SOME PHYSICAL AND STRENGTH PROPERTIES OF LESSER KNOWN *APHLOIA THEIFORMIS* TIMBER FROM LUSHOTO TANGA, TANZANIA

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ABSTRACT

Some physical and strength properties of lesser known *Aphloia theiformis* timber grown in and around Magamba Forest Reserve, Lushoto district, Tanga region were determined. A total of three sample trees were randomly selected and felled for this study. Test samples for moisture content, basic density and Strength properties determination were prepared and tested according to Lavers (1969), BS 373 (1957), ISO 3130 (1975), ISO 3131 (1975), ISO 3133 (1975) and ISO 3349 (1975). It was observed that *Aphloia theiformis* timber has a sapwood and heartwood colour ranging from cream-coloured to whitish pink resembling that of *Grevillea robusta*. The average basic density was 519 kg/m^3 with a standard deviation of 4.2 which can be classified as medium-density timber. The basic density showed a slight decrease from butt end to top end. Regarding strength properties, *Aphloia theiformis* timber had a mean modulus of rupture of about 55.8 N/mm^2 and modulus of elasticity of about 3854 N/mm^2. The work to the maximum load was about 0.06mmN mm-^{3}, while total work averaged 0.08mmN mm-^{3}. The compression and shear parallel to the grain were 37.4 and 12.6N mm-^{2} respectively. Furthermore, all strength properties of *Aphloia theiformis* were positively correlated with basic density. The properties of this timber were also comparable to properties of *Grevilea robusta* and are always rated the same by timber dealers. While *Aphloia theiformis* had higher tearing strength than *Grevillea robusta*, the modulus of rupture and compression parallel to the grain values were comparable. *Aphloia theiformis* can therefore substitute *Grevilea robusta* in many areas of its application.

Key words: *Aphloia theiformis* - lesser known - physical and strength properties

INTRODUCTION

Tanzania has a total area of approximately 89 million ha out of which 33.51 ha (about 37.7%) is under forest cover (FAO, 1995). Of the 33.51 million ha, 13 million has been gazetted as forest reserves including about 80,000 ha which are under plantation and 1.6 million ha under water catchments (Kimaryo, 1982; Anon 1997). Very few, well known timber species are harvested, processed and utilised from different natural forests in the country. In some cases, the well-known and expensive timber species are presently being utilised for purposes, which other potentially suitable and far cheaper timbers could be used (Desch, 1981; Ishengoma *et al.*, 2004). If lesser known timber species could be utilised, a greater volume of prime timber would be available for quality utilisation or export. The few well-known timber species are already scarce if not depleted and is likely that some of the lesser known and lesser-utilised timber species will become merchantable when more is known. According to Ishengoma *et al.,* (1998), utilization of lesser known timber species could also reduce pressure on better known timber species and therefore important to conduct research on lesser known and lesser-utilised timber species to rescue the tropical forests (Ishengoma *et al.*, 1998).

Bryce (1967) in his book titled, "Commercial Timbers of Tanzania" recorded over 89 marketable timber species from the indigenous forests. However the utilisation is only concentrated on a few of these species. The timber species that are seldom used in most cases are partly due to technical reasons such as difficult in machining and proper seasoning as well as lack of knowledge on their physical and strength properties, including colour, basic density, strength, stability in services, durability, ease of working and quality of finish (Yeom, 1984; Smith *et al.,* 1994).

In mountain areas of Tanzania especially in Lushoto - Tanga region, there is abundant wood from *Aphloia theiformis* or Mdandana in Sambaa but small amount of this wood is currently inefficiently used for firewood, and the rest left elsewhere unutilised. *Aphloia theiformis* belongs to the family *papilionaceae*. Due to increasing demand for wood coupled with the diminishing natural resource, *Aphloia theiformis* tree may save as alternative or substitute timber to some of well known timber species which due to over harvesting, they are already in short supply.

It appears that despite of the contribution of the Mdananda wood to mankind, very little or no studies on the physical and strength properties of wood have been reported to be done in Tanzania. This is due to the fact that the species is neither in the list of commercial timber of Tanzania (Bryce, 1967), a book which gives a summary of properties and uses of most timber species, including commercial timbers, nor in the checklist of the forest trees and shrubs of British Empire-Tanganyika Territory (Bayard 1940), a book which crosschecks vernacular names of trees and shrubs with their corresponding scientific names. The tree is also not documented in the book by Mbuya *et al.* (1994) on some useful trees and shrubs of Tanzania. *Aphloia theiformis* timber could be used efficiently if the properties are studied, known, published and promoted to both domestic regional and export markets.

