VITEX DONIANA SWEET: A POTENTIAL LESSER-KNOWN AND LESSER UTILIZED AGRO-FORESTRY TIMBER SPECIES IN KILOSA DISTRICT, MOROGORO TANZANIA

Makonda, F.B.S.[1]*, D.H. Kitojo[1], S. Augustino[1], C. Ruffo[3], R.C. Ishengoma[1], P.R. Gillah[1], S. Eriksen[2] and H.P. Msanga[3]

[1]Sokoine University of Agriculture (SUA),
[2]University of Life Sciences, Norway (NMBU),
[3]Tanzania Tree Seed Agency (TTSA),
*Corresponding author: Email; bulabo.makonda@gmail.com

Abstract

Tanzania is classified as among the 15 poorest nations in the world, with an estimated per capita income of less than US$ 190. Over 80 % of the country's population of about 46 million lives in rural areas. Living in such a poor country, the people have few feasible alternatives to exploiting the forest resources resulting in high deforestation rate estimated at 2 % annually. Nevertheless, many timber species are still not known to users, resulting into over-exploitation of few well-known timber species. The timber stakeholders need alternatives and the national economies need better ways to derive value from the remaining forests in order to maintain their many useful but under-valued functions. One option is to optimize the production and utilization of lesser-known and lesser-utilized indigenous timber species which are potential for agro-forestry. One of such species is *Vitex doniana* Sweet which belongs to the family Lamiaceae. It is a deciduous tree with medium-growth rate and is widespread in tropical Africa. *V. doniana* is being threatened by habitat loss. This paper attempts to analyze some potentials of *V. doniana* as an agroforestry tree. The studied properties were: i) Physical – Tree dimension, form and quality, wood colour, texture, workability and basic density ii) Strength - Static bending, compression, shear and cleavage and iii) Anatomical - growth rings, **v**essels arrangement, density and size, gum deposits, parenchyma and ray tissue**.** The average physical properties are as follows: The sapwood is white while the heartwood is pale greyish-brown and basic density is 650 kg m^{-3}. The strength properties are: Modulus of elasticity (11,100 N mm^{-2}), Modulus of rapture (98.14 N mm^{-2}), Work to maximum load before failure (0.131 mm N mm^{-3}) and Total Work (0.239 mm N mm^{-3}). The impact bending strength was 1.02 m, Hardness (4,580 N), Compression parallel to the grain (52.5 N mm^{-2}), Shear parallel to the grain (15.6 N mm^{-2}) and Cleavage (9.0 N mm^{-1}). This species depicts well-marked growth rings and therefore ring-porous, meaning a course textured timber. The average strength properties are closely comparable to those of *Tectona grandis* (Teak). Also, *Vitex doniana* has other multiple benefits: bears edible fruits, suitable as ornamental tree and windbreak, shade and its leaves are useful as vegetable and as well as for soil improvement.

Key words: *Vitex doniana*, properties, Kilosa, *Tectona grandis*, agro-forestry, ring-porous

1 INTRODUCTION

1.1 Background information

FAO (1996) recognized the richness in tree species composition of Tanzania's 33.6 million hectares of natural forests. It was earlier on however, realized by FAO (1976) that the presence of wood species with varying properties and characteristics impair the full utilization of these forests. Consequently, only a few well known timber species have commercially been utilized, and often used for purposes which other lesser-known or lesser-utilized but equally suitable and cheaper timber species could be used.

The well-known commercial timber species such as *Milicia excelsa*, *Pterocarpus angolensis*, *Ocotea usambarensis* and *Khaya anthotheca* are increasingly over-exploited to the extent that they are now very scarce if not depleted and their regeneration is threatened (Ishengoma *et al.*; 2000; 2004). But, improving timber utilization calls for optimization of the values of the individual species. The greater use of the lesser-known and lesser-utilized timber species of commercial importance adds to the benefit of consumer as well as that of the nation as a whole. This can be achieved through optimization of the production and utilization of lesser-known and lesser-utilized indigenous timber species which are potential for agro-forestry. One of such species is *Vitex doniana* Sweet syn.*Vitex cienkowskii* Kotschy et Peyr., *Vitex cuneata* Schum. et Thonn. which is also known as Mfudu/Mfulu (Swahili) or Prune leaf/Black plum (English). This species belongs to the family of Lamiaceae. It is a deciduous medium sized tree growing to 8 – 18 m high, with a heavy rounded crown and a clear bole reaching 5 m length.

The species has medium growth rate with trees reaching maturity at age 45 years (Orwa *et al.*, 2009), abundant and geographically widespread in savannah regions. According to Mbuya *et al*. (1994), Storrs (1995), Burkill (2000) and Ruffo *et al*. (2002), *Vitex doniana* is common in coastal woodlands, riverine, lowland and uplands where water table is high and the soils are deep sandy-loam. The species is reported by Ky (2008) as being threatened by habitat loss but not by genetic erosion.

