figure 5 Total work fracture variation in radial (a) and axial (b) directions for *A. indica*

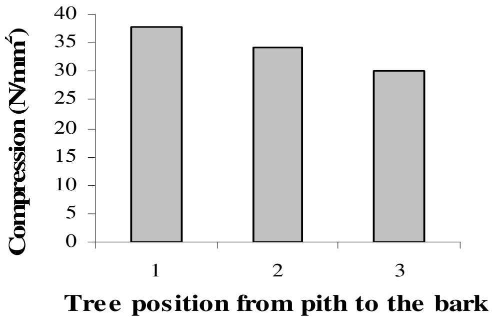
Compression parallel to grain

Results showed that *A. indica* timber has the compression strength parallel to the grain of 34.06 N/mm^2, a value lower than that of *K. anthotheca and T. emetica* (Table 3). There were variations of compression strength parallel to the grain within sampled tree in radial and axial directions, although this difference was not statistically significant ($p > 0.05$). The wood of *A. indica* showed a decrease of compression strength parallel to the grain from the pith to the bark (Figure 6a) and a high compression parallel to the grain at the bottom increasing to maximum towards the top (Figure 6b). The variations could probably be explained by differences between the structural arrangements of the wood fibres in radial and axial directions (Gibson & Ashby, 1997).

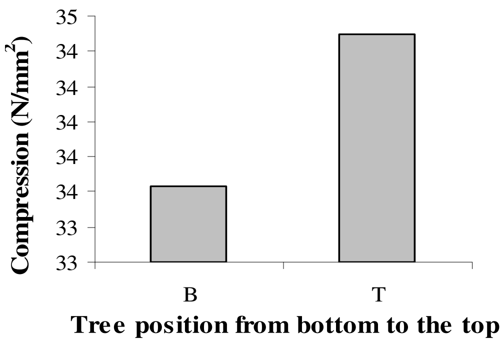
Table 3 Comparison of properties of *Azadirachta indica* with other Meliaceae members

Species/ Properties	*Azadirachta indica*	*Khaya anthotheca**	*Trichilia emetica**
Basic density (kgm^{-3})	646	657	596
MOE (Nmm^{-2})	1811	9604	8496
MOR (N/mm^2)	62	66	61
W_{max} (mmNmm^{-2})	0.05	0.07	0.06
W_{total} (mmNmm^{-2})	0.09	0.11	0.07
Shear parallel to the grain (Nmm^{-2})	12.9	10.1	13.2
Compression parallel to the grain (Nmm^{-2})	34.1	48.3	42.6
Cleavage strength (Nmm^{-1})	19.4	11.0	10.0

According to Dinwoodie (1981), compression strength is important for wood used in columns and structural works. On the other hand, Ishengoma and Nagoda (1991) noted that the crushing strength value is directly proportional to the toughness of wood in carrying load when used in structural works. Based on the above facts, it seems that *A. indica* can be used for high constructions works which require high compressive strength parallel to the grain.



(a)



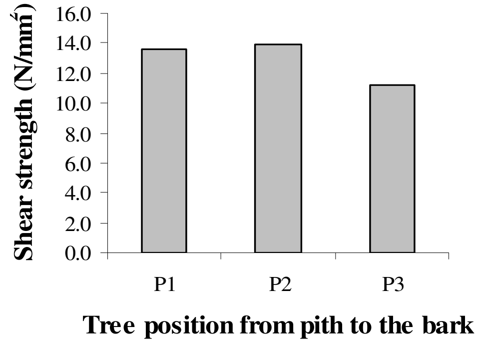
(b)

Figure 6 Compression strength variations in radial (a) and axial (b) directions for *A. indica*

Shear strength

A. indica wood was observed to have higher shear strength than that of *K. anthotheca and T. emetica* timbers (Table 3). The species however, showed variation of shear strength in radial and axial directions, though not statistically significant ($p > 0.05$). Shear strength seems to be high at the pith, increasing outwards and then decreasing close the bark (Figure 7a) and axially the value tended to increase from the bottom toward the top (Figure 7b). The variations could probably be explained by differences between the structural arrangements of the wood fibres in radial and axial directions (Gibson & Ashby, 1997). Shear strength is important in designing of joints especially in construction work (Ishengoma and Nagoda, 1991) and low shear strength presents design of joint problems (Walker, 1993). This means that *A. indica* is superior for use in designing of joints as compared to species like *K. anthotheca*.

Therefore, *A. indica* can substitute this timber species in those applications.