This study was done to investigate and document important physical and strength properties of lesser-known *Aphloia theiformis* (Mdananda) growing naturally in Magamba, Lushoto Tanga. By comparing the results from this study with those reported by other researchers from other timber species, recommendations will be put forward which might lead to efficient utilisation of Mdananda wood. This might help to lessen the pressure of over exploitation of few well-known timber species since harvesters and timber users might use the species as alternative or substitute timber species.

MATERIALS AND METHODS

Study area

Samples were collected from Magamba Forest Reserve in Lushoto district from *Aphloia theiformis* trees species. The Magamba Forest Reserve lies North of Lushoto town at 203.2 km from Tanga municipal. The area receives the short in November to December and long rains from mid March to May. The mean annual rainfall amounts to about 1000 mm. Temperature is low and the months of June and September are normally dry and cold throughout the area. Anon (1981) described topography of the areas comprising two types of vegetation; montane rain forest and montane dry forest. The soils are clay in nature and rich in manganese. The pH generally ranges from neutral to acidity, and for a long time the pH values have ranged between 3.5 and 8.5.

Data Collection

Tree sampling

Three trees, with no visible defects were randomly selected and marked before felling. The selected trees were observed to note and record the general physical properties such as tree form, branching pattern and bark colour before felling. For each felled sample tree, diameter at breast height (dbh) and total tree height were measured and recorded (Table1). For each tree, logs of 1.5 m were cut from the butt, middle and top of the bole length and marked accordingly.

Table 1 Parameters measured for sample tree of *Aphloia theiformis* from Magamba Forest Reserve Lushoto Tanzania

Tree No.	DBH (cm)	Total height (m)
1	44.56	17.58
2	45.84	16.34
3	43.76	16.45

Sawing

The 1.5 m long logs were transported to the nearby sawmill where logs were sawn to produce centre cants. Sawing was done according to the procedure described by Lavers (1969). Each log was roughly sawn through and through to obtain a cant of 65 mm (Lavers, 1969). Centre cants from all logs were transported to the Laboratory of Department of Wood Utilization of the Faculty of Forestry and Nature Conservation at SUA, Morogoro for test samples preparation. At SUA, the 1.5 m centre cants were reduced further to 1 m lengths and converted to planks of 30 x 65 x 1000 mm from the pith left and right directions towards the bark. The 0.5 m portions removed were used in the determination of basic density. The planks were then re-sawn into small scantlings of 30 x 30 x 1000 mm. The scantlings were numbered and labelled sequentially to show the position of extraction. This procedure is well described by Lavers (1969). The scantlings were then air dried before they were further plained down into 20 x 20 x 1000 mm from which test samples for various tests were extracted. Fans were used to accelerate test samples air-drying.

Laboratory procedures

Determination of physical properties of *Aphloia theiformis*

The physical properties determined experimentally were moisture content and basic density.

(a) Moisture content

Moisture content of every test sample was determined at time of strength tests. This was done by first measuring the initial weight of the sample before testing, then after testing, the test samples were placed in the oven in order to get final weight after oven drying. The tested samples were oven dried at a temperature of 102 ± 3^0C to constant weights. The test sample sizes for different strength tests which the moisture content was determined are shown in Table 2. The two readings (initial and oven dry weights) recorded for each sample were used to determine moisture content by using a formula by developed by Ishengoma and Nagoda (1991).

(b) Basic density

Wood samples for basic density determination were extracted from the scantlings before drying. Oven dry weight and green volume are important parameters for determination of basic density. The green volume of each test sample was obtained by the water displacement methods, according to Archimedes Principle (Lavers, 1969). A beaker of distilled water was placed on a weighing balance and set to zero reading. Each sample was full immersed in water using a needle clamped on a retort stand. The weight in grams of water displaced, which is equal to the volume in cubic centimetres for each test sample was recorded. The test samples were then oven dried at a temperature of 102 ± 3^0C to constant weight. The test samples were finally cooled in a desiccator and reweighed, and the oven dry weight of each test sample recorded in grams. The basic density (kg/m^3) was calculated using a formula by Ishengoma and Nagoda (1991).

Determination of strength properties
Test samples of *Aphloia theiformis* for different strength test were prepared and tested using methods described by BS 373 (1957), Lavers (1969), ISO 3130 (1975), ISO 3131 (1975), ISO 3133 (1975), ISO 3349 (1975) and Ishengoma and Nagoda (1991). From each air-dried scantling of 20 x 20 x 1000 mm, samples for various strength tests were extracted. Table 2 gives summary of dimensions of different test samples.