1.2 Objectives

This study investigated some potential of *Vitex doniana* as an agro-forestry timber species in Kilosa District, for enhancement of its efficient utilization. Specifically, the study dealt with:

i. Determination of the following physical properties of *V. doniana*

a. Tree dimension, form and quality
b. Wood colour, texture and workability
c. Wood basic density.

ii. Determination of the following mechanical properties of *V. doniana*
Wood static bending properties including

- Modulus of Elasticity (MOE)
- Modulus of Rapture (MOR)
- Work to Maximum Load

- Total Work in bending.

Wood impact bending strength
c. Wood compression strength parallel to the grain
d. Wood tangential shearing strength
e. Wood Hardness strength
f. Wood cleavage strength.

iii. Characterization of the following anatomical properties of *V. doniana*
c. Growth rings, vessel arrangement, density and size, gum deposits, parenchyma and ray tissue.

2. METHODOLOGY

2.1 Study area description

This study was conducted in Kilosa District, Morogoro Tanzania. The district is located between latitudes 5°55' and 7°53' S and longitudes 36°30' and 37°30 E. The data for *Vitex doniana* tree characteristics and sample materials were collected from Rudewa Gongoni Village Forest Reserve in Kilosa District, Morogoro Tanzania. The forest is located about 25 km north of Kilosa Town, at latitude 6°47' S and longitude 37°08' E and altitude of 495 meters above sea level.

2.2 Sampling and data collection

The information concerning uses of *Vitex doniana* was availed during a timber stakeholders meeting involving 65 participants. A total of 30 mature trees were assessed for their general external physical characteristics. The assessment was on Diameter at Breast Height (Dbh), total height and tree form.

The wood samples were collected from three mature and defect free trees, randomly picked after thorough observation of their physical appearance. The trees represented small, medium and large sizes (Table 1). They were felled and three billets of 1.5 m length were cut from 1.3 m height upwards from each tree felled.

Table 1: Sample tree measurements for *Vitex doniana* from Kilosa District, Morogoro Tanzania

No.	Dbh (cm)	Crown diameter (m)	Height (m)
1.	102.5	7.5	25.5
2.	68.0	7.0	23.5
3.	35.5	6.8	20.0

The billets were sawn to cants and then transported to SUA for further processing. Using standard methods, the cants were re-sawn to scantlings and stacked for drying until the moisture contents became lower than 15 %. The scantlings were further planed down to 20 mm x 20 mm x 1,500 mm from which various dimensions of different test samples were extracted (Table 2).

Determination of moisture content of the samples was done according to Desch (1981) using oven dry method. The colour of the timber 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. The different mechanical properties, were carried out following the procedures described by BS 373 (1957; 1976), Lavers (1969), Panshin and de Zeeuw (1980), ISO 3130 and ISO 3133 (1975).

Table 2 *Vitex doniana* wood test samples for strength properties

Type of test	Test sample size (mm)	Sample count
Static bending	20 x 20 x 300	72
Impact bending	10 x 10 x 50	72
Compression parallel to grain	20 x 20 x 60	72
Shear parallel to the grain	20 x 20 x 20	72
Cleavage parallel to the grain	20 x 20 x 45	72
Hardness	20 x 20 x 60	72

2.3 Data analysis and interpretation

The obtained data were summarized and subjected to Excel Computer packages for analysis employing mostly, descriptive statistics. The properties of *Vitex doniana* were compared with those of selected well-known and better or even over-utilized timber species as documented by other researchers. These species are *Tectona grandis* L.f. (Teak), *Milicia excelsa* (Welw.) C.C. Berg (Mvule) and *Pterocarpus angolensis* DC. (Mninga).

3. RESULTS AND DISCUSSION

3.1 Tree description

The inventory results showed that *Vitex doniana* is a single-stemmed tree, growing high to heights ranging from 17 to 30 m with a mean height of 26 m. The mean dbh was 45 cm and ranged from 32 to 180 cm. These observations are an indication that the species is highly prolific in terms of merchantable timber. From this biomass, the species is suitable for mitigating climate change through carbon sequestration (Marland and Schlamadinger, 1995; Schlamadinger and Marland, 1996; Gustavsson *et al.,* 2006; 2007; SRU, 2007).

The tree bole is straight, round and cylindrical, the characteristics which improve timber recovery during sawing. The results are congruent to observations made by Orwa *et al.* (2009). These features make the species an excellent ornamental, windbreak and shade tree. Other observations confirmed that *V. doniana* is a semi-deciduous tree with average crown diameter of 10.5 m. These findings are an indication that the species has large crown making it suitable for shade and wind protection as also noted by Orwa *et al.* (2009). Moreover, the fallen leaves produce a useful mulch of litter, improving the soil nutrients and other properties. Mapongmetsem *et al.* (2005) reported the annual quantity of dry litter produced by *V. doniana* to be about 200 g m^{-2}, compared to a range of 0 – 250 g m^{-2} of various agricultural crop species recorded by UN (2001). The fruits of *V. doniana* are edible and are quite useful in times of food shortage.

