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SELECTED PHYSICAL AND MECHANICAL PROPERTIES OF TWELVE-YEAR OLD GARDEN TEAK IN GHANA

IZBRANE FIZIKALNE IN MEHANSKE LASTNOSTI LESA 12-LETNIH DREVES TIKA IZ GANE

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UDK: 630*812:630*174 *Tectona grandis*
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Abstract / Izvleček

Abstract: To supplement the timber stock in the natural forests of Ghana, efforts have been made to plant varied timber species including *Tectona grandis* (teak) in both plantations and home gardens for local use. However, the related timber patrons do not have adequate information on the properties of short rotation home-garden teak to build confidence in its appropriate utilization. This study therefore evaluated the physical and mechanical properties of 12-year-old teak using ASTM and BS standards to determine whether 12-year-old, garden-grown teak has density and mechanical properties comparable to those of mature plantation-grown teak, and whether it is suitable for light structural applications. Ten trees were selected from home environments in the Ashanti Region of Ghana. The results indicated average values of 34%, 628 kg/m³, 13,014 N/mm², 98 N/mm² and 43 N/mm² the for moisture content, density, static bending MOE, MOR and compression strength parallel to the grain, respectively. Overall, in addition to the density found being higher than that reported in other studies, the bending properties were also favourable compared to those of some 50- to 65-year-old teak trees given in the literature. The 12-year-old garden teak could thus be used for some medium to light structural applications, such as door and window frames, doors, furniture, and ceiling panels, among others.

Keywords: *Tectona grandis,* teak, wood, density, mechanical properties, physical properties, deforestation, Ghana

Izvleček: Da bi dopolnili lesno zalogo iz naravnih gozdov Gane, si prizadevajo za sajenje različnih drevesnih vrst, vključno s tikom (*Tectona grandis*), tako v nasadih kot tudi v domačih vrtovih za lokalno uporabo. Ob tem lastniki lesa nimajo ustreznih informacij o lastnostih lesa tika s kratko rotacijo, da bi pridobili zaupanje v njegovo uporabo. V tej študiji smo proučili fizikalne in mehanske lastnosti lesa 12 let starih dreves tika z uporabo standardov ASTM in BS. Deset dreves je bilo izbranih iz nasadov okoli domov v regiji Ashanti v Gani. Rezultati so pokazali naslednje srednje vrednosti za vlažnost, gostoto, statični upogib (e-modul in trdnost) in tlačno trdnost vzporedno z vlakni: 34 %; 628 kg/m³; 13.014 N/mm²; 98 N/mm² in 43 N/mm². Poleg tega, da je ugotovljena gostota lesa višja od gostot, določenih v nekaterih drugih študijah, so tudi trdnostne lastnosti ugodne v primerjavi z lastnostmi približno 50 do 70 let starih dreves tika. Tako bi lahko 12 let star »vrtni« tik med drugim uporabili za nekatere srednje do lahke konstrukcijske namene, za izdelke kot so okvirji vrat in oken, vrata, pohištvo in stropne plošče.

Ključne besede: *Tectona grandis* = tik, les, gostota, mehanske lastnosti, fizikalne lastnosti, izsekavanje gozdov, Gana

1 INTRODUCTION
1 UVOD

Urgent efforts are being made globally to adopt other building materials, such as metals and plastics, in an attempt to supplement or replace wood because of the scarcity of this natural material due to deforestation, as well as the overexploitation of wood, and Ghana is no exception to this. However,

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many construction practitioners continue to prefer wood to some of the alternative materials, due to its many favourable attributes. Wood has a number of advantages when used in buildings, such as flexibility and low weight, satisfactory insulating capacity, fire resistance, high construction speed and low cost, and lower risk to the environment compared to materials such as steel, concrete and so on (Adler, 2022).

As a result of the continued preference for wood – as well as the health and other benefits that trees have for human existence, and the need to reduce carbon emissions – issues such as the reforestation of depleted and degraded forests, as well as afforestation of fallow lands, have become a subject of global concern (Gorte & Sheik, 2010). Teak (*Tectona grandis*) is the top ranked tree species in more than 20 countries with regard to plantation and urban forestry efforts aimed at the conservation and management of the genetic resources of forests (Brown et al., 2016b). One such country, Ghana, is taking tree-planting seriously and pursuing it vigorously, with teak as the dominant species being planted at homes (i.e. in gardens) and on farms. Form Ghana, a company engaged in reforestation and afforestation programmes in Ghana, has reported that its work involves 90% teak and 10% other native tree species (Form Ghana, 2017).