Table 2 Dimensions of different test samples for different strength test

Type of test	No. of samples	Sample size (mm)
Static bending	48	20 x 20 x 300
Compression parallel to the grain	48	20 x 20 x 60
Shear parallel to the grain	48	20 x 20 x 20
Cleavage	48	20 x 20 x 45

The data obtained from different tests were analysed using basic statistical descriptors where means, standard deviations and coefficient of variations were determined. The basic density and strength properties for the axial positions and the overall trees were calculated as the mean of results for all the test samples and all tests. The mean values for each tree were calculated as the arithmetic mean basic densities and mechanical property values. Regression analysis was performed to establish relationships between properties. For better understanding of relationship existing between basic density and strength properties, prediction based on simple linear regression equation was developed for average tree basic density and strength property values.

RESULTS AND DISCUSSION

Physical Properties of *Aphloia theiformis*

Physical appearance and wood colour
Aphloia theiformis trees have straight bole with tapered upper end and smooth whitish bark and few branches. *Aphloia theiformis* wood was found to have a colour ranging from cream-coloured to whitish pink colour sapwood and heartwood respectively, which could make it suitable for many end uses associated with colour for decorative work. In comparison with other known timber species the wood of *Aphloia theiformis* resembles more closely the wood of *Grevillea robusta.*

Basic density
Taking into consideration all physical properties of wood, basic density is considered to be the key indicator for most strength properties (Kollman and Cote, 1968; Ishengoma and Nagoda, 1991; Walker, 1993). Results from this study showed that *Aphloia theiformis* had a mean basic density of 519.8 kg/m^3 (about 520kg/m^3) and Standard deviation of 4.2. *Aphloia theiformis* can therefore be classified as a medium density timber.

Axial variation in basic density
Considering axial variation in basic density, there were slight differences in mean basic densities from butt to top end (Table 3). Actually a slight decrease in basic density from butt end to top end of the tree was noted in all trees, and on overall a small variation in basic density among trees was noted. This is supported well with a very low Coefficient of variation of mean basic density of *Aphloia theiformis*. The low coefficient of variation shows that there is small variation in basic density values at different positions from butt end to top end of the trees and between the trees. The slight decreasing trend from butt to top end of the trees is a desirable pattern since the central part of the stem constitutes large

volume of merchantable timber. Also this is a normal trend if timber is compared with other timber species (Dinwoodie, 1981; Desch and Dinwoodie, 1996).

Table 3 The basic density of *Aphloia theiformis* at different heights in the stem and overall mean.

Basic density (kg/m3				
Tree No	Butt	Middle	Top	Mean
1	531	530	527	529(4.0)*
2	523	520	518	520(2.5)
3	522	503	507	510(1.8)
Mean	525	518	517	519(4.2)

* Values in parentheses are coefficients of variation

Strength properties of *Aphloia theiformis*

Application of timber in the production of manufactured items or in the wide range of timber construction work depends to larger extent on the selection of the most suitable timber for the task. However the selection of most suitable timber for a particular task depends on the species properties which include the strength properties (Ishengoma and Nagoda, 1991). Table 4 summaries the mean values for the studied strength properties of *Aphloia theiformis* timber.

Table 4 Mean Strength properties of *Aphloia theiformis* timber

Strength Properties	**Mean strength values**
Modulus of rupture, N/mm^2	55.80 (2.2)*
Modulus of elasticity, N/mm^2	3853.80 (6.1)
Work to maximum load, mmN/mm^3	0.60 (3.0)
Total work, mmN/mm^3	0.08 (6.3)
Compression parallel to the grain, N/mm^2	37.34 (5.1)
Shear parallel to the grain, N/mm^2	12.57 (6.3)

* Values in parentheses are coefficients of variation

Relationship between basic density and strength properties

The relationship between basic density and strength properties were observed by using regression analysis. The result showed that there is a strong relationship existing between basic density and strength properties (Table 5). The regression models were not only significant, but also had coefficient of determination (R^2) values of above 50%. This indicates that the strength properties of *Aphloia theiformis* can be predicted from its basic density. Strength properties such as modulus of rupture (MOR), modulus of elasticity (MOE), work to maximum load (Wmax) and total work (Wtotal) were positively and strongly correlated to basic density with R^2 ranging from 0.91 to 0.99. The positive correlation between basic density and other wood properties show that for any increase or decrease on basic density there is an increase or decrease on the wood strength properties.

