Variation of basic density and fibre length in *Lonchocarpus capassa* (Rolfe) wood from Kilosa District, Tanzania

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ABSTRACT
Within tree radial and axial variations of wood basic density and fibre length of *Lonchocarpus capassa* (Rolfe) were investigated using three mature defect free trees from Kilosa District, Tanzania. Samples for determination of wood basic density and fibre length were collected from the butt, the middle and the tip of the stem height and six radial positions. Wood basic density and fibre length were determined following standard procedures. The average wood basic density and fibre length were 569.3 kg m^{-3} and 1.38 mm, respectively. Statistical analysis indicated that stem height and radial positions had significant effect on wood density and fibre length. There was no positive linear relationship between wood basic density and fibre length. Based on density, the wood of *L. capassa* is heavy and is more or less comparable to that of *Khaya anthotheca*. The two species can therefore be used exchangeably if wood density is the only pre-requisite. Normally, heavy timbers are suitable for wood fuel from their high calorific values. The fibres of *L. capassa* are longer than those of the commonly used species in pulp and paper production in Tanzania, showing the potential of *L. capassa* for being used in pulp and paper making.

Key words: Wood basic density, fibre length, *Lonchocarpus capassa*, Tanzania

INTRODUCTION
Lonchocarpus capassa (Rolfe) (Mfumbili) is among the indigenous lesser known and lesser utilized timber species in Tanzania that have potential for incorporation in agroforestry for multiple benefits. The species belongs to the family and sub-family *Fabacea* and *Papilionoideae*, respectively. It is found in deciduous woodlands and wooded grasslands, usually along water courses, from 150 to 1,650 m above sea level. It is found in Tanzania, Democratic Republic of Congo, Angola, Zambia, Malawi, Mozambique, Zimbabwe and South Africa (Backéus *et al.* 2006). In Tanzania, it is common in Tabora, Dodoma, Morogoro and Iringa regions. The tree has various uses namely firewood, timber, utensils, tool handles, food, medicine, fodder and bee forage (Mbuya *et al.* 1994). Nevertheless, the use of the species has been on the basis of experience as there are no any scientific backings so far that have been established.

This study aimed at investigating the wood basic density and fibre length of *L. capassa*. The assessment of these properties is necessary for marketing and promoting of the species in both local and international markets.

Wood density is an important attribute of timber because it significantly influences other wood properties (Zobel and Van Buijtenen 1989). Mostly, it correlates with the wood's strength properties (Sonderegger *et al.* 2008). Walker (1993) reported that basic density of any wood provides an index of wood quality to which all end uses can relate. To saw millers, high density indicates that the timber will be hard and stiff to saw, while to the pulp mill, it indicates high pulp yield, but also problems in chipping and in paper formation. Haygreen and Bowyer (1996) reported that the strength of wood is usually closely correlated to density and it is possible to estimate wood strength based on density without detailed knowledge of the species. Wood density is highly affected by cell wall thickness, cell diameter and the ratio of early wood to latewood, tree species, annual ring width, the position within a stem and the presence of juvenile wood (Zobel and Van Buijtenen 1989).

Fibre length is another wood quality which affects its strength. Walker (1993) reported that the minimum fibre length of 2 mm is required to produce acceptable kraft pulp. Fibre length is an important index for pulp and paper production. This index has a positive influence on the quality of pulp and paper (Wangaard and Woodson 1973; Panshin and de Zeeuw 1980) and wood mechanical strength properties (Bisset *et al*. 1951).

Fibre length has an important effect on the physical and mechanical properties of wood-based products such as paper, paper board, insulation board, medium-density fiberboard, particleboard, hardboard, and wood fibre polymer composites (Takahashi *et al.* 1979; Mark and Gillis 1983; Lee et *al.* 2001; Huber *et al*. 2003). Significant variability in fibre length exists for wood fibres from the same tree and from different tree species. In the same tree, the length of individual fibres may vary depending on many factors such as distance from the ground, distance from the pith, early wood or late wood, heartwood or sapwood (Mark and Gillis 1983).

