PROPERTIES OF ALBIZIA SCHIMPERIANA OLIV.: A LESSER-KNOWN AGRO-FORESTRY TIMBER SPECIES FROM MOSHI RURAL DISTRICT, KILIMANJARO TANZANIA

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ABSTRACT

Albizia schimperiana Oliv. is a lesser- known and lesser-utilized timber species found in the tropical eastern Africa. In Tanzania, particularly Kilimanjaro region this species is incorporated in agro-forestry systems as a shade tree for coffee. Using standard methods, this study investigated some potentials of *A. schimperiana* for timber. The studied properties are: i) Physical – Tree dimension, form and quality, wood colour, texture, workability and basic density ii) Strength - Static bending, compression, shear and cleavage. The average physical properties of *A. schimperiana* are as follows: The colour of sapwood is yellowish-white while that of heartwood is medium-brown and basic density is 455 kg m^{-3}. The strength properties are: Modulus of elasticity (7,182 Nmm^{-2}), Modulus of rapture (53.14 Nmm^{-2}), Work to maximum load before failure (0.381 $mmNmm^{-3}$), Compression parallel to the grain (35.5 Nmm^{-2}), Shear parallel to the grain (12.0 Nmm^{-2}) and Cleavage (18.5 Nmm^{-2}). The average strength properties are closely comparable to those of *Bombax rhodognaphalon, Entandrophragma stolzii* and *Maesopsis eminii.* With increasing scarcity of timber therefore, *Albizia schimperiana* can replace some uses of these traditional timber species. There is a strong relationship between basic density and strength properties except for Modulus of Elasticity. *Albizia schimperiana* should be promoted in agro-forestry and plantations to improve its timber availability and utilized in various uses as a substitute timber and also due to its high potential for climate change mitigation.

Key words: Mfuruanje-density-Marangu-*Maesopsis eminii- Bombax rhodognaphalon*

INTRODUCTION

The 33.6 million hectares of Tanzania's natural forests are recognized by FAO (1996) to be rich in tree species composition. The presence of wood species with varying properties and characteristics poses stubborn problems impending the full utilization of these forests (FAO, 1976). The selection of tree species for utilization, apart from its availability, depends on how well the user is informed on the quality of wood. This is signified by the technical performance of wood in physical and mechanical properties (Ishengoma *et al.*, 2004). In this aspect, much pressure is exerted on the well known commercial timber species such as *Milicia excelsa*, *Pterocarpus angolensis*, *Ocotea usambarensis* and *Khaya anthotheca*, which are increasingly over exploited. Ishengoma *et al.* (2000) reported that only a few well known tree species are commercially utilized and often used for purposes which other lesser-known or lesser-utilized but equally suitable and cheaper timber species could be used.

The terms lesser-known wood species, secondary species and little-used species have been used to characterize insufficiently used wood species. None of these terms is associated with an exact description of the circumstances which make a particular species lesser-known, little-used, or secondary. There are several reasons which make it difficult to arrive at plausible and generally valid definitions, for instance, it may happen that a particular species is little used in one country and fully commercialized in another. Also in some countries statistics of wood species are insufficiently covered, mainly because of insufficient attention given to collecting production trade and consumption data (FAO, 1976). If the technical properties of lesser-known species are known and found to be suitable for different uses, and if through promotion the properties and uses are brought to attention of different users, they can replace or substitute some of the primary well known timber species threatened by over exploitation and expand timber market (Gillah *et al.*, 2005).

The well known commercial timber species are very scarce if not depleted and their regeneration is threatened (Ishengoma *et al.*, 2000). Increasing efforts are needed to introduce lesser known species and to intensify regeneration. Because of the strong relationship between wood properties and end use requirements in aspects of physical and mechanical properties (FAO, 1976), the information on the lesser-known timber species, therefore, need to be availed for market promotion. Improving timber utilization calls for optimization of the values of the individual species. The greater use of the lesser-known species of commercial importance adds to the benefit of consumer as well as that of the nation as a whole.

