TIMBER PROPERTIES OF LESSER KNOWN *POLYSCIAS FULVA* (HIERN) HARMS AND *ALLOPHYLUS ABYSSINICUS* HOCHST. RADLK. FROM IRINGA TANZANIA

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ABSTRACT

Two lesser-known and lesser utilized timber species namely *Polyscias fulva* and *Allophyllus abyssinicus* from Iringa, Tanzania were studied to determine basic density and some strength properties. Three trees for each species were randomly selected, felled, test sampled prepared and properties tested according to standard methods. Data analysis was conducted employing Microsoft excel computer software where descriptive statistics were computed. Analysis of variation was done to establish relationships existing between density and strength properties. Variation in basic density between trees and t-test was carried out to compare wood properties of the two species. In addition, regression analysis was used to establish the existing relationship. Tests of strength properties on clear specimens showed that on average, the overall strength properties for *Polyscias fulva* and *Allophyllus abyssinicus* were comparable respectively to *Pinus caribaea* and *Terminalia superba*, the commercially utilized timber species in Tanzania. Further, with exception of compression parallel to grain, the two species were significantly different. There was statistically significant difference within species in basic density and strength properties with exception of modulus of rupture and cleavage strength for *Polyscias fulva* and work to maximum load, compression parallel to the grain and cleavage for *Allophylus abyssinicus*. Furthermore, there were direct relationships between basic density and strength properties for the two timber species. While *Pinus patula* can substitute *Polyscias fulva, Terminalia superba* can substitute *Allophyllus abyssinicus* in most of its applications. The two timber species can be used for light construction work, sporting goods and furniture making. Further work on the studied species is required on other strength as well as chemical properties and natural durability.

Key words: Density- strength- *Terminalia superba* - *Pinus caribaea* – Dabaga - Ulongambi forest

INTRODUCTION

Wood is the dominant basic material for construction and form of energy in most developing countries particularly in Africa (Kimaryo and Ngereza, 1993; Ishengoma and Chihongo, 1995). In Tanzania, nearly all houses are constructed with wood as the base frame (Temu and Phillip, 1981). On the other hand, about 78% of walls and 72% of roofs in traditional houses in the country are constructed by poles. Poles were noted by Ishengoma *et al.* (1992) to remain the most widely used building materials in rural Tanzania and to a lesser extent in urban areas. Furthermore, wood energy in Tanzania accounts for 90% or more of total energy requirements. Natural forests in Tanzania however can only supply 55.9 % of wood consumed per annum, through the currently few commercially well-known species while others remain unknown (Ishengoma *et al.*, 1992).

Tanzania has a total land area of 88.6 million hectares (MLNRT, 1989). In 1989, about 50% of her land was covered by forests of which 13.8% were nationally protected. Land suitable for cultivation and grazing but with varying soil types and degree of fertility covered about 45% of the total land area (Kilahama, 1988). Due to rapid increase of population, there has been over utilization of natural forests in the country (O'ktingati and Monela, 1991). According to URT (1998), Tanzania was losing about 2 % of her forest cover annually. In densely populated areas, most of the land is under cultivation (Ewusie, 1986; Hofstand, 1988, Stone *et al.,* 1993). Therefore there is a high demand for forest products from the remaining natural forest (Rocheleau *et al.,* 1988).

Bryce (1967) documented that Tanzania has over 200 marketable timber species from her indigenous forests nonetheless, to-date the utilization is only concentrated on a few of those species which are harvested from different natural forests. The well known commercial timber species have become 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 their regeneration. If these species could be utilized, a greater volume of prime timber would be available for quality utilization and export (Ishengoma *et al.,* 1998).

The availability of timber from *Polyscias fulva* (family Araliaceae) and *Allophylus abyssinicus* (family Sapindaceae), both being lesser known would considerably raise the total merchantable timber volumes in the market. Nevertheless, as FAO (1976) advocated, this needs to avail first, the proper knowledge and properties of these species to the users followed by an exhaustive study in terms of inventory to estimate their volumes. This could eventually, justify investments in sawmilling for local and commercial utilization, thereby reserving the well-known timbers which are currently threatened by over harvesting for heavy construction work. The properties of timber species determined in this paper form a basis for recommendation on their consideration for rational and increased efficient utilization. The overall impact is on substitution with some of well-known timber species, reduction on pressure on their over-exploitation and improvement on income of mostly, the rural people.