3.2 Timber description

3.2.1 Physical properties

Tree dimension, form and quality

Vitex doniana has white sapwood whereas the heartwood is pale greyish–brown and very decorative. According to Gurmartine (2009), the heartwood is very similar to that of *Tectona grandis* (Teak). The timber texture is coarse with wavy grain and well-marked growth zones. The timber saws easily and machines to excellent finish.

The mean basic density is 650 kg m^{-3} (Table 3) implying that the timber is moderately heavy. The timber of *V. doniana* is heavier than that of Teak with 625 kg m^{-3} and very close to *Pterocarpus angolensis* (Mninga) and *Milicia excelsa* (Mvule) each with 657 kg m^{-3} (Table 4). Where weight is a determining factor for timber use, *V. doniana* can be used as a substitute of Mninga and Mvule.

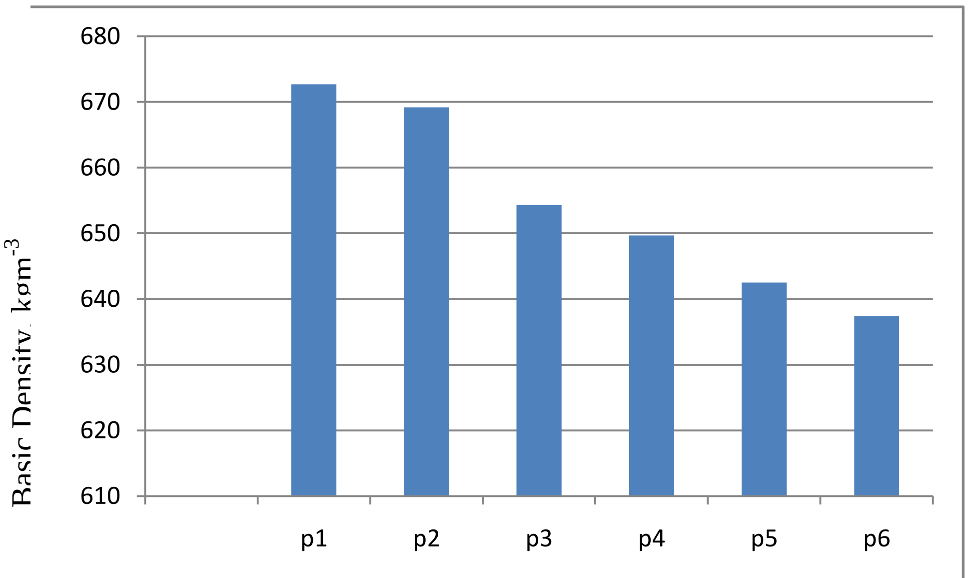
Basic density and its variations

Variation in basic density was assessed between and within a tree in the radial direction 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 *Vitex doniana* can equally be weighted if however, careful assessment is conducted during sampling.

Table 3: Between tree variation in basic density and strength properties for *Vitex doniana* from Kilosa District, Morogoro Tanzania

Strength property		Tree mean value			Overall mea value
		Tree 1	Tree 2	Tree 3	
Basic density, kg m^{-3}		69	62	64	650 ± 2
MOE, N mm^{-2}		10,94.6	11,602.1	11,203.	11,100± 50
MOR, N mm^{-2}		104.7	93.3	95.6	98.14± 8.0
WorkMax, mm Nmm^{-3}		0.13	0.12	0.13	0.131± 0.0
Compression, N mm^{-2}		54.4	51.1	51.9	52.5± 1.
Hardness, (N)		4,89	4,31	4,52	4,580± 28
Shear stress, N mm^{-2}		17.4	14.1	15.5	15.6± 2.3
Cleavage, N mm^{-2}	Radial	11.1	8.0	8.8	9.0± 1.8
	Tangenti	13.	9.6	11.0	11.3± 1.9

The radial variations of basic density within a tree are presented in Fig. 1. *Vitex doniana* has the most dense wood in areas towards the bark (672.7 kg m^{-3}), followed by a decrease inwards with the lightest wood around the pith (about 637 kgm^{-3}). Conversely, statistical analysis indicated non-significance in the observed differences for both directions ($p \leq 0.05$). This pattern was also congruent to that of *Tectona grandis*, reported by Malomo *et al.* (2002). The observations for the variation can be explained by the prominent nature of the growth rings which is an indication of uneven distribution of vessels and wood substance. According to this nature, *Vitex doniana* could be confirmed to belong to class of ring porous hardwood species (Panshin and de Zeeuw, 1980). Deepak *et al*. (2010) noted the same pattern for *Tectona grandis*.



Position from pith to bark

Figure 1: Basic density radial variation of *Vitex doniana* from Kilosa District, Morogoro Tanzania

3.2.2 Strength properties

The mechanical properties of *Vitex doniana* are presented and compared with those of the three commercial timbers of Tanzania; *Tectona grandis, Milicia excelsa* and *Pterocarpus angolensis* in Table 4.