Variations in wood density and fibre length are present in trees in the radial and longitudinal directions and within the annual rings (Zobel and Van Buijtenen 1989). In this study, the axial and radial variation of wood basic density and fibre length within a stem for *L. capassa* was assessed.

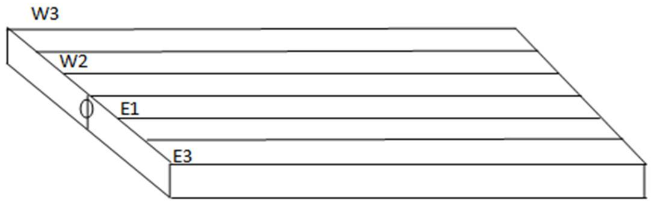
METHODOLOGY

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. *L. capassa* sample trees were collected from Rudewa Gongoni Village Forest Reserve in the district. 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. This area receives annual rainfall ranging from 600 to 1,200 mm and the mean temperature is 22^{o}C (KDC 1997).

Sampling and data collection

The wood samples for determination of basic density and fibre length were collected from three mature and defect free trees in accordance to ISO (1982), purposively picked after thorough observation of their physical appearance. The trees represented small, medium and large sizes. They were felled and three logs cross cut to represent butt, middle and top part of each tree. The logs were then reduced to cants, each measuring 250 mm thick and 1,500 mm long and transported to Sokoine University of Agriculture for further processing. Using standard methods, the cants were re-sawn to 94 scantlings each measuring 30 mm x 30 mm x 1,500 mm, labelled from the pith outwards showing the position of extraction (Figure 1).



E_1, E_2, .., E_n, W_1, W_2, ..,W_n denote direction of extraction

Figure 1: Sawing and labelling of scantlings

The scantlings were stacked to air dry for four weeks until the moisture content reached roughly 15% when they were further planed down to 20 mm x 20 mm x 1,500 mm from which test samples for basic density (20 mm x 20 mm x 10 mm) and fibre length (20 mm x 20 mm x 20 mm) were extracted. The wood basic density was determined following standard procedures described by ISO 3131 (1975). The specimens were soaked in water to attain green state volumes. The weight of each test specimen was determined after oven drying the samples at a temperature of $103^{o}C \pm 2^{o}C$.

The basic density for each sample was computed as follows:

$$\rho = \frac{Mo}{Vu}$$

Where: ρ = Basic density (kg m^{-3}),

Mo = Oven dry weight (kg), and

Vu = Green volume (m^3)

Determination of wood fibre length

Fibre length was determined using Franklin's method as described by Oluwadare (2007). In summary, each sample was split into small splinters and cooked at $70^{o}C$ for 48 hours using hydrogen peroxide (H_2O_2) (50%) and glacial acetic acid (CH_3COOH) in a 1:1 volume ratio. The macerated fibres were then washed with distilled water and finally shaken to separate them and stained with safranin solution. Defect free stained fibres were then mounted on slides ready for measuring their lengths using a microscope.

DATA ANALYSIS

Basic density and fibre length data were summarized and subjected to Excel Computer packages employing mostly descriptive statistics. Within stem variations in the studied properties were analyzed using analysis of variance (ANOVA). Linear regression analysis was used to determine the relationship between basic density and fibre length.

The properties of *L. capassa* were compared with those of selected well-known and better or even over-utilized timber species as documented by other researchers. These species are *Afzelia quanzensis* Welw. (Mkongo), *Milicia excelsa* (Welw.) C.C. Berg (Mvule), *Khaya anthotheca* (Welw.) C. DC. (Mkangazi) and *Pterocarpus angolensis* DC. (Mninga) for basic density. For fibre length, comparison was made with the important pulp and paper species in Tanzania. These are *Eucalyptus grandis* W. Hill ex Maiden, E. *maidenii* F. Muell., *E. saligna* Sm, *Pinus patula* Schiede ex Schltdl. & Cham. and *P. kesiya* Royle ex Gordon.

