

Research Article

Effect of Spacing Regimes on Growth, Yield, and Wood Properties of *Tectona grandis* at Longuza Forest Plantation, Tanzania

Eliakimu Zahabu,¹ Tumaini Raphael,² Shabani Athumani Omari Chamshama,³ Said Iddi,¹ and Rogers Ernest Malimbwi⁴

¹Department of Forest Mensuration, Sokoine University of Agriculture, P.O. Box 3013, Morogoro, Tanzania

²Tanzania Forestry Research Institute, P.O. Box 166, Mwanza, Tanzania

³Department of Forest Biology, Sokoine University of Agriculture, P.O. Box 3010, Morogoro, Tanzania

⁴Department of Wood Utilization, Sokoine University of Agriculture, P.O. Box 3014, Morogoro, Tanzania

Correspondence should be addressed to Eliakimu Zahabu; zahabue@yahoo.com

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This study examined the effects of planting spacing on growth, yield, and wood properties of teak planted at square spacing regimes of 2 m, 3 m, and 4 m at Longuza Forest Plantation, Tanzania. To achieve this, tree, stand, and wood properties were studied at age of 14 years. Results showed that diameter at breast height and total height increased with increasing spacing. Mean annual increment increased significantly with increasing spacing while spacing did not have significant effect on total volume production and basal area. Basic density is also not affected by spacing while heartwood proportion increases as planting spacing increases. All studied wood properties (modulus of rupture, modulus of elasticity, compression strength tangential to grain, and shear tangential to the grain) except cleavage tangential to grain were not significantly affected by increasing spacing. It is recommended to use the spacing of 3 × 3 m, but if thinning can be done before onset of competition at 5 years, the currently used spacing of 2.5 × 2.5 m can still be used. However, the use of a spacing of 4 × 4 m can give at least 50% heartwood at shorter rotation age of 30 years.

1. Introduction

Teak (*Tectona grandis*) is a high quality timber species of the *Verbenaceae* family [1]. It is native to India, Myanmar, Thailand, and Laos and was first brought to Indonesia about 400 to 600 years ago where it is now considered to be a naturalised species [2, 3]. It is one of the most valuable tropical hardwoods in the world because of its strength, straightness, workability, and resistance to many pests and diseases [2]. Moreover, today it is considered the most widely cultivated tree species worldwide, established in plantations as an exotic species for production of high quality poles and timber in the whole intertropical region excluding desert areas of Africa [4].

It was first introduced in tropical Africa to supplement local timber supplies. In Tanzania, teak was introduced as

trial plantings by the Germans in 1898 specifically in Dar es Salaam and Mhoro sites using seed originating from Calcutta region of India [5]. Later, trial plots were established in different parts of Tanzania from 1905 to 1936 using seed from Burma, Java, India, and Thailand. The high growth rates of these experimental trials together with a need to alleviate pressure on indigenous forests, as well as continued demand and good price of teak timber in the international market, led to initiation of state owned teak plantations in Mtibwa, Longuza, and Rondo in the 1950s [6]. In 1992, Commonwealth Development Corporation (CDC) identified a global shortfall in the supply of natural teak and consequently set up a private company, that is, Kilombero Valley Teak Company (KVTC) with the objective of supplying teak to the world market [7]. In Tanzania, teak now covers more than 7,000 ha [8, 9]. In Nigeria, teak was introduced in 1902 followed by

Ghana in 1905 with seed originating from India. In 1929, seeds obtained from Ghana were used to establish plantations in Ivory Coast [10].