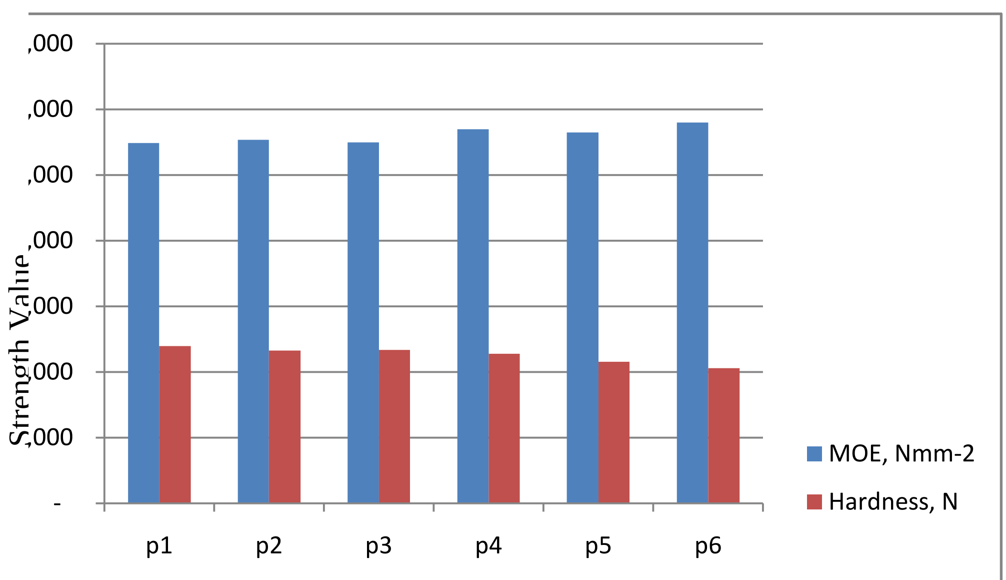
Static bending

The timber of *Vitex doniana* was found to have Modulus of Elasticity of 11,100 N mm^{-2}, Modulus of Rupture of 98.14 N mm^{-2} and Work to maximum Load before failure of 0.131 mm N mm^{-3}. All of these values are higher than those of *Tectona grandis*, *Milicia excelsa* and *Pterocarpus angolensis*. 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 for MOE (Fig. 2) and MOR (Fig. 3) but significant for Work to Maximum Load (Fig. 4).

Table 4: Mechanical properties of *Vitex doniana* in comparison to those of some commercial timbers of Tanzania

Property		Values			
		Vitex doniana [a]	*Tectona grandis* [b]	*Milicia excelsa* [b]	*Pterocarpus angolensis*[b]
MOR, N mm^{-2}		98.14	85.00	90.00	94.00
MOE, N mm^{-2}		11,100	10,930	9,345	8,443
Wmax, mmN mm^{-3}		0.131	0.072	0.088	0.104
Total Work, mmN mm^{-3}		0.239	0.117	0.184	0.313
Impact Bending, m		1.02	0.81	0.71	1.06
Compression, N mm^{-2}		52.5	52.5	54.7	57.0
Hardness, N mm^{-2}		4,580	3,969	5,600	6,578
Shear, N mm^{-2}		15.6	15.0	15.6	17.2
Cleavage, (mm width	Radial	9.0	8.8	12.4	12.7
	Tangential	11.3	11.3	14.6	13.3

Source*:* [a] This study, [b] Bryce (1967)



Position from pith to bark

Figure 2 Modulus of Elasticity and Hardness radial variation of *Vitex doniana* from Kilosa District, Morogoro Tanzania

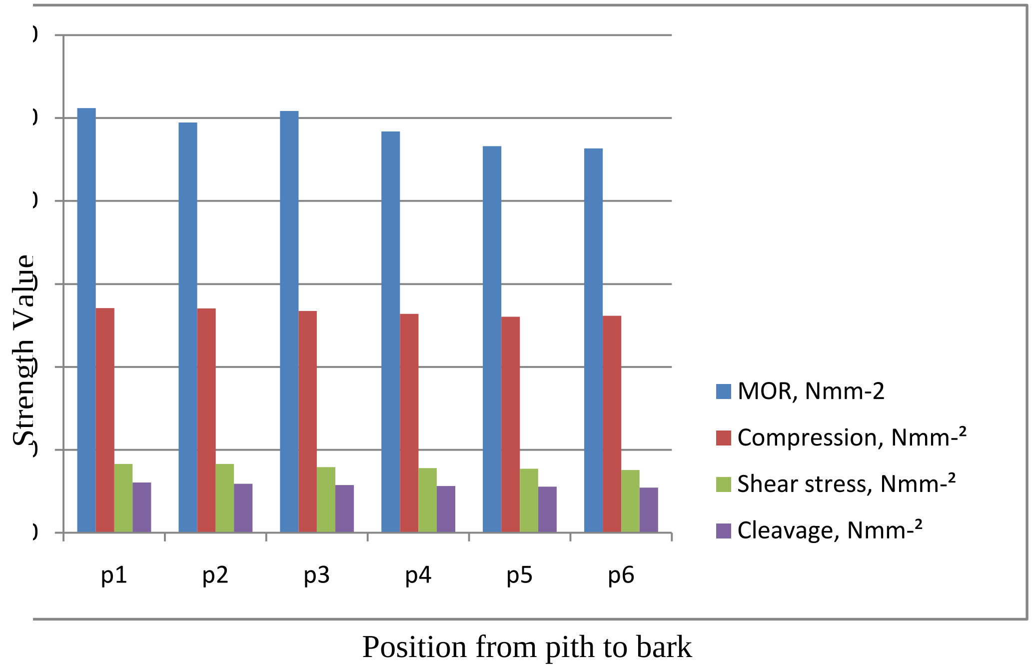


Figure 3 Modulus of Rupture, Compression, Shear and Cleavage radial variation of *Vitex doniana* from Kilosa District, Morogoro Tanzania