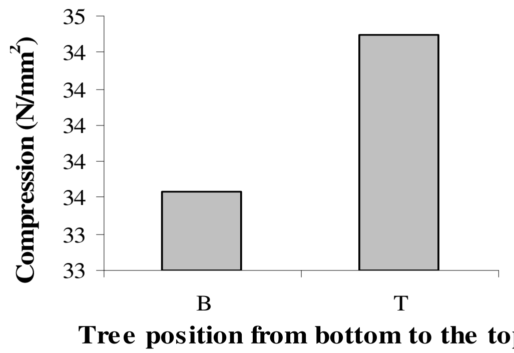
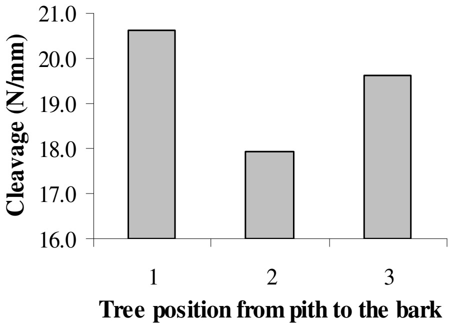


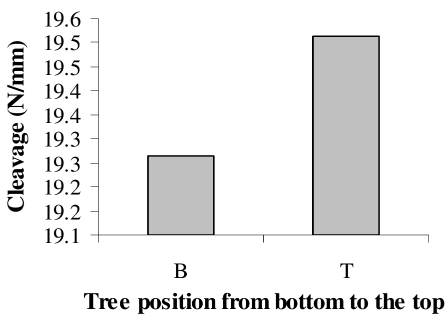
Figure 7 Shear strength variations in radial (a) and axial (b) directions for *A. indica*

Cleavage strength

The cleavage strength of *A. indica* was found to be 19.39 N/mm, a value which is greater than that of other two members of Meliaceae (Table 3). This means that the species can be used to substitute *K. anthotheca and T. emetica*. Despite lack of statistical difference in radial direction ($p > 0.05$), the wood of *A. indica* showed high cleavage strength at the pith, decreasing outwards and then increasing toward the bark (Figure 8a). There was an increase from the bottom towards the top in axial direction (Figure 8b). The variations could probably be explained by differences between the structural arrangements of the wood fibres in radial and axial directions (Gibson & Ashby, 1997). Cleavage is defined as a measure of resistance in wood against splitting and is needed when nails and other fasteners are used (Ishengoma and Nagoda, 1991). This implies that *A. indica* could be the best choice for the uses where nails and screws are used like in package cases.



(a)



(b)

Figure 8 Cleavage strength variations in radial (a) and axial (b) directions for *A. indica*

Conclusion and Recommendations

From the study the following conclusions can be drawn:

i) *A. indica* timber has mean basic density of 646 kg/m3. Its colour varies from greyish-white (sapwood) to brownish (heartwood), different from other two members of Meliaceae *i.e. K. anthotheca* (with yellowish-brown sapwood and reddish-brown heartwood) and *T. emetica* (usually pinkish in colour with little difference between sapwood and heartwood).

ii) The strength properties of *A. indica* include Modulus of rupture (62 N/mm^2), Modulus of elasticity (1811 N/mm^2), work to maximum load (0.05 mmN/mm^3), Total work (0.09 mmN/mm^3), Compression parallel to the grain (34.1 N/mm^2), Shear parallel to the grain (12.9 N/mm^2) and cleavage strength of about 19.4 N/mm.

iii) The timber of *A. indica* is comparable to those of *K. anthotheca* and *T. emetica* in terms of basic density and colour. In terms of strength properties, *K. anthotheca* and *T. emetica* are stiffer than *A. indica*. The timber of *A. indica* has comparable bending strength to that of *K. anthotheca* and *T. emetica*, however, has higher total work to that of *T. emetica*. The superiority of *A. indica* is in cleavage strength which is higher than that of *K. anthotheca* and *T. emetica.*

iv) Based on wood colour, basic density and strength properties, *A. indica* can successfully substitute the other two Meliaceae timber species in uses which demand bending strength, shear strength parallel to the grain and cleavage strength.

v) From the properties determined, *A. indica* timber is suitable for uses such as tool handles, sporting goods, shunting poles, construction works, design of joints and manufacture of packaging cases.

REFERENCES

Bendtsen, B.A. & Senft, J.F., 1986. Mechanical and anatomical properties in individual growth rings of plantation-grown eastern cottonwood and loblolly pine. Wood Fibre Science, 18(1):23-38.

Bryce, J.M., 1967. The commercial Timber of Tanzania. Forestry division, Ministry of Agriculture and Cooperative, Utilization Section Moshi, Tanzania. 315 p.

BS 373, 1957. Methods of Testing Small Clear Specimens of Timber. British Standard Institution, London. 32 p.

Butterfield, B.G. & Palv, LV., 1998. Relating microfibril angle to wood quality in clonal seedlings of radiata pine. Proceedings of the IAWA/IUFRO International Workshop on the significance of microfibril angle, Christchurch, NZ: University of Canterbury. pp. 337-347.

Cowdrey, D.R. & Preston, R.D., 1966. Elasticity and microfibrillar angle in the wood of *Sitka spruce*. Proceeding of the Royal Society of London B, 166: 245-271.

Desch, H.E., 1981. Timber: Its Structure and Properties. 6th Edition. Macmillan Press Limited, London. 410 p.