This paper provides an understanding of some physical and strength properties of lesser utilized *Polyscias fulva* (Mdeki) and *Allophylus abyssinicus* (Mnyakisagi) growing naturally in Iringa Region. These properties are: Physical (Tree dimension, form and quality, wood colour and texture, and basic density) and Strength (Modulus of elasticity, Modulus of rupture, Work to maximum load, Compression parallel to the grain, Shear parallel to the grain and Cleavage).

MATERIALS AND METHODS

Study area description

The test specimens were collected from New Dabaga-Ulongambi Forest Reserve in Kilolo District, Iringa Region located between latitudes $7^0 48'$ – $8^0 20'$ S and longitudes $35^0 40'$– $37^0 00'$ E. The nearest area of this forest by road is about 50 km Southeast of Iringa town. This forest being elevated between 1,200 – 1,700 m.a.s.l. is of a sub-montane type with dominant tree species of *Parinari curatellifolia, Bersama abyssinica, Rauvolfia caffra*, *Albizia gummifera*, *Prunus africana* and *Millettia oblata* (Lovett and Poćs, 1992; CELP, 2001).

In the area, the rainfall pattern is uni-modal occurring during December – March period with mean annual rainfall of 1,000 mm and the mean monthly temperature ranges from 18^0C to 27^0C. The dry seasons are from June to October and wind blows from Southwest to Northeast. The terrain is flat with clayey sandy loam soils with pH ranging from 3.5 to 8.5.

Sampling, material collection and preparation

Thirty randomly selected mature standing trees, for each of the two species studied were assessed for their dimensions in which diameter at breast height (Dbh), total tree and merchantable heights were measured. Other parameters including tree bole straightness and cylindricity, all of which are important when considering a tree for timber, were inspected visually.

For each species, three defect free trees whose measurements are presented in Table 1, were selected and felled. Logs of 1.5 m each were cut from the butt, middle and top of the bole length of each sample tree and marked accordingly. The logs were transported to a nearby sawmill and sawn according to Lavers (1969), using a through and through method to obtain a 65 mm thick central plank. Careful observation was made to describe the colour and figure of the wood. The planks were then transported to the Department of Wood Utilization laboratory, at Sokoine University of Agriculture in Morogoro, where they 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 1 Sample tree measurements for *Polyscias fulva* and *Allophylus abyssinicus*

Tree No.	Tree species			
	Polyscias fulva		*Allophylus abyssinicus*	
	Dbh (cm)	Height (m)	Dbh (cm)	Height (m)
1	37.6	17.6	38.0	15.5
2	45.2	21.3	44.2	17.3
3	42.0	19.0	36.4	16.5

Table 2 Dimensions of samples used for strength test for *Polyscias fulva* and *Allophylus abyssinicus*

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

Laboratory procedures

Determination of physical properties

Determination of physical properties of wood involved examining wood colour and texture and preparation of test samples for determination of basic density.

Wood colour and texture

Apart from examination in the laboratory, observation on wood colour was made in the forest during conversion of trees to logs and planks. The colour of the timbers 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.

Determination of basic density

Basic densities of the test samples were determined using oven dry weight and maximum moisture content volume, explicitly described by ISO 3131 (1975).

Determination of strength properties

Tests for the strength properties were conducted following procedures by BSI 373 (1957), Lavers (1969), ISO 3130 (1975), ISO 3133 (1975), ISO 3349 (1975) and Desch (1981). All the tests were carried out at room temperature and relative humidity, using Monsanto Tensometer wood testing machine.