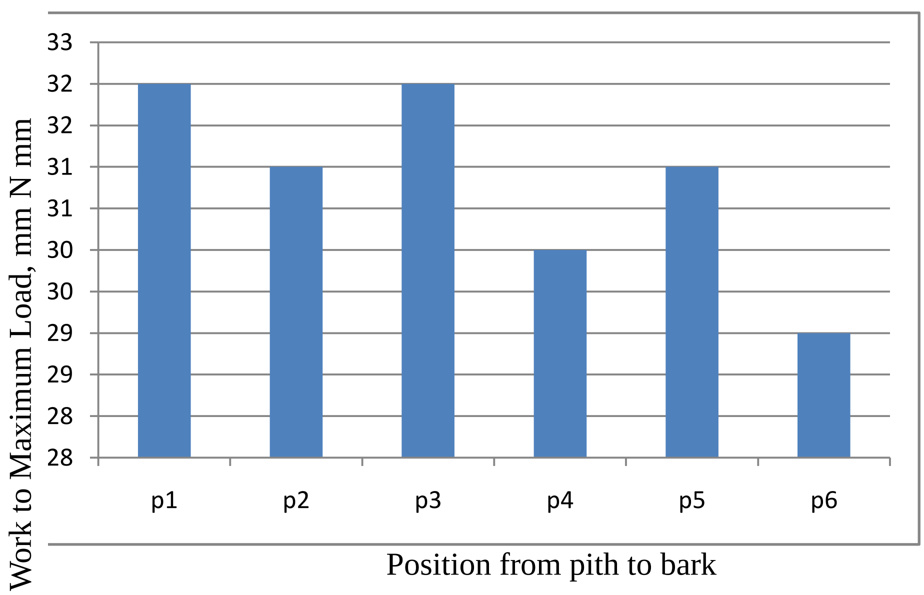


Figure 4 Work to Maximum Load radial variation of *Vitex doniana* from Kilosa District, Morogoro Tanzania

Compressive strength parallel to the grain

The resistance to compression forces parallel to the grain for *Vitex doniana* was 52.5 Nmm^{-2} which is equal to that of *Tectona grandis* but lower than those recorded by Bryce (1967) for *Milicia excelsa* and *Pterocarpus angolensis*. This property value is still high (Aydin and Yardimci, 2007), making the timber species suitable for work such as construction where loading is parallel to the direction of the grain. In other words, *Vitex doniana is* suitable for structural applications.

Variations in compressive strength between trees as shown in Table 3 were proven statistically non-significant ($p \leq 0.05$). Likewise, within tree radial variations were non-significant (Fig. 3).

Hardness

In hardness strength, *Vitex doniana* with 4,580 N mm^{-2} surpasses *Tectona grandis* (3,969 N mm^{-2}) and is weaker than *Milicia excelsa* (5,600 N mm^{-2}) and *Pterocarpus angolensis* (6,578 N mm^{-2}). According to Bryce (1967), the famous timbers for parquet flooring materials in Tanzania have hardness strength of at least 7,200 N mm^{-2}. They include *Bobgunnia madagascariensis* (Paurosa) with 7,200 N mm^{-2}, *Milletia stuhlmanii* (Pangapanga) with 7,227 N mm^{-2} and *Brachylaena huillensis* (Mhuhu) with 9,733 N mm^{-2}. The lower hardness strength of *Vitex doniana* exhibits that the timber is unsuitable for parquet floor. There were no statistical differences of Hardness strength between trees (Table 3) and within a tree in the radial direction as depicted in Fig. 2.

Shear strength parallel to the grain

Shear strength of *Vitex doniana* was found to be at an average of 15.6 N mm^{-2} which also, is equal to that of *Milicia excelsa* and a bit higher than that of *Tectona grandis* (15.0 N mm^{-2}) but lower than that of *Pterocarpus angolensis* (17.2 N mm^{-2}). Nonetheless, this strength property, which is highly sought for designing of joints in construction work, is still low as hinted out by Bryce (1967). There were no statistical differences of Shear strength between trees (Table 3) and within a tree in the radial direction (Fig. 3).