RESULTS

Wood basic density

Results (Table 1) show that the mean wood basic density of *L. capassa* was 569.3 kg m^{-3} with a standard deviation of 45.17 kg m^{-3}. The average radial and axial variations of wood basic density of *L.* are presented in Figures 2 and 3. ANOVA proved significant ($p<0.05$) differences in wood basic density both in radial and axial directions. However, the interaction between wood density and the variation in both radial and axial positions was not significant ($p>0.05$).

Table 1. Comparison of mean values of basic densities of *L.* with some well known timber species of Tanzania

Species name		Mean basic density (kg m^{-3})	Remarks
Botanical	Kiswahili		
L. capassa	Mfumbili	569.3	Heavy wood
Afzelia quanzensis[a]	Mkongo	865	Heavy wood
Pterocarpus angolensis[a]	Mninga	657	Heavy wood
Khaya anthotheca[a]	Mkangazi	577	Heavy wood
Milicia excelsa[a]	Mvule	657	Heavy wood

Source: [a] Bryce (1967)

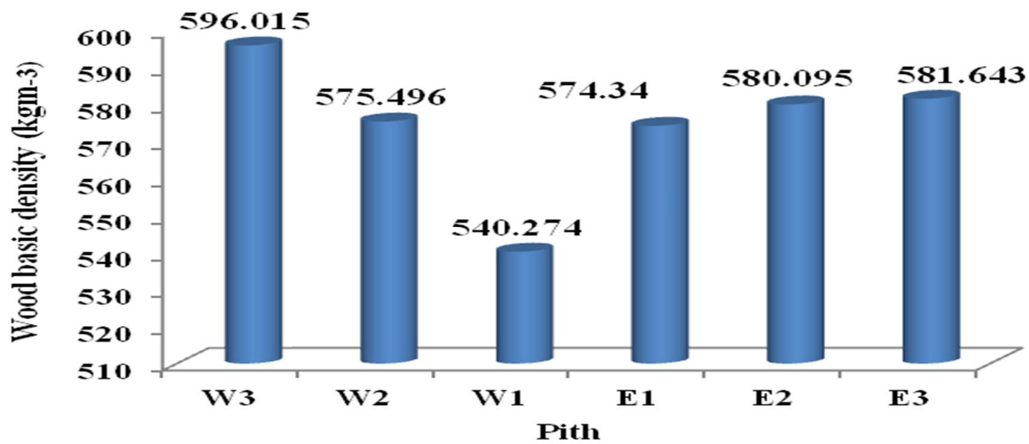


Figure 2: Radial variation of basic density of wood of *L. capassa* from Kilosa District, Tanzania

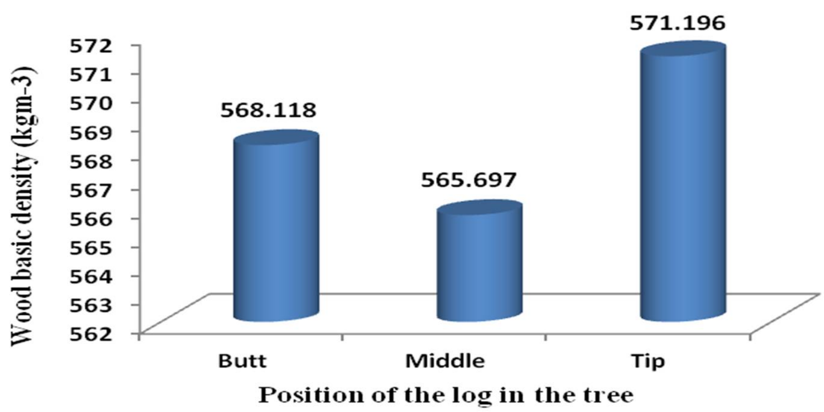


Figure 3: Axial variation of basic density of wood of *Lochocarpus capassa* from Kilosa District, Tanzania