Data Analysis

Data obtained from this work 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

Tree dimension, form and quality

From the 30 sampled trees, *Polyscias fulva* confirmed to be a large tree, with a mean dbh of 40 and merchantable and total height of 20 and 25 m respectively, with a straight trunk. The branches form at high level, increasing the merchantable height for use as timber. *Allophylus abyssinicus* is a medium-sized to large tree with mean Dbh, merchantable and total height of 35 cm, 10 and 20 m respectively. These observations are in conformity with documentation by Hyde and Wursten (2009a; b) for the two species. The findings annotate that the two species are prolific as far as merchantable timber is concerned.

Wood color and texture

The colour of *Polyscias fulva* wood varied from yellowish-brown sapwood to dark-greenish heartwood, with coarse texture. *Allophyllus abyssinicus* wood was observed to have yellowish-white sapwood and dark-brown heartwood, with coarse texture. For *Polyscias fulva,* Hyde and Wursten (2009a) generalized a reddish-yellow wood colour. Many studies have shown that the presence of extraneous substances in wood imparts colour to wood, thus increasing beauty when used for furniture (Desch and Dinwoodie, 1996).The course textured wood of the species is an indication that they are ring porous hardwoods (Panshin and de Zeuw, 1980; Zobel and Van Buijtenen, 1989).

Mean basic density

The basic density values for the wood of *Polyscias fulva* and *Allophylus abyssinicus* are presented in Table.3

Table 3 Basic density values for wood of *Polyscias fulva* and *Allophyllus abyssinicus*

Species	Basic density (kg m^{-3})		
	Minimum	Maximum	Mean
Polyscias fulva	149	542	316 (16.8)[1]
Allophylus abyssinicus	166	487	454 (9.1)

[1] Values in parentheses are coefficients of variation (CV) in %

It can be noted from Table 3 that, the mean basic density values of *Polyscias fulva* and *Allophylus abyssinicus* are 316 kg m^{-3} and 454 kg m^{-3} respectively, the former being lighter than the later by 12%. According to Panshin and de Zeeuw (1980), *Polyscias fulva* can be classified as light density and *Allophylus abyssinicus* as medium density wood.The basic density values obtained from this study for the two species are lower than those of other lesser known species of *Milletia oblata* sub. s*pp stolzii* (Mbafwa) studied by Ishengoma *et al*. (1998), *Albizia amara* (Mpogolo) by Ishengoma *et al.* (2000) and *Uapaca kirkiana* (Mkusu) by Gillah *et al.* (2007). Also, the densities are lower than those of the well known commercial timbers of Tanzania documented by Bryce (1967) of *Milicia excelsa* (Mvule), *Pterocarpus angolensis* (Mninga) and *Ocotea usambarensis* (Camphor).

Variation in basic density

Variation in basic density between the species of *Polyscias fulva* and *Allophylus abyssinicus* and between trees within the species based on average values is presented in Table 4

Table 4 Variation of mean basic density between and within *Polyscias fulva* and *Allophylus abyssinicus*

Tree No.	Basic density, kg m^{-3}	
	Polyscias fulva	*Allophylus abyssinicus*
1	341 (22.1)[1]	417 (11.2)
2	297 (17.5)	465 (8.8)
3	309 (8.7)	480 (7.5)
Mean	**316 (16.8)**	**454 (9.1)**

[1]Values in parentheses are coefficients of variation (CV) in %

Between species
The wood densities of the two timber species vary significantly ($p < 0.05$). Zobel and van Buijtenen (1989) urged that the most important factors for this variation are genetical and environmental. The results imply that, based on their densities, these two species cannot be used interchangeably when density consideration is prime. As almost all mechanical properties are closely correlated to density (Kollman and Côte', 1968; Wangaard, 1981; Walker, 1993), Schlich (1990) noted that grading of lumber products in some countries is done on the basis of density rather than species.

Between trees
There is greater variation of wood density in *Polyscias fulva* indicated by the higher value of its coefficient of variation. From Table 4, it can be noted that variation in basic density within species is significant for *Polyscias fulva* whereas it is insignificant for *Allophylus abyssinicus* ($p < 0.01$). The significance in the difference of basic density between trees of the former implies that the trees differ in strength properties (Kollman and Côte', 1968; Wangaard, 1981; Walker, 1993). For *Polyscias fulva* therefore, plus trees can be selected in breeding programmes so as to improve wood quality.