Albizia schimperiana Oliv. syn. *A. schimperana* Oliv., *A. amaniensis* Baker f., *A. maranguensis* Engl. (CELP, 2001), is geographically distributed in Eastern, Central and Southern Tropical Africa (Brenan, 1959; CELP, 2001). This species, also known in English as long-podded albizia is a lesser-known timber species documented by Brenan and Greenway (1949) and Brenan (1959) with its natural range in Tanzania widespread particularly in the Usambara, Pare, Meru and Kilimanjaro mountains, growing at between 1,000 and 1,700 masl (Lambrechts *et al.*, 2002). CELP (2001) however, documented a wide distribution from lowland, submontane to montane forest. It is also documented by CELP (2001) to be locally known by such vernacular names as olsanguwesi (Maasai), mfuruanje/mruka (Chagga), mchenje (Gogo), mkenge (Luguru) and mshai (Sambaa). This species whose family is Fabaceae and subfamily Mimosaceae is commonly used in agro-forestry systems (Anthofer *et al.*, 1998; Stigter *et al.*, 2002) as a shade tree for coffee particularly in Kilimanjaro region (Fernandes *et al.,* 1984; Mndeme, 1997; Hemp, 2005). Mbuya *et al.* (1994), Zewge *et al.* (2003), Deribe (2008) and MGT (2009) documented other uses to include woodfuel, timber, tool handles, medicine, stools, grain mortars, spoons and bee forage.

This study investigated some physical and mechanical properties of *Albizia schimperiana* growing naturally in agro-forestry systems in Marangu, Moshi Rural District Tanzania for enhancement of its efficient utilization. Specifically, the study dealt with the following:

i. Physical properties of *A. schimperiana*
   a. To determine tree dimension, form and quality
   b. To determine wood colour, texture and workability
   c. To determine wood basic density

ii. Mechanical properties of *A. schimperiana*
   a. To determine wood static bending properties including
      - Modulus of Elasticity (MOE)
      - Modulus of Rapture (MOR)
      - Work to Maximum Load
   b. To determine wood compression strength parallel to the grain
   c. To determine wood tangential shearing strength.

METHODOLOGY

Study area description

The test samples were collected from Marangu West Ward, located in Moshi Rural District in Kilimanjaro Region between latitudes $7^0 48'$ – $8^0 20'$ S and longitudes $35^0 40'$– $37^0 00'$ E at an altitudinal range of between 1,300 and 1,890 masl. This area has a bimodal rainfall pattern with short rains from October to December and long rains from March to May making an average annual rainfall of between 1,000 and 1,700 mm (Fernandes *et al.,*1984; Mungo, 2003). The soils are volcanic, fertile with a high base saturation and cation exchange capacity.

Marangu Ward which is situated about 30 km North East of Moshi town, is one of the most densely populated areas in Tanzania with over 320 reported by Mungo (2003) nevertheless, Fernandes *et al.* (1984) reported about 500 people km^{-2} particularly in the southern parts. The major tribe in the area is Chagga who practice agro-forestry. The major components of this system are coffee, multipurpose trees mainly *Albizia schimperiana*, *Croton macrostachys*, *Grevillea robusta*, *Persea americana*, and *Rauvolphia caffra* and banana and vegetables in combination with zero grazed livestock.

The natural vegetation is of montane rain forest type, composed of such species as *Albizia* spp *Ocotea usambarensis, Podocarpus usambarensis, Newtonia buchananii, Macaranga kilimandscharica, Olea africana and Olea welwitschli*

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Sampling, material collection and preparation

Thirty five randomly selected standing *Albizia schimperiana* trees from farmers' agro-forestry plots were assessed for their dimensions in which diameter at breast height (dbh), total tree and merchantable heights were measured. Other parameters including crown diameter, tree bole straightness and cylindricity, all of which are important when considering a tree for agro-forestry and timber, were inspected visually. From this sample, three mature and defect free trees whose measurements are presented in Table 1 were objectively selected, felled and from each, three 1.5 m long logs bucked from the butt, middle and top of the bole length of each sample tree and marked accordingly. The logs were thorough and thoroughly pitsawn (Lavers, 1969) and from each, a 65 mm thick and 1.5 m long central plank was extracted meanwhile careful observation was being made to describe the colour and figure of the wood (ISO 7724,1984). The planks were finally transported to the SUA Wood Utilization Laboratory in Morogoro for further processing.