Teak is usually planted via seed which can be planted directly in the field or using stumps made by uprooting the seedlings from the seedbed, pruning the root laterals, and cutting the main stem. Worldwide, planting spacing ranges from 1.8×1.8 m to 2×6 m with a common spacing of 3×3 m depending on site conditions, type of planting stock, and silvicultural techniques adopted [11]. These planting spacing regimes play an important role in tree growth since they influence the quantity and quality of wood produced [12]. Some studies on teak [13] have reported negative relationship between planting spacing, volume production, and basal area (BA), while BD, heartwood proportion, modulus of rupture (MOR), modulus of elasticity (MOE), and compression strength (CS) tangential to grain increased with increase in planting spacing [14]. Despite the long history of teak as a plantation species [3], adequate information on the effect of the different spacing regimes on growth and wood properties in Tanzania is not available. The objective of this study was therefore to determine the effect of spacing regimes on survival/stocking, growth, yield, and wood properties of *Tectona grandis* at LFP Tanzania.

2. Methods

2.1. Study Area. The study was carried out at Longuza Forest Plantation (LFP) which is located in Muheza district, Tanga region, at latitude $4^{\circ}48'$ and $5^{\circ}13'S$ and longitude $38^{\circ}32'$ and $38^{\circ}48'E$ [15]. The average altitude is 180 m above sea level [16]. The mean maximum temperature of the area varies between $26^{\circ}C$ and $32^{\circ}C$ and minimum ranges from $15^{\circ}C$ to $20^{\circ}C$. The mean annual rainfall is 1,548 mm with dry spell between June and September. The area experiences short rains from October to December and long rains from March to May [17].

The topography varies between undulating lower slopes with slope gradients ranging from 5.71 to 11.31 degrees to steeper upper slopes ranging on average from 14.04 to 19.29 degrees. The soil depth ranges from shallow (less than 20 cm) to very deep (greater than 120 cm) although most are moderately deep (40–80 cm). The soil surface horizons are generally sandy clay loams in texture, which grade into clays down the soil profile. Soils are variable from dark reddish brown to dark red or red and become redder down the profile [15].

2.2. Experimental Layout. The field spacing trial reported in this study was established in April 1998 at LFP which lies within the foothills of the East Usambara Mountains. Complete Randomised Block Design (CRBD) with three treatments (2×2 m, 3×3 m, and 4×4 m) replicated three times was used. Each replicate is surrounded by two guard rows to avoid edge effects. Spacing of 2×2 m is referred to as treatment 1, 3×3 m as treatment 2 and spacing of 4×4 m as treatment 3.

2.3. Data Collection. At the age of 14 years (2012), data on Dbh, total Ht, stocking, total volume and volume increment,

and wood properties (physical and mechanical properties) were collected.

The Ht and Dbh of all trees in each treatment were measured using Suunto clinometer and diameter tape, respectively. Diameter assessment formed the basis for determining the stand growth and yield.

Three trees with straight stems, normal branching, without pests or diseases attack and any physical damage, were selected randomly from each treatment and felled for wood physical and mechanical properties determination [18, 19]. The trunks from felled trees were cut into four disks of 5 cm thickness at Dbh (1.3 m), 30%, 60%, and 90% of the total tree height [20]. Then, all disks were taken to laboratory for determination of BD and heartwood proportion [19]. In addition, one meter long central board for all sampled trees was cut [17] at Dbh upward for determination of MOR, MOE, CS, shear tangential to the grain, and cleavage tangential and radial to the grain [21].

BD was determined using oven dry weight and green volume. Water displacement method was employed to measure the green volume of strip cut from each disc running from bark to pith [20]. The oven dry weight of each sample was measured after being dried in an oven at $105^{\circ}C$ for 48 hours to a constant weight [14].

The heartwood percentage was determined on each stem disk, where a map of disc area under bark, sapwood, and heartwood areas was traced on tracing paper. Next, the area for each disc was determined on the disc map by using a planimeter and finally, the heartwood and sapwood proportions in percent for each disc at 1.3 m, 30%, 60%, and 90% of the total tree Ht were calculated [20].

The static bending test from which MOR and MOE were determined was conducted by using specimen size of $20 \text{ mm} \times 20 \text{ mm} \times 300 \text{ mm}$ [22, 23]. The test involved a centre-loading supported on a span of 280 mm while the force was applied on the radial face at midspan using a loading rate of 0.25 mm/min and beam of 500 kgf on a Hounsfield Tensometer machine.