Cleavage strength

Vitex doniana timber has cleavage strength of 9.0 and 11.3 N mm^{-2} in the radial and tangential direction, respectively. These values are of equal magnitude with those of *Tectona grandis* but lower than those of *Milicia excelsa* and *Pterocarpus angolensis* (12.4 and 14.6 N mm^{-2} and 12.7 and 13.3 N mm^{-2} in the radial and tangential direction, respectively). Bryce (1967) noted that timbers with such strength are easy in splitting, therefore suitable for uses needing easy splitting for instance pulping and for firewood. The conspicuous nature of the growth rings of these timbers can explain for this characteristic. With reference to Table 3 and Fig. 3, there were no significant differences noted between and within tree ($p \leq 0.05$).

Relationship between basic density and strength properties

The results presented in Table 4 as indicated by coefficient of determination (R^2) show that in *Vitex doniana* timber, there is a strong relationship between basic density and all strength properties studied with an exception of Shear which had R^2 of 8% only. However, the low R^2

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 hardness (R^2 = 0.84) and basic density and cleavage (R^2 = 0.83). This means that basic density contributed to about 84% to hardness and 83% to cleavage strengths and the remaining 16 and 17%, respectively by unexplained factors. Therefore the cause and effect between basic density and hardness and cleavage is strong. The same argument stands for the other strength properties.

Table 4 Relationship between Basic density and strength properties of *Vitex doniana* from Kilosa District, Morogoro Tanzania

Strength properties	Regression equation	oefficient of determination (R^2)
lus of Elasticity	,237.6 + 9.87χ	0.37
lus of Rupture	14.25 + 0.173χ	0.60
to Maximum Load	0.78 + 0.001351χ	0.52
ression parallel to grain	9.01 + 0.0226χ	0.69
ess	4.52 + 6.785χ	0.84
parallel to grain	2.42 + 0.0285χ	0.08
age	.79 + 0.011χ	0.83

Where: Y = Strength property, χ = Basic density

3.2.3 Anatomical properties

Observations on the anatomical properties of *Vitex doniana* timber revealed that there is distinct seasonal variation in tracheary-element diameter, growth rings are therefore prominent. Due to this kind of vessel arrangement, the timber is placed in ring-porous hardwood group as far as major classes of wood anatomy are concerned (Phillips *et al.*, 1996). The vessels are numerous, with a mean density of 18 mm^{-2}. The vessel size ranged from 0.02 mm to 0.1 mm. The timber does not have gum deposits. The parenchyma tissues are indistinct and ray tissues have density of 12 to 16 mm^{-1}, very fine with size less than 0.05 mm. *Tectona grandis*, a closely related species has abundant rays (Ahmed and Chun, 2011). Those of *Pterocarpus angolensis* are 12 to 17 mm^{-1} and size reaching 0.05 mm, for *Milicia excelsa* is 3 - 9 mm^{-1} (Richter and Dallwitz, 2000).

The above observations for *Vitex doniana* indicate that the timber is permeable to chemical preservation. In other words, the timber can readily be impregnated satisfactorily under both non-pressure and pressure methods.

4. CONCLUSIONS AND RECOMMENDATIONS

From its merchantable timber volume, *Vitex doniana* is a prolific potential lesser-known indigenous agro-forestry tree that is also fairly fast in growing. The species is a multipurpose tree suitable for amenity, shade, fodder, edible fruits, soil improvement, firewood and timber.

It can therefore, be grown in agro-forestry systems and sustainably managed for other purposes before it reaches its rotation age.

There are no statistically significant differences between and within *Vitex doniana* trees (radially), in all of the studied properties. Any properly selected mature and defect free tree therefore can be of equal importance as far as mechanical properties are concerned.

The studied properties indicate that the timber is suitable for furniture, cabinet work, paneling, veneer, and construction purposes. The average strength properties are closely comparable to those of *Tectona grandis* (Teak). From the technical information gathered on *Vitex doniana* it is important that this species is marketed. It is henceforth, recommended that this species is used as an agro-forestry tree in Kilosa District.

Acknowledgements

This work was carried out with funds from the Programme for Enhancing Pro-poor Innovations in Natural Resources and Agricultural Value Chains (EPINAV).

REFERENCES

Ahmed,S.A. & Chun, S.K. (2011). Permeability of *Tectona grandis* L. as affected by wood structure. *Wood Science and Technology* 45(3): 487 - 500.

Aydin, S. & Yardimci, M.Y. (2007). Mechanical Properties of Four Timber Species Commonly Used in Turkey. *Turkish J. Eng. Env. Sci.* 31: 19 – 27.

Bryce, J. M. (1967). *The commercial Timbers of Tanzania*. Revised 2nd Edition of 2000. Tanzania Forestry Research Institute, Morogoro Tanzania.

BSI 373. (1957). *Methods of testing small clear specimens of Timbers*. (B.S 373 MTSCST) British Standards Institution. 2 Park Street, London 31p.

Burkill, H.M. (2000. *The useful plants of West Tropical Africa*. 2nd Edition. Volume 5, Families S–Z, Addenda. Royal Botanic Gardens, Kew Richmond, UK 686 pp.

Deepak, M. S., S.K. Sinha & R.V. Rao (2010). Tree-ring analysis of teak (*Tectona grandis* L. f.) from Western Ghats of India as a tool to determine drought years. *Emir. J. Food Agric.* 22 (5): 388 - 397.