Table 1 Sample tree measurements for *Albizia schimperiana* from agro-forestry in Moshi Rural District, Kilimanjaro Tanzania

Tree No.	Dbh (cm)	Crown diameter (m)	Height (m)
1.	122.5	13.5	38.5
2.	98.6	11.5	33.5
3.	120.8	12.0	40.0

At SUA, the planks were re-sawn into small scantlings measuring 30 mm x 65 mm x 1000 mm, from the pith left and right towards the bark. The scantlings were numbered and labeled accordingly, to show the position of extraction and then were air dried, planed to 20 mm x 20 mm x 1000 mm before being converted into test samples for various strength tests (Table 2). For basic density determination, 10 mm x 20 mm x 20 mm specimens were extracted from 0.5 m length portions of each scantling.

Table 2 Test sample dimensions and count for determination of strength properties of *Albizia schimperiana* from agro-forestry in Moshi Rural District, Kilimanjaro Tanzania

Test	Sample size (mm)	Sample count
Basic density	50 x 20 x 20	52
Static bending	20 x 20 x 300	52
Compression parallel to the grain	20 x 20 x 60	52
Shear parallel to the grain	20 x 20 x 20	52
Cleavage	20 x 20 x 45	52

Laboratory procedures

Determination of physical properties

Laboratory determination of physical properties of wood of *A. schimperiana* involved examining wood colour, texture and workability and preparation of test samples for determination of basic density.

Wood colour, texture and workability

The colour of the timber of *A. schimperiana* was determined using standard methods described by ISO 7724 (1984) after authentic samples were seasoned and planed. The texture was determined by visual methods, supplemented by feeling with hand the fineness of the planed timber surface. The timber workability was assessed through sawing, planning, sanding, nailing, screwing and polishing.

Basic density

Basic density was determined according to the method described by ISO 3131 (1975), employing oven dry weight and maximum moisture content volume.

Determination of mechanical properties

The tests were carried out following the procedures described by Lavers (1969),BS 373 (1957; 1976), ISO 3133 (1975), Panshin and de Zeeuw (1980) and Desch (1981) for testing clear wood specimens. All the tests were carried out at room temperature and relative humidity, using Monsanto Tensometer wood testing machine.

Data analysis

Analysis of results was accomplished employing descriptive statistics, variance and simple regressions. The properties of *Albizia schimperiana* were compared with those of selected well-known and better or even over-utilized timber species as documented by other researchers. These species are *Bombax rhodognaphalon* K. Schum., *Entandrophragma stolzii* Harms. and *Maesopsis eminii* Engl. *Albizia amara* (Roxb.) Boivin was included in the least as it is also still a lesser known timber species though its technical information was availed almost a decade now by Ishengoma *et al.* (2000). The selection of the former species was based on similarities in the studied properties between *Albizia schimperiana* and the selected species.

RESULTS AND DISCUSSION

Physical properties

Tree dimension, form and quality

Results confirm that *Albizia schimperiana* is a semi-deciduous tree with average crown diameter of 10.5 m. The tree has dbh ranging between 45 to over 210 cm and a mean height of 30 m. The bole is straight, medium to 30 m which is congruent to observations made by CELP (2001). The tree has numerous and heavy branches whose diameters reach 80 cm which can make them useful for timber as well. For this species, CELP (2001) and Deribe (2008) reported dbh of 200 cm and total height reaching 45 m, whereas Kainkwa and Stigter (2000) reported average crown diameter of 10 m.

These findings are an indication that the species has large crown making it suitable for coffee shade and wind protection as also noted by Stigter *et al.* (2002) and highly prolific in terms of merchantable timber. From this biomass, the species is suitable for mitigating climate change through carbon sequestration (Schlamadinger and Marland, 1995; 1996; Gustavsson *et al.,* 2006; 2007; SRU, 2007). Nonetheless, FAO (1984) noted that the tree takes over 100 years to reach maturity. On the other hand, from 1952 to 1982, the forest cover in the area had declined by 38.6% (Mungo, 2003) and timber species such as *Ocotea usambarensis* (camphor) had almost disappeared.