2.4. Data Analysis. Total over back volume equation developed by Malimbwi et al. [24] was used for the computation of total volume of the individual trees. This equation is

$$V = 0.00024 * \text{Dbh}^{2.35}, \quad (1)$$

where V = volume ($\text{m}^3 \text{ ha}^{-1}$) and Dbh = diameter at breast height (cm). The sum of all trees' volume in a plot formed the volume per treatment.

Stand basal area was calculated as the sum per ha of cross-sectional areas of all trees estimated at Dbh. It was calculated from measured Dbh of stems for all trees in each treatment.

BD was calculated as a ratio of oven dry weight to the green volume (g cm^{-3}); that is,

$$\text{Basic density} = \frac{\text{oven dry weight (g)}}{\text{green volume (cm}^3)}. \quad (2)$$

TABLE 1: Effect of spacing on growth and yield of *T. grandis* at LFP.

Treatment	Height (m)	Dbh (cm)	Mean	
			Basal area (m ²)	Total volume (m ³ ha ⁻¹)
2 × 2 m	19.52 ^{a+}	15.95 ^a	17.38 ^a	149.21 ^a
3 × 3 m	23.09 ^b	20.79 ^b	22.76 ^a	208.38 ^a
4 × 4 m	24.05 ^b	25.9 ^c	18.84 ^a	185.71 ^a
ANOVA	*	*	NS	NS

+ Within the same column, means with the same letter are not significantly different ($p > 0.05$); * = $p < 0.05$; NS = not significant; $p > 0.05$.

All mechanical properties were determined using wood dried for ten weeks to a moisture content of 12% [25, 26] and were calculated using the following formulae:

$$\begin{aligned}
 \text{MOR} &= \frac{3PL}{2bd^2}, \\
 \text{MOE} &= \frac{P^1L^3}{4Ybd^3}, \\
 \tau_{\text{cr}} &= \frac{P_{(\text{max})}}{A_0}, \\
 \tau &= \frac{P^2}{A}, \\
 \tau_{\text{cl}} &= \frac{P_{(\text{max})}}{b},
 \end{aligned} \quad (3)$$

where P = maximum load in Newtons (N), L = span length in mm, b = width of the test sample in mm, d = depth of the test sample in mm, P^1 = load in Newtons to limit of proportionality, Y = deflection in mm at mid length at limit of proportionality, V = volume of test sample in mm³, τ_{cr} = crushing strength in N/mm², $P_{(\text{max})}$ = maximum crushing load in Newtons (N), τ = shearing strength in N/mm², τ_{cl} = cleavage strength (N/mm), P^2 = maximum load in Newtons (N) causing shear, A_0 = area of the test sample in mm², and A = area in shear in mm².

Statistical analysis was carried out using SAS [27]. Each assessed variable was subjected to analysis of variance using treatment means obtained by using appropriate formulae to determine the effect of spacing on the variables. Duncan's multiple range test ($p = 0.05$) was used to separate significant variables' means [16].

3. Results and Discussion

This study assessed the effect of spacing on growth, yield, and wood properties of *Tectona grandis* grown at LFP.

3.1. Effect of Spacing on Height and Diameter Growth. The mean total heights (Hts) for all spacing regimes are shown in Table 1. The results show that the mean total Hts at age of 14 years were significantly lower in spacing of 2 × 2 m compared with other two remaining spacing regimes of 3 × 3 m and 4 × 4 m. This could have been contributed by micro-site differences since height growth is sensitive to differences in site quality [25]. It is also possible that competition has actually affected height growth in the closer spacing. However, the results are in agreement with those reported by

TABLE 2: Effect of spacing on volume increment of *T. grandis* at LFP.