Desch, H.E & Dinwoodie, J.M., 1996. Timber: Structure, Properties, Conversion and Use. 7th Edition. Macmillan Press Ltd, London. 306 p.

Dick, J.B., 1972. Handbook of Hardwoods. Building Research Establishment, Princes Resborough, Buckinghamshire. 254 p.

Dinwoodie, J.M., 1981. Timber: Its Structure and Behaviour. Van Nostrand Reinhodl Company Ltd., England. 350 p.

Donaldson, L.A., 1992. Within- and between-tree variation in microfibril angle in *Pinus radiata*. New Zealand Journal of Forest Science, 22(1):77-86.

Elliot, G.K., 1970. Wood density in conifers. Commonwealth Forestry Bureau. Technical Communication, No 8, Oxford, England. 44 p.

Gibson L.J. & Ashby, M.F., 1997. Cellular solids: structure and properties. Cambridge University Press, Cambridge, UK. 234 p.

Hakan, L., 1996. Basic density in Norway spruce. Wood and Fibre Science, 28 (40).

ICRAF, 1992. A selection of useful trees and shrubs for Kenya: Notes on their identification, propagation and management for use by farming and pastoral communities. ICRAF Annual Report, Nairobi, Kenya. 28 p.

Ishengoma, R.C. & Nagoda, L., 1991. Solid Wood: Physical and Mechanical Properties. A teaching compendium, Faculty of Forestry, Sokoine University of Agriculture, Morogoro. 282 p.

Ishengoma, R.C. & Gillah, P.R., 1992. Comparison of basic density, strength properties and fibre length of juvenile wood of *Pinus patula*, grown in Meru Forest Plantation, Arusha. Faculty of Forestry Record No. 55.

Ishengoma, R.C. & Chihongo, A.W., 1995. Strength properties of lesser known *Brachystegia* species (*Brachystegia longifilia, Brachystegia boehmii* and *Brachystegia lamarindoiles*). Commonwealth Forestry Review 74(2).

Ishengoma, R.C., Gillah, P.R. and Chihongo, A.W., 1997. Properties of lesser utilized *Trichilia emetica* (*T. rocka*) and *Pterocarpus stolzii* timber species of Tanzania. Annals of Forestry, 5: 10 – 15.

ISO 3131, 1975. Wood Determination of moisture contents for physical and mechanical tests. International Organization for Standardization, UDC 674.03, 543.812. 34 p.

Kaale, B.K., 1984. Trees for Village Forestry. Forest Division. Ministry of Lands, Natural Resources and Tourism, Dar es salaam, Tanzania. 125 p.

Katende A.B., Birnie, A. & Tegnas, B., 1995. Useful trees and shrubs for Uganda. Identification, Propagation and Management for Agricultural and Pastoral Communities. Regional Soil Conservation Unit (RSCU), Swedish International Development Authority (SIDA). 710 p.

Lavers, G.M., 1969. The Strength Properties of Timbers. 2nd Edition. Forest Products Research Laboratory Bulletin 50, HMSO. London, 62 p.

Luoga, E.J., 2000. The effect of human disturbances on diversity and dynamics of eastern Tanzania miombo arborescent species. PhD Thesis, University of Witwatersrand, Johannesburg, South Africa.

Machado, J.S. & Cruz, H.P., 2005. Within stem variation of Maritime Pine timber mechanical properties. Holz als Roh-und Werkstoff, 63(2): 154 -159.

Mbuya, L.P., Msanga, H.P., Ruffo, C.K., Birnie, A. & Tengnas, B., 1994. Useful trees and shrubs for Tanzania: Identification, Propagation and Management for Agricultural and Pastoral Communities. Regional Soil Conservation Unit (RSCU), Swedish International Development Authority (SIDA). 541 p.

Mendoza, B.A., 1988. The effect of density and some machining variable on power consumption and planning quality of Coconuts (*Cocos nucifera* Linn) Lumber. FPRADI-Journal 17(1-4).

Mugasha A.G., Chamshama, S.A.O., Singo K. & Mgangamudo, M.A., 2001. Early performance of *Azadirachta indica* provenances at Mkundi and Chamwino, Tanzania. Journal of Tropical Forest Sciences 17(1).

National Research Council of United States of America (NRC), 1992. Neem: A Tree for Solving Global Problems. National Academic Press, Washington, DC. 141 p.

Panshin, A.J. & de Zeeuw, C., 1970. Textbook of Wood Technology, 3rd Edition. Mc Graw–Hill Book Co. New York. 705 p.

Walker, J.C.F., 1993. Primary Wood Processing: Principles and Practice. Chapman and Hall, London. 89 p.

Zziwa, A., Kaboggoza, J.R.S., Mwakali, J.A., Banana, A.Y. and Kyeyune, R.K., 2006. Physical and mechanical properties of some less utilized tropical timber tree species growing in Uganda. Uganda Journal of Agricultural Sciences, 12(1): 29 – 37.