Desch, H. E. (1981). *Timber: Its structure and properties.* Macmillan Press Ltd., London.

FAO (1976). The marketing of tropical wood: Wood species from African tropical moist forests. Rome, Italy.

FAO (1996). European timber trends and prospects: *Into the21st Century*. Geneva Timber and Forest Study Papers, No. 11. Geneva.

Gurmartine, T. (2009).Edited by Goudzwaard, L. Tree factsheet: *Tectona grandis L.* Forest Ecology and Forest Management Group, Wageningeni University

Gustavsson, L., Sathrea, R., Schlamadinger, B. & Kimberly, R. (2006). Efficient Use of Biomass for Mitigating Climate Change. *Journal of Mitigation and Adaptation Strategies for Global Change,* 11(5 – 6): 933 - 934.

Gustavsson, L., Holmberga, J., Dornburga, V., Sathrea, R., Eggersa, T., Mahapatraa, K. & Marlanda, G. (2007). Using Biomass for Climate Change Mitigation and Oil Use Reduction. *Energy Policy* 35(11): 5671 – 5691.

Ishengoma, R. C., Gillah, P.R., Amartey, S.A., Makonda, F. B. S. & Hamza, K. F. S. (2000). Important physical and mechanical properties of *Albizia amara*: A lesser utilized species in Tanzania. *Tanzania journal of Forestry and Nature Conservation* 73: 94 – 98.

Ishengoma, R. C., Gillah, P. R., Buyeya, J. & Kitojo, D. H. (2004). Assessment of some physical and strength properties of *Faurea saligna* and *Bridelia micrantha* the lesser known and lesser utilized timbers from Iringa, Tanzania. *Tanzania journal of Forestry and Nature Conservation* 10: 65 - 70.

ISO 3131. (1975). *Wood-Determination of Density for Physical and Mechanical Test*. Printed in Swizerland.

ISO 3349. (1975). Wood-Determination of Modulus of Elasticity in Static Bending. 1st Ed. Printed in Switzerland.

ISO 7724 (1984). Paints and varnishes Calorimetry Part 3. Calculation of colour differences, 3pp.

Ky, K.J.M., 2008. *Vitex doniana* Sweet. Record from PROTA 4U. Louppe, D., Oteng-Amoako, A.A. & Brink, M. (Editors). PROTA (Plant Resources of Tropical Africa / Ressources végétales de l'Afrique tropicale), Wageningen, Netherlands [Online] Available: http://www.prota4u.org/search.asp (January 10, 2016).

Lavers, G. M. (1969). *The strength properties of timbers*. Forest Product Research, Bulletin No. 50, Her Majesty's Stationary Office, London. 61p.

Malomo, P. O., Oyagade, A.O. & Fuwape, J.A. (2002). Variation in wood qualities of plantation - grown teak (*Tectona grandis* L.f) in Ogbbse Forest Reserve, Ekiti State Nigeria. A dissertation submitted to the school of Post Graduate Studies in partial fulfillment of the requirements for the award of Master in Agricultural Technology degree, Federal University of Technology, Akure, Nigeria.

Mapongmetsem, P.M., Benoit, L.B., Nkongmeneck, B.A., Ngassoum, M.B. Gübbük, H., Baye–Niwah, C. & Longmou, J. (2005). Litterfall, Decomposition and Nutrients Release in *Vitex doniana* Sweet. and *Vitex madiensis* Oliv. in the Sudano–Guinea Savannah. *Akdeniz Üniversitesi Ziraat Fakültesi Dergisi,* 18(1): 63 - 75.

Marland, G. & Schlamadinger, B. (1995). Biomass Fuels and Forest Management do we Strategies: How Calculate the Greenhouse-Gas Emissions Benefits? *Energy* 20: 1131 - 1140.

Mbuya, L.P., Msanga, H.P., Ruffo, C.K., Birnie, A. & Tengnäs, B. (1994). *Useful trees and shrubs for Tanzania: identification, propagation and management for agricultural and pastoral communities.* Technical Handbook 6. Regional Soil Conservation Unit/SIDA, Nairobi, Kenya. 542 pp.

Orwa, C., Mutua, A. Kindt, R., Jamnadass, R. & S. Anthony (2009). Agroforestry Database: A Tree Reference and Selection Guide version 4.0 [Online] Available: http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp (January 10, 2016).

Panshin, A. J. & de Zeeuw, C. (1980). *Textbook of Wood Technology*: Structure, Identification, Properties and Uses of Commercial Woods of the United State of Canada 4th edition. McGraw Hill Book Company, New York, 722pp.

Phillips, N., Oren, R. & Zimmermann, R. (1996). Radial patterns of xylem sap flow in non-diffuse and ring-porous tree species. *Plant, Cell and Environment* 19: 983 – 990.

Richter, H.G., & Dallwitz, M.J. (2000). Commercial timbers: descriptions, illustrations, identification, and information retrieval.