Treatment	Volume increment (m ³ ha ⁻¹)
	14 years
2 × 2 m	10.66 ^{a+}
3 × 3 m	14.88 ^b
4 × 4 m	13.27 ^c
ANOVA	*

+ Within the same column, means with the same letter are not significantly different ($p > 0.05$); * = $p < 0.05$.

Sibomana et al. [21] who observed a significant increase in total Ht with increase in planting spacing at age of 9 years.

Table 1 further shows the mean Dbh for *T. grandis* at 14 years. At this age it was observed that the mean Dbh increased significantly with increase in spacing. These results are in agreement with those reported by Ola-Adams [13] who found an increase in diameter of teak with increasing planting spacing in 18-year-old teak stands in Nigeria. At LFP in Tanzania, a trial established in 1979 and assessed at the age of 9 years showed similar results of significant increase in diameter with increasing planting spacing, where out of four square spacing regimes used, the spacing of 3 × 3 m resulted in larger Dbh than other three spacing regimes [21]. The increasing Dbh with increasing spacing is due to the fact that trees at wider spacing utilize effectively the advantage of having more growing space for crown and root development as a result of reduced competition. However, Iddi et al. [12] observed that increase in mean Dbh of trees in wider spacing may or may not be an advantage depending on market since it increases stem taper and reduces lumber recovery when the logs are sawn.

3.2. Effect of Spacing on Yield

3.2.1. Basal Area and Volume Production. The effects of spacing on BA and total volume production of *T. grandis* at LFP are shown in Table 1. Both BA and total volume production were not significantly affected by spacing at 14 years. There are, however, some slightly higher values of both BA and volume for the spacing regime 3 × 3 m. Similar findings have also been reported by Sibomana et al. [21] on volume production which showed a nonsignificant decreasing trend with increasing planting spacing.

3.2.2. Volume Increment. In this study, MAI was significantly higher at the spacing of 3 × 3 m compared to the other spacing regimes at 14 years (Table 2). This could be attributed

TABLE 3: Effect of spacing on wood density of *T. grandis* at LFP.

Treatment	Total BD (g cm ⁻³)	BD DBH	BD 30% (g cm ⁻³)	BD 60% (g cm ⁻³)	BD 90% (g cm ⁻³)
2 × 2 m	0.469 ^{a+}	0.502 ^a	0.409 ^a	0.437 ^a	0.526 ^a
3 × 3 m	0.483 ^a	0.485 ^a	0.413 ^a	0.5155 ^a	0.562 ^{ab}
4 × 4 m	0.454 ^a	0.459 ^a	0.472 ^a	0.485 ^a	0.398 ^b
ANONA	Ns	NS	NS	NS	*

+ Within the same column, means with the same letter are not significantly different ($p > 0.05$); * = $p < 0.05$; NS = not significant; $p > 0.05$.

by few numbers of stems surviving in the 4 × 4 m spacing at the age of 14 years compared to the 3 × 3 m spacing regime. Madoffe and Maghembe [6] reported MAI ranging from 13.7 to 19.6 m³ ha⁻¹ year⁻¹ for ten provenances planted at spacing of 1.83 × 1.83 m. The results are also in agreement with those reported by Pérez and Kanninen [28] who observed significant rapid decrease in MAI of teak with decreasing planting spacing. The higher mean Dbh and yet reduced MAI of the wider spacing (4 × 4 m) suggests that this spacing is too wide to utilize effectively the site conditions at the age of 14 years.

3.3. Effect of Spacing on Physical Properties of Wood

3.3.1. Basic Density. The effects of spacing on BD of *T. grandis* at the age of 14 years are presented in Table 3. The results indicate that spacing has no significant effect on mean BD at all Hts for all spacing regimes except at 90% Ht, where spacing of 2 × 2 m had similar BD to that of 4 × 4 m, but significantly higher compared to that of 3 × 3 m. The 4 × 4 m spacing had similar BD to that of 3 × 3 m. The results are in agreement with those reported by Pérez and Kanninen [28] who found that BD of teak in India did not differ significantly at different spacing regimes. Moya et al. [18] and Zanin [2] also concluded that different spacing management regimes in teak had no significant effect on BD. The results however contrast with ones reported by Sibomana et al. [21]. The authors found significant increase in BD with increase in spacing at age of 14 years and values reported are also higher than the ones reported in this study. The low density at 90% of total tree Ht in wider spacing is probably contributed by high proportion of early wood, which has low density.