Growing this species can still be economically viable as it is for multipurpose uses. The bark is reported by Mungo (2003) to be of medicinal value treating headache and general body malaise and since it is rough, it is used for brushing human feet for enhancing smoothness. *Albizia schimperiana* is among the indigenous species highly valued by communities not only for wood but also their aesthetic and spiritual values (Zewge *et al.*, 2003). In the Maasai communities for instance, Mhita (2006) documented that the exuding of water from the leaves of *Albizia schimperiana* before the onset of the rains is generally accepted as indication of a good forthcoming rain season.

Wood colour, texture and workability

Whereas the sapwood of *Albizia schimperiana* was found to be yellowish-white, the heartwood is medium brown. The texture is coarse with irregular and interlocked grain and the timber has flecking characteristics which, as it has been put forward by Bryce (1967) it is indicative of this species' abundance of parenchyma tissues. The workability of the species' timber could be challenging due to fine chocking dust, blunting effects on tools, the irregular grain and large and numerous knots. The timber nailed with difficulty accompanied with splitting and poor nail-holding power and dried very slowly with little degrade. It was good on finishing nevertheless, leaving a somehow rough surface. These characteristics are also documented by MGT (2009).

Basic density and its variations

The mean basic density of *Albizia schimperiana* was 455 kgm^{-3}, which according to Panshin and de Zeeuw (1980) classification system is medium density timber or, as classified by MGT (2009), the timber is fairly heavy. This density is close to those of *Bombax rhodognaphalon* and *Entandrophragma stolzii* both of which have 465 kgm^{-3} and higher than that of *Maesopsis eminii* of 417 kgm^{-3}. On the other hand, *Albizia amara* with density of 677 kg m^{-3} is classified as heavy timber.

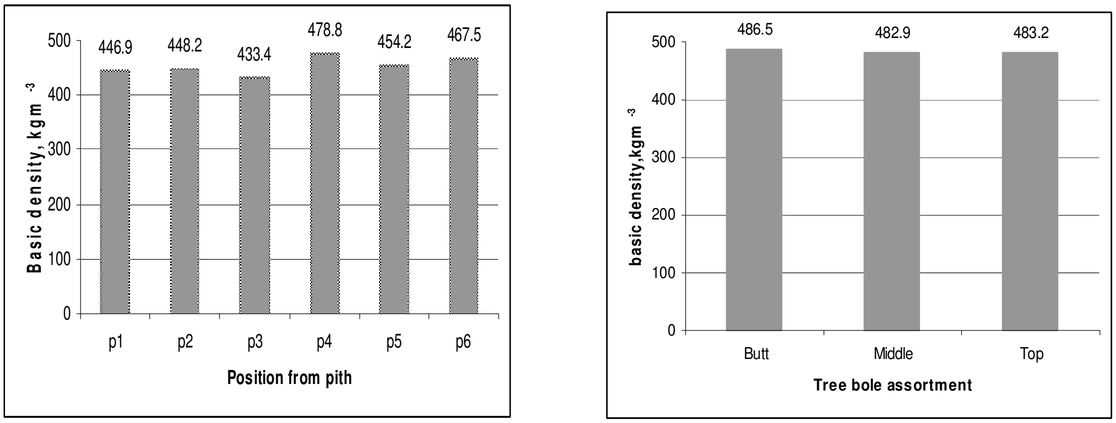
Variation in basic density was assessed between and within a tree in both radial and axial directions based on average values. Results for the between tree variations are presented in Table 3. The variations of density between the three studied trees were not significant ($p \leq 0.05$) indicating that any mature defect free tree of *Albizia schimperiana* can equally be weighted if however, careful assessment is conducted during sampling.