Fibre length

The mean fibre length of *L. capassa* was 1.38 mm with a standard deviation of 0.058 mm. The variations in axial and radial directions are presented in Figures 4 and 5. Statistical analysis revealed significant differences ($p<0.05$) in axial and radial direction but the interaction between wood basic density and fibre length was not significant. The mean fibre length values increased in the axial direction from the butt end upwards the tree, varying from 1.29 mm to 1.42 mm. This pattern of variation was also found in *Eucalyptus globulus*, *E. regnans* and *E. grandis (*Dharm and Tyagi 2011). For the radial variation, fibre length values showed an increase from the pith towards the bark varying from 1.31 to 1.42 mm.

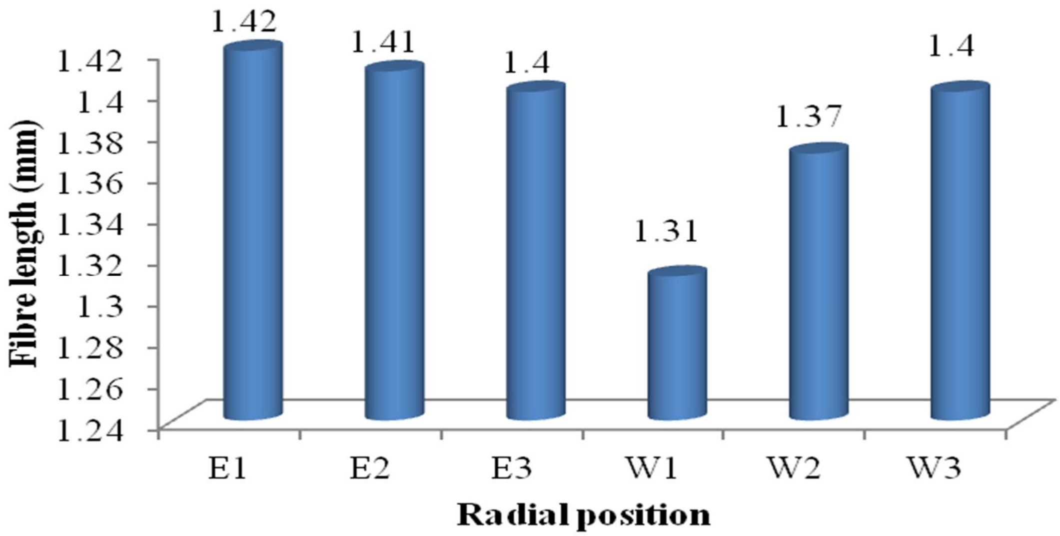


Figure 4: Radial variation of fibre length of wood of *Lochocarpus capassa* from Kilosa District, Tanzania

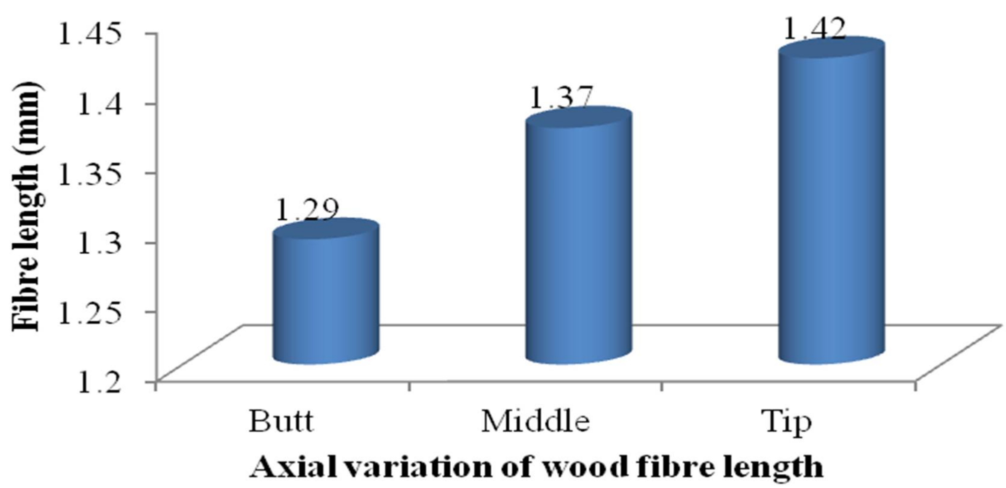


Figure 5: Axial variation of fibre length of wood of *Lochocarpus capassa* from Kilosa District, Tanzania