3.3.2. Heartwood Proportion. The effect of spacing on heartwood proportion of *T. grandis* at the age of 14 years is shown in Table 4. The results indicate an increase of heartwood proportion as planting spacing increases although the increase is not statistically significant. Similarly, Arce [29] observed greater heartwood proportion in wider spacing of 10-year-old teak plantations. Also, Bhat [30] and Kokutse et al. [31] found an increase in heartwood proportion of teak with increase in planting spacing in Kerala, India, and Togo, respectively.

The observed heartwood of 25–32% at year 14 is however low. Previously, a rotation age of 60 years was recommended for *Tectona grandis* in Tanzania [32]. This implies that a minimum rotation age of 30 years might be needed to achieve at least 50% of heartwood.

TABLE 4: Effect of spacing on heartwood proportion of *T. grandis* at LFP.

Treatment	Heart wood proportion (%)
	14 years
2 × 2 m	24.83 ^{a+}
3 × 3 m	27.87 ^a
4 × 4 m	31.67 ^a
ANOVA	NS

+ Within the same column, means with the same letter are not significantly different ($p > 0.05$); * = $p < 0.05$; NS = not significant; $p > 0.05$.

3.3.3. Mechanical Properties. Table 5 shows the effect of spacing on static bending, CS tangential to grain, shear strength tangential to grain, and cleavage tangential and radial to the grain. Statistical analysis indicated nonsignificant effect of spacing on almost all variables studied except cleavage strength tangential to the grain. Cleavage strength tangential to the grain was significantly lower at narrower spacing of 2 × 2 m but not significant in other spacing regimes. These results are not in agreement with those reported by Sibomana et al. [21] who found that MOE, MOR, CS tangential to grain, and shear strength tangential to grain of teak growing at LFP increased significantly with increasing planting spacing. The difference between the observed mechanical properties and the reported in the previous study might be caused by, among other factors, differences in seed sources.

4. Conclusions

Total tree Ht and Dbh growth increased significantly with increase in planting spacing at 14 years. The volume increment increased significantly with increase in spacing although spacing of 3 × 3 m produced higher increment than the other two studied spacing regimes. Moreover, the study has shown that all mechanical properties except cleavage tangential to grain are not significantly affected by planting spacing. It is recommended that if thinning cannot be done earlier, the spacing of 3 × 3 m can be used, but if it can be conducted before onset of competition at 5 years, the currently used spacing in Tanzania of 2.5 × 2.5 m can still be used as it provides better opportunity of obtaining superior final stand and higher stand volume than the other two spacing regimes considered in this study. However, the use of spacing of 4 × 4 m is expected to give at least 50% heartwood at shorter rotation age of 30 years.

TABLE 5: Effect of spacing on other wood properties of *T. grandis* at LFP.

Treatment	Static bending		Compression parallel to grain	Strength (Nmm ⁻²)		
	MOR	MOE		Shear parallel to grain	Cleavage parallel (tangential) to grain	Cleavage perpendicular (radial) to grain
2 × 2 m	79.07 ^a	8275.84 ^a	40.993 ^a	8.93 ^a	14.27 ^a	15.64 ^{a+}
3 × 3 m	82.20 ^a	8277.87 ^a	39.901 ^a	8.70 ^a	15.72 ^b	15.36 ^a
4 × 4 m	81.86 ^a	7167.88 ^a	39.471 ^a	8.47 ^a	18.93 ^b	14.10 ^a
ANOVA	NS	NS	NS	NS	*	NS