Within a tree
The variation of basic density within a tree for each species was assessed radially and axially. For both species, dense wood was observed in areas close to the pith followed by a gradual decrease towards the bark as shown in Fig. 1 (a). Likewise, in the axial direction the dense wood was observed in areas close to the butt followed by a gradual decrease towards the top (Fig. 1b). These observations are in agreement with Panshin and de Zeeuw (1980) and confirm that the two species are ring porous. According to these authors, density increases with increasing distance from the pith and axially, the heaviest wood is found at the base of the tree and there is a gradual decrease with increasing distance from it.

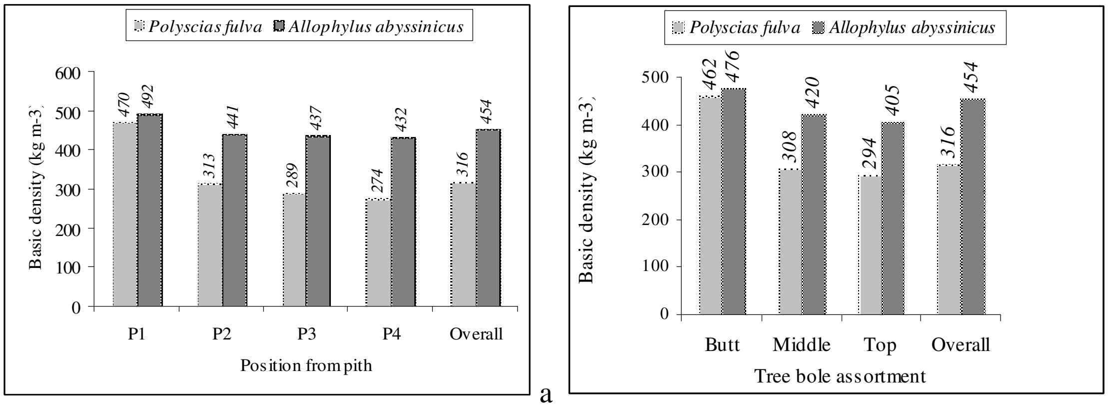

Figure 1 Basic density variation of *Polyscias fulva* and *Allophylus abyssinicus* (a) in the radial direction (b) in the axial direction

Strength properties of *Polyscias fulva* and *Allophylus abyssinicus*

Table 5 presents and compares strength properties of *Polyscias fulva* and *Allophylus abyssinicus*. The statistical results from t-test indicated that, with exception of compression strength, there were significant differences of Modulus of Elasticity (MOE), Modulus of Rupture (MOR), Work to Maximum Load, Cleavage and Shear strength ($p < 0.05$). While *Polyscias fulva* had higher Shearing strength than *Allophylus abyssinicus,* the later was stiffer, with higher bending strength, Work to Maximum Load and Cleavage strength.

Table 5 Comparison of strength properties between *Polyscias fulva* and *Allophylus abyssinicus*

Strength property	*Polyscias fulva*	*Allophylus abyssinicus*	t-test
Modulus of elasticity (MOE), N mm^{-2}	4,022.61	6,015.17	*
Modulus of rupture (MOR), N mm^{-2}	35.15	42.35	*
Work to maximum load, mm N mm^{-3}	0.027	0.028	*
Compression parallel to the grain, N mm^{-2}	22.34	19.77	NS
Shear parallel to the grain, N mm^{-2}	10.68	9.61	*
Cleavage, N mm^{-2}	9.61	11.26	*

*= Strength property difference statistically significant at $p \leq 0.05$, NS = Not significant at $p \leq 0.05$

Both species are weaker in all strength aspects than *Milletia oblata* sub. s*pp stolzii* (Ishengoma *et al.*, 1998), *Albizia amara* (Ishengoma *et al.*, 2000) and *Uapaca kirkiana* (Gillah *et al.*, 2007), the lesser known timber species and *Milicia excelsa*, *Pterocarpus angolensis* and *Ocotea usambarensis* (Bryce, 1967) the commercial timbers of Tanzania.