Comparison of the fibre length of *L. capassa* was made with those of the well-known species which are used in pulp and paper production in Tanzania (Table 2).

Table 2: Comparison of fibre length values of *L. capassa* with some well-known timber species of Tanzania

Species name		Fiber length	
Botanical	Swahili	(mm)	Remarks
L.	Mfumbili	1.38	Medium length
E. grandis[a]	Mkaratusi	1.06	Medium length
E. maidenii[b]	Mkaratusi	0.98	Medium length
E. saligna[b]	Mkaratusi	0.94	Medium length
Pinus patula[c]	Mpaini/Msindano	3.4	Long
P. kesiya[a]	Mpaini/Msindano	2.3	Long

Source: [a] Dharm and Tyagi (2011); [b] Iddi *et al.* (1998); [c] Bolza and Keating (1972)

Relationship between basic density and fibre length

Regression analysis showed an insignificant ($p>0.05$) positive linear relationship between basic density and fibre length (Fig. 5). This is an indication that fibre length is influenced much more by other factors than basic density.

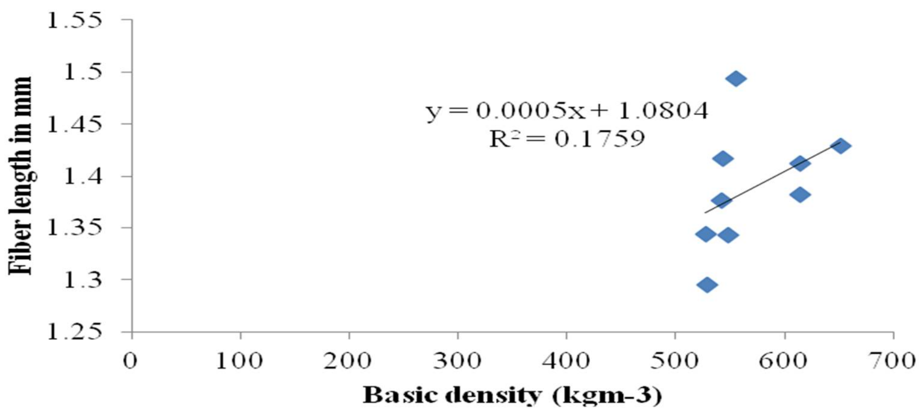


Figure 6: Relationship between basic density and fibre length in *Lochocarpus capassa* from Kilosa District, Tanzania

DISCUSSION

Panshin and de Zeeuw (1980) classified wood densities of 360 kg m^{-3} or less as light, 360 to 500 kg m^{-3} moderate and those with above 500 kg m^{-3} as heavy. The studied species therefore has heavy wood which is suitable for wood fuel. Downes *et al.* (1997) reported that in pulp and paper production, wood with a basic density in the range of 400 to 600 kg m^{-3} is preferable, showing the potential of *L. capassa* use in pulp and paper making.

In the radial direction, as depicted in Fig. 2, the density of *L. capassa* wood increased from the pith (540.3 kg m^{-3}) to the bark (596.1 kg m^{-3}). This pattern was also reported by Hamza *et al.* (2001) for *Artocarpus heterophylus*, Panshin and de Zeeuw (1980) for *Acacia mollissima, Betula pubescens, Eucalyptus robusta, Eucalyptus grandis* and *Terminalia superb* all of which are diffuse porous. Due to this variation, *L. capassa* can probably be classified as a diffuse porous species. In such species, Panshin and de Zeeuw (1980) observed that the mean basic density increases from the pith to the bark and the curve representing the changes may show continuous linear or curvilinear increase, or may flatten in the mature wood and exhibit a decrease for the outer parts of the trunk in old trees. However, in the current study this needed to be confirmed further by anatomical studies.