Table 3 Between tree variation in basic density and strength properties for *Albizia schimperiana* from agro-forestry in Moshi Rural District, Kilimanjaro Tanzania

Strength property	Tree mean value			Overall mean value
	Tree 1	Tree 2	Tree 3	
Basic density, kg m^{-3}	448	451	462	455 ± 18
MOE, Nmm^{-2}	6,974.76	7,214.06	7,213.73	7,182.29 ± 714
MOR, Nmm^{-2}	46.67	56.30	51.54	53.14 ± 11.05
WorkMax, mmNmm^{-3}	0.56	0.71	0.77	0.67 ± 0.11
Compression, Nmm^{-2}	33.42	36.12	38.61	35.50 ± 1.0
Shear stress, Nmm^{-2}	11.43	14.31	15.51	12.00 ± 2.39
Cleavage, Nmm^{-2}	15.91	20.31	21.33	18.48± 2.05

The radial and axial variations of basic density within a tree are presented in Fig. 1 (a) and Fig. 1 (b), respectively. In the radial direction, *Albizia schimperiana* has the most dense wood in areas middle to the pith and bark (478.8 kg m^{-3}), followed by slight decrease towards both directions with the lightest wood around the pith (about 450 kgm^{-3}). For the axial direction, the densest wood was found in the butt log (486.5 kg m^{-3}), the lightest wood was in the middle log (482.9 kg m^{-3}) and the top log had a density of 483.2 kg m^{-3}. Conversely, statistical analysis indicated non-significance in the observed differences for both directions ($p \leq 0.05$).

The observations for the radial directions can be explained by the indistinct nature of the growth rings which is an indication of even distribution of vessels and wood substance. According to this nature, *Albizia schimperiana* can be classified as a diffuse porous species (Panshin and de Zeeuw, 1980).



(a) (b)

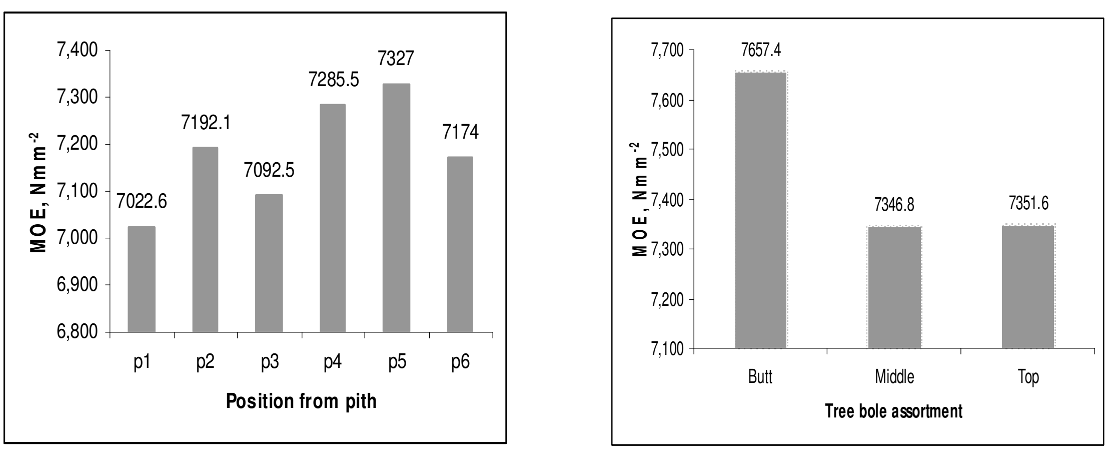
Figure 1 Basic density variation of *Albizia schimperiana* from agro-forestry in Moshi Rural District, Kilimanjaro Tanzania (a) in the radial direction (b) in the axial direction