Variation in strength properties within species

Polyscias fulva

The variation within species for *Polyscias fulva* is presented in Table 6.

Table 6 Variation of strength properties between trees of *Polyscias fulva*

Tree No.	MOR N mm^{-2}	MOR N mm^{-2}	Wmax mm N mm^{-3}	Comp. N mm^{-2}	Shear N mm^{-2}	Cleavage N mm^{-2}
1	4,150.11	34.64	0.037	22.46	5.6	9.5
2	3,976.26	35.34	0.022	21.87	7.15	9.55
3	4,036.96	35.43	0.025	23	6.26	9.6
F-value	**NS**	*	*	*	*	**NS**

* = Significant at $p \leq 0.05$, NS = Not significant at $p \leq 0.05$

It can be noted in Table 6 that, with exception of modulus of elasticity and cleavage strength, variation within species was significant for all other strength properties tested at $p \leq 0.05$.

Allophylus abyssinicus

Variation in strength properties within *Allophylus abyssinicus* timber species is presented in Table 7.

Table 7 Mean strength properties of *Allophylus abyssinicus* trees

Tree No.	MOR N mm^{-2}	MOR N mm^{-2}	Wmax mm N mm^{-3}	Comp. N mm^{-2}	Shear N mm^{-2}	Cleavage N mm^{-2}
1	5496.7	41.0	0.029	17.8	9.4	10.9
2	6979.2	47.7	0.031	21.5	10.7	11.0
3	5569.6	38.3	0.024	20.0	12.0	11.9
F-value	*	*	**NS**	**NS**	*	**NS**

* = Significant at $p \leq 0.05$, NS = Not significant at $p \leq 0.05$

As indicated in Table 7, variation within species for *Allophylus abyssinicus* is significant for modulus of elasticity, shear parallel to grain and modulus of rupture at $p \leq 0.05$. In other hand, there were no significant differences within species for compression parallel to grain, work to maximum load and cleavage strength.

The most important factor which is responsible for variation in strength properties within the studied species is basic density of the wood (Kollman and Côte', 1968; Wangaard, 1981; Walker, 1993).

Relationship between basic density and strength properties

Polyscias fulva

The relationship between basic density and strength properties for *Polyscias fulva* are presented in Table 8.

Table 8 Regression equation and coefficient of determination of *Polyscias fulva*

Regression equation	R^2
Modulus of Elasticity = $3.9055\chi + 2821.8$	0.9914
Modulus of Rupture = $-0.0182 \chi + 40.874$	0.8751
Work to Maximum Load = $0.0003 \chi - 0.0812$	0.9968
Compression parallel to grain = $0.007 \chi + 20.226$	0.0785
Shear = $-0.0325 \chi + 16.601$	0.8835
Cleavage = $-0.0016 \chi + 10.06$	0.5425

χ = Basic density

Table 8 indicates that all strength properties are positively correlated to density. The relationship between basic density and Work to Maximum Load indicated the highest coefficient of determination (R^2) of 99.7 % followed by the relationship between basic density and Modulus of Elasticity (99.1 %). The lowest coefficient of determination was shown in Compression parallel to grain of 7.9%. Coefficient of determination explains the strength of correlation between the properties. Higher coefficient of determination shows stronger correlation between basic density and strength with a steep slope of the curve. Lower R^2 means weak correlation with less steep curve.

Allophyllus abyssinicus

The relationships between basic density and strength properties for *Allophyllus abyssinicus* are presented in Table 9.

Table 9 Regression equations and coefficients of determination of *Allophyllus abyssinicus*

Regression equation	R^2
Modulus of Elasticity = 26.354 χ – 4319	0.5954
Modulus of Rupture = 0.0751 χ + 11.382	0.3609
Work to Maximum Load = 0.0001 χ - 0.0181	0.2717
Compression parallel to grain = 0.0696 χ + 0.3106	0.5799
Shear = 0.0112 χ + 2.7987	0.1914
Cleavage = 0.0289 χ + 0.4642	0.7426

χ = Basic density

For *Allophylus abyssinicus,* all strength properties were found to be positively related to the basic density. The highest coefficient of determination (R^2) was found in cleavage strength (74.3 %) followed by modulus of elasticity (59.5 %) and the least in shear parallel to grain (19.1%). It can also be noted from Table 8 that the regression equations for the relationships between basic density and modulus of elasticity and work to maximum load have negative y-intercepts. The negativity implies that there are other factors apart from density, which influence strength of wood but in the negative manner i.e. they reduce the modulus of elasticity and work to maximum load of wood (Ishengoma and Gillah, 1992).