Ruffo, C.K., Birnie, A. & Tengnäs, B. (2002). *Edible wild plants of Tanzania*. Technical Handbook No 27. Regional Land Management Unit/ SIDA, Nairobi, Kenya. 766 pp.

Schlamadinger, B. & Marland, G. (1996). The Role of Forest and Bioenergy Strategies in the Global Carbon Cycle. *Biomass and Bioenergy* 10 (5/6): 275–300.

SRU (2007). Climate Change Mitigation by Biomass. Special Report, German Advisory Council on Environment, Berlin, Germany, 122p.

Storrs A.E.G. (1995). Know your trees: some common trees found in Zambia. Regional Soil Conservation Unit (RSCU).

United Nations (2001). *Guidelines for Yield Assessment of Opium Gum and Coca Leaf*: From Brief Field Visits. United Nations International Drug Control Programme. Scientific Section, Illicit Crop Monitoring Programme, Vienna 59pp.

Biographies:

Prof. Fortunatus Bulabo Stephen Makonda - Associate Professor with over 20 years' experience in teaching, research and consultancy and 52 publications on Sustainable Utilization of Forest Products (Wood Properties, Lesser-known Timbers and Non-Timber Forest Products). A life member of the Association for the Taxonomic Studies of the Flora of Tropical Africa (AETFAT). Former Head of Department of Wood Utilization (2006 – 2014),

Mr. Daudi Hamza Kitojo - Chief Wood Technologist, with over 40 years' experience in teaching, research and consultancy and over 30 publications on Wood Science and Technology (Wood Properties, Lesser-known Timbers, Forestry Industries, Wood-Based Materials). Head of Wood Science Laboratory.

Dr. Suzana Augustino - Senior Lecturer with 16 years' experience in teaching, research and consultancy and over 35 publications on Sustainable Utilization of Forest Products both Timber and Non-Timber, Gender and CCIAM and REDD related issues. Member of Global Association of Foresters (GAOF), Women Scientists in African Union and Editorial Committee of *Journal of Forestry and Nature Conservation*. Current Head of Department of Wood Utilization.

Mr. Christopher Kilanga Ruffo - Chief Botanist, with vast global working experience of over 40 years with the Government of Tanzania, Kew Botanic Garden (UK), Government of Rwanda, Malawi, Zambia, Kenya etc. Over 60 publications mostly books including Useful Trees and Shrubs of Tanzania, Useful Trees and Shrubs of Rwanda, Catalogue of Lushoto Herbarium, Tanzania, Edible Wild Plants of Tanzania and Potential natural vegetation of Eastern Africa.

Prof. Romanus Cleophace Ishengoma - Professor, with 40 years' experience in teaching, research and consultancy and over 100 publications on Wood Science and Technology (Wood Properties, Lesser-known Timbers, Wood-Based Industries and Wood Energy). Member of Timber Technical Committee of Tanzania Bureau of Standards (TBS), Renewable Energy and

Environmental Conservation Association in Developing countries (REECA), Volunteers in Technical Assistance (VITA), The Tanzanian Society (Publishers of Tanzania Notes and Records), African Forest Research Network (AFORNET) and African Forest Forum (AFF). Former Head of Department of Wood Utilization (1987 – 1990, 1993 – 1996) and Dean of Faculty of Forestry and Nature Conservation (1996 – 2002).

Prof. Peter Reuben Gillah - Professor with 28 years' experience in teaching, research and consultancy and over 60 publications on Wood Science and Technology (Wood Properties, Lesser-known Timbers, Forestry Industries, Wood-Based Materials). Former Head of Department of Wood Utilization (2003 – 2006) and Dean of Faculty of Forestry and Nature Conservation (2006 – 2011). Current SUA Deputy Vice-Chancellor (Academic)

Prof. Siri Hallstrøm Eriksen - Associate Professor with 22 years' expertise and experience and teaching, research and consultancy and over 60 publications on Qualitative Social Research. Work experience in Southern Africa particularly on Management of Local Agro-Ecosystems in Kenya and Tanzania. Member of Editorial board of *Journal of Climate and Development*, Earthscan, Organising committee for the Research Council of Norway international conference on Environment and Poverty in 2002, Reviewer of the Intergovernmental Panel on Climate Change Report for Cambridge University Press and the following journals: *Agriculture and Human Values, Climate and Development, Environmental Science and Policy, European Journal of Development Research, Geoforum, Geographical Journal, Global Environmental Change, Journal of Arid Environments, Natural Resources Forum, New Political Economy, Regional Environmental Change* and *World Development*

Dr. Heriel Petro Msanga - Senior Forest Officer and Chief Executive with 37 years' experience as a researcher majoring on Forest Biology (Tree Seeds and Forest Ecology). Over 30 publications mostly books including Seed germination of indigenous trees in Tanzania, Useful Trees and Shrubs of Tanzania, Seed desiccation and storability of *Strychnos cocculoides*, *Ximenia americana* and *Warbugia salutaris.* Dormancy and germination of tropical tree seeds, Food and Fruit – Bearing Forest Species and Some Medicinal Forest Plants of Africa and Latin America.