+ Within the same column, means with the same letter are not significantly different ($p > 0.05$); * = $p < 0.05$; NS = not significant; $p > 0.05$.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

- [1] R. M. Robertson and D. F. Reilly, *Performance of a 16-Year-Old Stand of Teak (Tectona grandis L.F.) in the Darwin Area in Relation to That in Other Trials in the Northern Territory*, Northern Territory Government, Department of Primary Industry, Fisheries and Mines, Darwin, Australia, 2005.
- [2] D. K. Zanin, *Feasibility of teak production for smallholders in Eastern Panama [M.S. thesis]*, Forestry Michigan Technological University, 2005.
- [3] W. Ladrach, *Management of Teak Plantations for Solid Products*, Zobel Forestry Associates, Derwood, Md, USA, 2009.
- [4] I. Bermejo, I. Cañellas, and A. San Miguel, "Growth and yield models for teak plantations in Costa Rica," *Forest Ecology and Management*, vol. 189, no. 1–3, pp. 97–110, 2004.
- [5] W. Rance and O. Monteuis, "Teak in Tanzania. An overview of the context," 2011, http://bft.cirad.fr/cd/BFT_279_5-10.pdf.
- [6] S. S. Madoffe and J. A. Maghembe, "Performance of teak (*Tectona grandis* L.f.) provenances seventeen years after planting at Longuza," *Silvae Genetica*, vol. 37, pp. 175–178, 1988.
- [7] L. van Zyl, *Stem form, height and volume models for teak in Tanzania [M.S. thesis in Forestry]*, University of Stellenbosch, Stellenbosch, South Africa, 2005.
- [8] C. Bekker, W. Rance, and O. Monteuis, "Teak in Tanzania: II. The Kilombero valley teak company," *Bois et Forêts des Tropiques*, vol. 279, pp. 11–21, 2004.
- [9] Y. M. Ngaga, *Forest Plantation and Woodlots in Tanzania*, vol. 1 of *African Forest Forum Working Paper Series*, 2011.
- [10] J. B. Ball, D. Pandey, and S. Hirai, "Global overview of teak plantations," in *Proceedings of the Regional Seminar Site, Technology and Productivity of Teak Plantations*, p. 14, Chiang Mai, Thailand, January 1999.
- [11] G. D. Djagbletey and S. Adu-Bredu, "Adoption of agroforestry by small scale teak farmers in Ghana—the case of Nkoranza district," *Ghana Journal of Forestry*, vol. 21, pp. 1–13, 2007.
- [12] S. Iddi, S. A. O. Chamshama, and R. E. Malimbwi, *Planting Spacing in Forest Plantation: A Review*, Record 63, Faculty of Forestry, Sokoine University of Agriculture, Morogoro, Tanzania, 1996.
- [13] B. A. Ola-Adams, "Influence of spacing on growth and yield of *Tectona grandis* Linn. F. (teak) and *Terminalia superba* Engl. & Diels (afara)," *Journal of Tropical Forest Science*, vol. 2, no. 3, pp. 180–186, 1990.
- [14] L. D. Pérez Cordero and M. Kanninen, "Heartwood, sapwood and bark content, and wood dry density of young and mature teak (*Tectona grandis*) trees grown in Costa Rica," *Silva Fennica*, vol. 37, no. 1, pp. 45–54, 2003.
- [15] MNRT, "Longuza (North) forest reserve: a biodiversity survey. Metsahallitus-forest and park service," Technica paper 34, 1996.
- [16] A. P. Pedersen, J. K. Hansen, J. M. Mtika, and T. H. Msangi, "Growth, stem quality and age-age correlations in a teak provenance trial in Tanzania," *Silvae Genetica*, vol. 56, no. 3–4, pp. 142–148, 2007.
- [17] K. F. S. Hamza, F. B. S. Makonda, S. Iddi, and R. C. Ishengoma, "The relationship between basic density, anatomical, and strength properties of 35 years old *Tectona grandis* L.f. grown at Longuza, Tanga," *Sokoine University of Agriculture, Faculty of Forestry and Nature Conservation Record*, vol. 72, pp. 93–102, 1999.
- [18] R. Moya, L. D. Perez, and V. Arce, "Wood density of *Tectona grandis* at two spacing in Costa Rica plantation," *Tropical Forest Products*, vol. 9, pp. 153–161, 2003.
- [19] R. Moya and D. Pérez, "Effect of physical and chemical soil properties on physical wood characteristics of *Tectona grandis* plantations in Costa Rica," *Forest Science*, vol. 20, pp. 147–155, 2008.
- [20] K. F. S. Hamza, F. B. S. Makonda, and S. Iddi, "Basic density and heartwood content in the wood of *Tectona grandis* L.f. grown at Longuza, Tanga," *Forest Ecology and Management*, vol. 67, pp. 32–43, 1998.
- [21] G. Sibomana, F. B. S. Makonda, R. E. Malimbwi, S. A. O. Chamshama, and S. Iddi, "Effect of spacing on performance of teak at Longuza, Tanga, Tanzania," *Journal of Tropical Forest Science*, vol. 10, no. 2, pp. 176–187, 1997.
- [22] K. M. Bhat and P. B. Priya, "Influence of provenance variation on wood properties of teak from the Western Ghat region in India," *IAWA Journal*, vol. 25, no. 3, pp. 273–282, 2004.
- [23] D. N. Izekeor and J. A. Fuwape, "Variations in mechanical properties among trees of the same and different age classes of teak (*Tectona grandis* L.F) Wood," *Applied Sciences Research*, vol. 6, no. 4, pp. 562–567, 2010.
- [24] R. E. Malimbwi, A. G. Mugasha, S. A. O. Chamshama, and E. Zahabu, "Volume tables for *Tectona grandis* at Mtibwa and Longuza forest plantations, Tanzania," Record 71, Faculty of Forestry, Sokoine University of Agriculture, 1998.
- [25] R. E. Malimbwi, A. Persson, S. Iddi, S. A. O. Chamshama, and S. T. Mwihomeke, "Effects of spacing on yield and some wood properties of *Pinus patula* at Rongai, northern Tanzania," *Forest Ecology and Management*, vol. 53, no. 1–4, pp. 297–306, 1992.
- [26] R. C. Ishengoma, P. R. Gillah, and M. O. Andalwisy, "Some physical and strength properties of lesser-known *Milletia oblate*