The radial variations could be attributable to differences in properties and proportions between juvenile and mature wood, early and latewood, sap and heartwood and growth ring numbers and their widths. Knapic *et al*. (2008) found latewood to contribute on average to 61 % of the total density variation in *Quercus suber* (cork oak). These authors also supported by Mitchell and Denne (1997) who found the influences of cambial age and ring width to be responsible for within-tree radial variation within a cross-section. The latter estimated the influences to be 18% of the total variation in *Picea sitchensis*. The wood density decreased from pith to bark, corresponding to 19 – 24% of the total variation of wood density.

In the axial direction, as Fig. 3 shows, the density of *L.* decreased from the butt end (568.2 kg m^{-3}) to the middle (565.7 kg m^{-3}) and then it increased to the top of the tree (571.2 kg m^{-3}). A similar pattern was reported by Gillah *et al.* (2009) for *Uapaca kirkiana.* This pattern was reported by Schuldt *et al.* (2013) to be common in broad–leaved trees. The axial variation of wood basic density might have been caused by differential growth. Haygreen and Bowyer (1996) and Deng *et al.* (2014) noted the variations to arise from different factors, such as ring properties namely; width and orientation.

Comparison of basic densities of *L. capassa* with some well known and well utilized hardwood timber species of Tanzania in Table 1 shows that the studied species has lower density than *Afzelia quanzensis* (865 kg m^{-3}) and *Pterocarpus angolensis* and *Milicia excelsa* (each with 657 kg m^{-3}). However, the density of *L. capassa* approaches that of *Khaya anthotheca* (577 kg m^{-3}). With this range of density, *L. capassa* can therefore be exchangeable used with *Khaya anthotheca* if wood density is the only pre-requisite. The tree has other various uses including fuel, tool handles, utensils, medicine, fodder and bee-forage (Mbuya *et al.* 1994).

L. capassa had longer fibres (1.38 mm) than *E. grandis* (1.06 mm), 2011), *E. maidenii* (0.98 mm) and *E. saligna* (0.94 mm) from Tanzania (Iddi *et al.* 1998). These eucalypts are used in the production of pulp and paper in mixture with pines. The fibre lengths reported in this study are suitable for pulp and paper production since their lengths are within the limits of fibre length of broadleaves species used in pulp and paper production (FAO, 1973). According to Hosseini and Naghdi (2004), the fibres of hardwoods can be categorized in three groups namely; short fibres (<0.9 mm), medium length fibres (0.9 - 1.6 mm) and long fibres (>1.6 mm). From this classification, *L.capassa* wood is medium length fibred.

CONCLUSION AND RECOMMENDATIONS

Based on density, the wood of *L. capassa* is heavy and is more or less comparable to that of *K. anthotheca*. The two species can therefore, be used exchangeably if wood density is the only consideration. Normally, heavy timbers are suitable for wood fuel due to their high calorific values. The indication of significant differences in the radial and axial direction for wood density is a testimony that the lightest wood of *L. capassa* comes from the region adjacent to the pith and specifically from the middle log. The fibres of *L. capassa* are longer than those of the commonly used species in pulp and paper production in Tanzania, showing the potential of *L. capassa* for being used in pulp and paper making. The patterns of fibre length variations in the radial and axial directions indicates that the longest fibres are in the region adjacent to the bark and specifically from the top log. Based on the aspects studied, the other recommended uses of *L. capassa* include boat internal fittings, batons and other structural uses where moderately high density is a desired property. Studies on the mechanical, other physical and anatomical properties of *L. cappassa* are recommended for discovering its full potential uses.

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