Comparison of the results

Table 10 compares wood properties of *Polyscias fulva* and *Allophyllus abyssinicus* with those of *Pinus caribaea* and *Terminalia superba* respectively, the two similar timbers they could encounter in the timber market. The two timbers have similar basic densities with their counterparts, meaning that some of their properties can be comparable. Likewise, *Polyscias fulva* can substitute *Pinus caribaea* while *Allophylus abyssinicus* can substitute *Terminalia superba* in uses which demand good stiffness and shear parallel to the grain. Nevertheless, due to very low compression parallel to the grain of *Terminalia superba,* the substitution with this timber may become hazardous in uses where compression parallel to the grain is important.

Table 10 Some properties of *Polyscias fulva* and *Allophyllus abyssinicus* as compared to *Pinus caribaea* and *Terminalia superba* respectively

Properties	***Polyscias fulva***	***Pinus caribaea***[1]	***Allophylus abyssinicus***	***Terminalia superba***[1]
Basic density, kg m^{-3}	316	421	454	383
Modulus of elasticity, N mm^{-2}	4,150.11	4,145	5,496.74	5,103
Modulus of Rupture, N mm^{-2}	34.64	22	41.04	32
Shear parallel to the grain, N mm^{-2}	5.60	5.40	9.41	7.60
Cleavage strength, N mm^{-2}	9.50	5.10	10.88	7.50
Compression parallel to the grain N mm^{-2}	33.46	15.50	17.79	250

[1] **Source:** Bryce (1967)

Substituting the well-known timber species with lesser-known timber species will help to lessen the pressure of exploitation of the well-known timber from our forests and thus more volume of well-known timber species could be available from our forests.

CONCLUSION AND RECOMMENDATIONS

- It is evident from this study that *Polyscias fulva* and *Allophylus abyssinicus* are prolific as far as merchantable timber is concerned and have attractive timber colour. From these properties it can be concluded that, the two species are suitable for furniture. The timber texture however, is course demanding for adequate planing in timber finishing to make the surface more appealing.
- Whereas *Polyscias fulva* is a light density wood, *Allophylus abyssinicus* is a medium density wood and the difference in their densities is statistically significant. It can therefore be concluded that the species cannot be used interchangeably in structural applications. On density basis, *Pinus caribaea* and *Terminalia superba* are comparable to *Polyscias fulva* and *Allophylus abyssinicus* respectively and therefore, can accordingly be interchanged. Within species, *Polyscias fulva* is more variant in density, in tree breeding programme therefore, superior trees for this species must be considered for wood quality improvement.
- Corresponding to their densities, the strength properties of *Polyscias fulva* are significantly lower than those of *Allophylus abyssinicus*, except shear. *Polyscias fulva,* therefore is suitable only for light construction work. With exception of modulus of elasticity and cleavage strength of *Polyscias fulva* and work to maximum load, compression parallel to the grain and shear parallel to the grain of *Allophylus abyssinicus,* variations within species for the rest of wood properties were statistically significant. Wood quality improvement in tree breeding therefore, is only possible through selection.
- Radially, both of the studied species have the heaviest and strongest wood from around the pith and the lightest and weakest wood from around the bark. In the axial direction, the heaviest and strongest wood is from the butt and the lightest and weakest wood is from the top log. The butt log of the tree bole of these species should be considered and the wood near the end of top log avoided, in applications where strength is of at-most importance.
- Further research is required for *Polyscias fulva* and *Allophyllus abyssinicus* since other mechanical properties, such as impact bending, hardness as well as anatomical,

chemical and natural durability were not covered. This will enhance making concrete recommendations on the rational and efficient utilization of these species.

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