- Sub. Spp *Stoizii* from Tanzania,” *Forest Ecology and Management*, vol. 67, pp. 54–60, 1998.
- [27] SAS Institute, *Statistical Guide to Personal Computers*, SAS Institute, Cary, NC, USA, 6th edition, 1987.
- [28] D. Pérez and M. Kanninen, “Stand growth scenarios for *Tectona grandis* plantations in Costa Rica,” *Forest Ecology and Management*, vol. 210, no. 1–3, pp. 425–441, 2005.
- [29] V. H. Arce, *Sapwood-heartwood relationships and wood physical characteristics of 10-year-old teak from two different plantation densities in Playa Garza, Guanacaste [Bachelor’s thesis]*, Universidad Nacional, Heredia, Costa Rica, 2001.
- [30] K. M. Bhat, “A note on heartwood proportion and wood density of 8-year-old teak,” *Indian Forester*, vol. 121, pp. 514–516, 1995.
- [31] A. D. Kokutse, H. Baillères, A. Stokes, and K. Kokou, “Proportion and quality of heartwood in Togolese teak (*Tectona grandis* L.f.),” *Forest Ecology and Management*, vol. 189, no. 1–3, pp. 37–48, 2004.
- [32] Y. H. Malende and A. B. Temu, “Site-index curves and volume growth of teak (*Tectona grandis*) at Mtibwa, Tanzania,” *Forest Ecology and Management*, vol. 31, no. 1–2, pp. 91–99, 1990.



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