Strength properties and their variations

Static bending

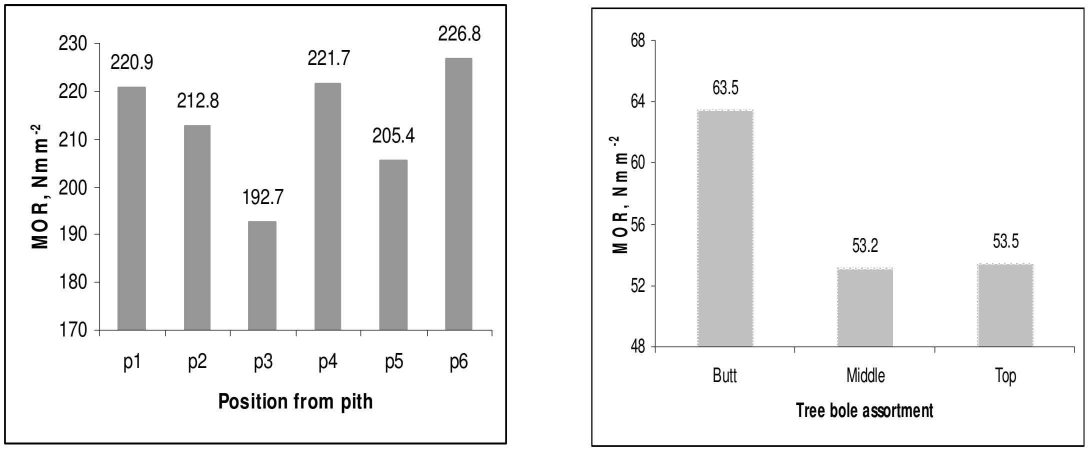
The timber of *Albizia schimperiana* was found to have Modulus of Elasticity of 7,182 Nmm^{-2}, Modulus of Rupture of 53 Nmm^{-2} and Work to maximum Load before failure of 0.381 mm N mm^{-2}. These values are more or less equal to those of *Bombax rhodognaphalon, Entandrophragma stolzii* and *Maesopsis eminii*. *Albizia amara* however, is superior in all aspects except Work to maximum load. Comparison for these properties is summarized in Table 5. MGT (2009) regarded this species as of low stiffness and moderate bending strength.

Variations in static bending strength between trees as shown in Table 3 were proven statistically non-significant ($p \leq 0.05$). Likewise, within tree variations were non-significant (Fig. 2) however, when analyzed in the axial direction, there were significant differences proven in Modulus of Rupture (Fig. 3 b).



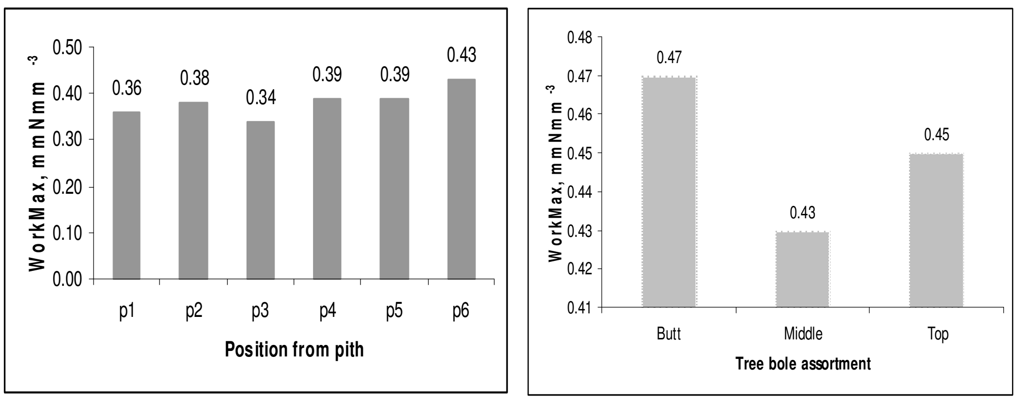
(a) (b)

Figure 2 Modulus of Elasticity variation of *Albizia schimperiana* from agro-forestry in Moshi Rural District, Kilimanjaro Tanzania (a) in the radial direction (b) in the axial direction



(a) (b)

Figure 3 Modulus of Rupture variation of *Albizia schimperiana* from agro-forestry in Moshi Rural District, Kilimanjaro Tanzania (a) in the radial direction (b) in the axial direction