Table 5 Relationship between basic density and strength properties of *Aphloia theiformis* timber

Strength Property	Regression equation	R^2
Compression parallel to the grain	y =0.079x – 2.408	0.962
Shear parallel to the grain	y = 54.68x + 15.78	0.958
Modulus of rupture	y = -84.61x + 99.69	0.981
Modulus of elasticity	y = 2261x - 789	0.986
Work to maximum load	y = 1.05x + 0.048	0.997
Total work	y =0.13x - 0.00065	0.917

X = Basic density
Y = Strength properties

Comparison of results from this study with results reported by other researchers

There are no documented works in literature showing studies, which have been done regarding the physical and strength properties of *Aphloia theifomis* growing in Tanzania. This work and results obtained are very important to timber users, since will help in assigning this timber rational uses. The results also add to the literature available of commercial timbers from Tanzania.

Comparisons of properties of *Amphloia theiformis* with those of *Grevillea robusta*

The selection of *Grevillea robusta* timber for comparison with *Aphloia theiformis* was based on similarities in appearance of timber. The timber of these two species looks alike. Their resemblance could allow timber dealers to sale these timber species in the same group. However, it was of interest to compare the properties of these two timber species to note their differences in basic density and strength properties. As shown in Table 6, since both timber had basic densities of more than 500kg/m^3 , can be classified as high density timber species. However there is a slight difference in their densities with *Grevillea robusta* being slightly heavier than *Aphloia theiformis* where the later specie is about 17% lighter than *Grevillea robusta*

Table 6 Comparison of basic density and strength properties of *Aphloia theiformis* and *Grevillea robusta* timber

Properties	*Aphloia theifomis*	*Grevillea robusta**
Basic density, (kg/m^3)	519.00	608.70
Modulus of rupture (N/mm^2)	55.80	60.49
Modulus of elasticity (N/mm^2)	3853.82	7900.00
Work to maximum load (mmN/mm^3)	0.06	-
Total work (mmN/mm^3)	0.08	-
Compression parallel to grain (N/mm^2)	37.34	36.01
Shear parallel to grain (N/mm^2)	12.57	7.30

* Source: Bryce (1967).

The two timber species had comparable compression parallel to the grain and modulus of rupture strengths. However *Grevillea robusta* is stiffer than *Aphloia theiformis* as noted by higher modulus of elasticity value. The modulus of elasticity of *Grevillea robusta* is almost 51% high than that of *Aphloia theiformis.* Despite a slight difference in basic densities of these timber species, *Aphloia theiformis* had higher shearing strength compared to that reported for *Grevillea robusta.* The superiority in shearing strength of *Aphloia theiformis* is about 42%. Since these timber meet in market places, the timber from *Aphloia theiformis* can be used as a substitute to *Grevillea robusta* for uses which modulus of rupture and compression parallel to the grain Strength properties is required. The advantage of *Aphloia theiformis* is in the uses, which demand high shearing strength. For that particular use, *Aphloia theiformis* is recommended to substitute *Grevillea robusta* due to high shearing strength parallel to grain.

Conclusion and Recommendations

Conclusion

The wood of *Aphloia theiformis* was found to have colour ranging from cream-coloured to whitish pink. The colour of this timber resembles that of *Grevillea robusta.*

The mean basic density of *Aphloia theiformis* grown at Magamba Forest reserve was 519 kg/m^3 with standard deviation of 4.2. The timber is therefore medium in density.
Basic density decreased from butt end to the top end of tree.

The strength properties of *Aphloia theiformis* were positively and strongly correlated to the basic density with the values of R^2 greater than 50% for all strength properties.

When compared to *Grevillea robusta*, *Aphloia theiformis* timber had comparable modulus of rupture and compression parallel to the grain values. However *Aphloia theiformis* had higher shearing strength, with a superiority of almost 42%.

Aphloia theiformis can substitute *Grevillea robusta* in uses or application which demand medium modulus of rupture and compression parallel to grain properties. Comparatively, the timber could also be an excellent substitute to *Grevillea robusta* in application areas demanding high shearing strength such as joinery and furniture timber.

Recommendations

It is recommended that, depending on the basic density of *Aphloia theiformis*, the timber can be used for construction work and furniture. It is further recommended that due to similarities in appearance of *Aphloia theiformis* and *Grevillea robusta, Aphloia theiformis* timber can be used as a substitute in furniture for those materials whose emphasis are based on physical appearance. Also based on strength properties, the wood of *Aphloia theiformis* can be used as a substitute timber to *Grevillea robusta* for the reasons suggested in concluding remarks.

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