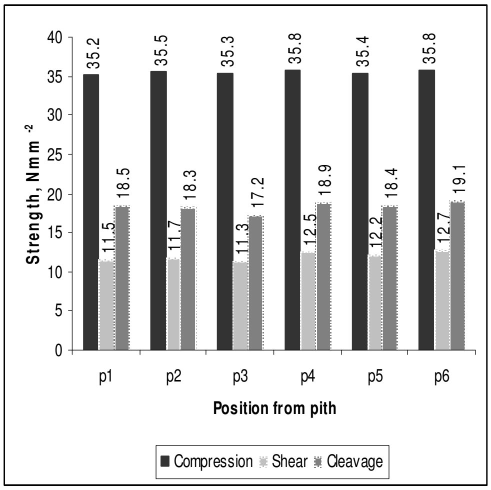
(a) (b)

Figure 4 Work to Maximum Load variation of *Albizia schimperiana* from agro-forestry in Moshi Rural District, Kilimanjaro Tanzania (a) in the radial direction (b) in the axial direction

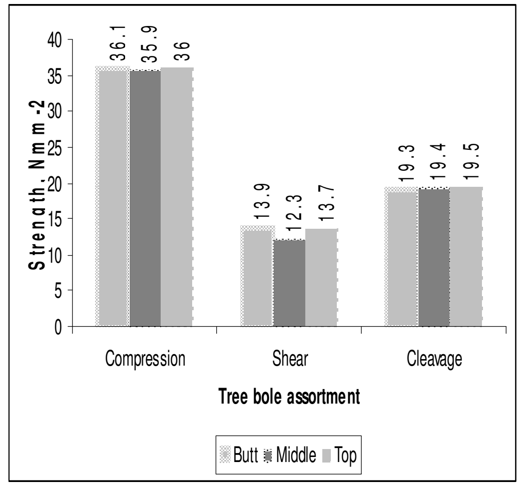
Compression strength parallel to the grain

The resistance to compression forces parallel to the grain for *Albizia schimperiana* was about 35 Nmm^{-2} which is a bit higher than those recorded by Bryce (1967) for *Bombax rhodognaphalon, Entandrophragma stolzii* and similar to that of *Maesopsis eminii*. This property value is low, making the timber species unsuitable for work such as construction where loading is parallel to the direction of the grain. Conversely, *Albizia amara* surpasses with 50.8 Nmm^{-2} making it suitable for structural applications (Table 5).

Variations in static bending strength between trees as shown in Table 3 were proven statistically non-significant ($p \leq 0.05$). Likewise, within tree variations were non-significant (Fig. 2) however, when analyzed in the axial direction, there were significant differences proven in Modulus of Rupture (Fig. 3 b).



(a)



(b)

Figure 5 Compresion, Shear and Cleavage strength variation of *Albizia schimperiana* from agro-forestry in Moshi Rural District, Kilimanjaro Tanzania (a) in the radial direction (b) in the axial direction

Shear strength parallel to the grain

Shear strength was found to be at an average of 12 Nmm^{-2} which also, is a bit higher than those of *Bombax rhodognaphalon* and *Entandrophragma stolzii* but greatly lower than that of *Albizia amara* (20.5 Nmm^{-2}). Nonetheless, this strength property, which is highly sought for designing of joints in construction work, is still low for *Albizia schimperiana* as hinted out by Bryce (1967). There were no statistical differences of Shear strength between trees and within a tree in the radial direction (Fig. 5 a). But when analyzed in the axial direction, the differences in Shear strength become evident (Figure 5 b).

Cleavage strength

The timber has cleavage strength of 18.5 Nmm^{-2} which is a bit lower than that of *Albizia amara* with 19.4 Nmm^{-2}, however Bryce (1967) noted that timbers with such strength are moderately difficult in splitting, therefore not suitable for uses needing easy splitting for instance pulping and for firewood. The irregular and interlocked nature of the grain of these timbers can explain for this characteristic. There were no significant differences noted between and within tree ($p \leq 0.05$).

Relationship between basic density and strength properties

The results in Table 4 as indicated by coefficient of determination show that there was a strong relationship between basic density and all strength properties studied with an exception of Modulus of Elasticity with coefficient of determination of 34%. The low coefficient of determination does not mean that there is no correlation but that the correlation is weak and non-linear. The strongest relationship was between basic density and cleavage which had the highest coefficient of determination ($R^2 = 0.83$). This means that basic density contributed to about 83% and the remaining 17% by unexplained factors. Therefore the cause and effect between cleavage and basic density is strong. The same argument stands for shear which had a coefficient of determination of 82%.

Table 4 Relationship between Basic density and strength properties of *Albizia schimperiana* from agro-forestry in Moshi Rural District, Kilimanjaro Tanzania

Strength properties	Regression equation	Coefficient of determination
Modulus of Elasticity	$Y = 5,295.6 + 4.148\chi$	0.34
Modulus of Rupture	$Y = -13.15 + 0.146\chi$	0.56
Work to Maximum Load	$Y = -0.29 + 0.002\chi$	0.55
Compression parallel to the grain	$Y = 29.14 + 0.014\chi$	0.79
Shear parallel to the grain	$Y = -2.68 + 0.032\chi$	0.08
Cleavage	$Y = 5.39 + 0.029\chi$	0.83

Where: Y = Strength property, χ = Basic density

Table 5 Comparison of results for properties of *Albizia schimperiana* with those of some of the better-known species in Tanzania

Property	**Species**				
	Albizia schimperiana	*Bombax rhodognaphalon*[1]	*Entandrophragma stolzii*[1]	*Maesopsis eminii*[1]	*Albizia amara*[2]
Basic density, kgm^{-3}	455	465	465	417	677
MOE, Nmm^{-2}	7,182	5,669	7,154	7,348	9,753.40
MOR, Nmm^{-2}	53.14	49.00	52.00	60.00	114.7
Workmax, $mmNmm^{-3}$	0.381	0.047	0.052	0.063	0.176
Compression, Nmm^{-2}	35.5	32.0	33.7	35.9	50.8
Shear stress, Nmm^{-2}	12.0	7.1	10.9	8.1	20.5
Cleavage, Nmm^{-2}	18.5	7.9	8.4	10.1	19.4

Source: [1]Bryce (1967), [2] Ishengoma *et al.* (2000)

CONCLUSIONS AND RECOMMENDATIONS

- From this study it can be conclude that *Albizia schimperiana* is a prolific lesser known timber tree taking into account its merchantable timber volume. However, it is a slow growing species taking over 100 years to reach maturity. Since the area's vegetation cover has been greatly denuded and *Albizia schimperiana* is a multipurpose tree species, it can still be grown in agro-forestry systems and plantations and managed for other purposes before it reaches its rotation age.

- If managed and used sustainably, *Albizia schimperiana* has potentials to contribute to the efforts devoted to poverty alleviation and mitigating climate change. Farmers should therefore be advised on good management practices geared towards production of suitable timber but also compatible with other agro-forestry components.

- *Albizia schimperiana* has timber with attractive colour, coarse textured with irregular and interlocked grain and fine chocking dust which pose difficulty in working with. It can here be concluded that the species is suitable for various furniture. It is however, recommended to season the wood adequately before working with, to use nasal muffles, to pre-drill for screwing or nailing and to fill the grain voids for a smoother surface.

- When *Albizia schimperiana* is compared with *Bombax rhodognaphalon* and *Entandrophragma stolzii*, its density is a bit lower, but higher than that of *Maesopsis eminii*. The strength properties are however more or less similar. Generally, it is concluded that *Albizia schimperiana* can well replace uses of *Bombax rhodognaphalon*, *Entandrophragma stolzii* as well as *Maesopsis eminii* timber species. The timber is suitable for low-grade boxes and crates vehicle bodywork, joists, interior construction and for production of veneer.

Because of its medium density wood, *Albizia schimperiana* is not recommended for uses in heavy structural applications.

- There are no statistically significant differences ($p \leq 0.05$) between and within *Albizia schimperiana* trees, in almost all of the studied properties. Any properly selected mature and defect free tree and log can be of equal importance as far as mechanical properties are concerned. For applications requiring high Shear strength however, the middle log should be avoided, and the opposite is true.

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