Teak, described as the queen of tropical hardwoods (Thulasidas & Baillères, 2017) is both weather-, termite- and pest-resistant due to the presence of some natural extractives in its cell walls. These attributes, among others make the wood very durable and extremely suitable for outdoor and indoor applications. The species is much preferred for electricity transmission poles, garden furniture, and boat decks, and is sometimes used even without any preservative treatment (Brown et al., 2016a; Form Ghana, 2017). The attractive appearance of teak, with its different colour streaks due to the various oils and chemicals it contains, means that this wood is also desired for use in interior design and furniture. Teak flooring, cutting boards, tongued and grooved ceilings, and veneer, among other highly rated wood products, remain popular throughout the world (Form Ghana, 2017). Teak is thus one of the tropical hardwoods that is most in demand for luxury products, and teak farmers in Ghana, for instance, can achieve averages of more than 19% return on investment based on the Internal Rate of Return (IRR), in addition to besides income from carbon offset schemes (Brown et al., 2016a; Brown et al., 2016b). Moreover, teak grows relatively quickly, is well-suited for farmers with small holdings, does well in intercropping systems, and does not suffer much from disease, which reduces the risks of plantation failure and the impact of sustainable teak production on the environment, as very little or no chemical treatment may be required (Form Ghana, 2017; Brown et al., 2016a). This makes teak farming easier and less demanding, which has naturally attracted more people to plant teak trees, both at homes and on farms.

The quality of wood is primarily determined by its physical and mechanical properties, which are functions of its age, position in trees, and species, among other things. In order to optimize such qualities, tree felling cycles or rotations for many species are usually >30 years (Desch & Dinwoodie, 1996; Shmulsky & Jones, 2011), but this is too long for many growers, who want to see a faster return on their investment. In contrast, teak is reported to produce wood of a significant quality after growing for just seven to 15 years, within which period production thinning is carried out in some countries (Pandey & Brown, 2000; Rizanti et al., 2018). In this context, it is important to determine the properties of wood of short rotation trees, such as teak aged between 10 and 15 years – the lowest range of ages for plantation trees to produce useable wood (Pandey & Brown, 2000; Arbofino, 2023) – in order to promote this business, and thus help replenish degraded forests and reduce the deforestation rate. However, data on some of the physical and strength properties 10- to 15-year-old teak are either limited or unavailable (Midgley et al., 2007), especially for trees grown around homes. That said, an assessment of some of the properties of young plantation teak from Laos indicated that the physical and mechanical properties of such wood of trees aged 10, 15, 20, and 25 years were not significantly different (Wanneng et al., 2014). A study of Ghanaian teak (Amoah & Inyong, 2019) did report some data of interest, but did not include anything on the moisture content (MC), density, compression and bending properties of teak wood of 10-year-old trees. Moreover, while a more recent study on Ghanaian teak did examine 10-year-old trees, this was from a plantation forest and not from around homes (Dadzie et al., 2023). Meanwhile, there appears to be a general belief among timber traders and users that teak wood of trees grown in homesteads (home/garden teak) is inferior to that from natural or plantation forests in terms of strength properties (Bryce, 1966). Although it is scientifically proven that wood properties can be significantly affected by the growth environment (i.e. different ecological zones) and the position in the tree, as well as due to differences in the soil and the minerals it contains, rainfall patterns and other growth factors (Tsoumis, 1991; Amponsah & Meyer, 2000; Schmulsky & Jones, 2011), there remains a lack of data on this in relation to garden teak, which this study aimed to address.

In this context it should also be noted that a higher oven-dry density is an indication of the better mechanical properties of wood (i.e. stronger wood), irrespective of the initial MC. As a result, when knowing the oven-dry density and adjusting the values of mechanical properties measured at any MC to a standard MC (usually 12%), it is possible to make better comparisons between different wood samples (Stamm, 1964).

Based on the factors outlined above, the current study was undertaken on wood of 12-year-old Ghanaian garden teak trees to ascertain its physical and mechanical properties – as measured from the base of the tree to the top –in relation to those in the literature for teak trees of the same age or older. It was hypothesized that wood of 12-year-old garden-grown teak has a density and mechanical properties comparable to those of mature plantation teak thus making it suitable for light structural applications. The findings will be significant with regard to encouraging the utilization of wood of such young garden teak trees, which will help in making more wood available for use, aid carbon sequestration in homes and towns, provide cleaner air, and an earlier return on investment for tree planters and farmers, which will then attract more people into home and urban forestry, thus improving the environment and generating income.

2 MATERIALS AND METHODS
2 MATERIALI IN METODE

2.1 SAMPLE COLLECTION AND PREPARATION
2.1 ODVZEM IN PRIPRAVA VZORCEV

Ten 12-year-old teak trees were felled from a homelike environment (the campus of Kumasi Technical University) in the Ashanti Region. Samples for testing were taken purposively as billets from three main sections along the boles of the trees (i.e., butt/bottom section 310 cm from the ground, middle section 320 to 630 cm from the ground, and top section 650 to 870 cm from the ground). Quadrants of each of these sections were prepared for ease of transport and use. These were then further processed and cut into boards 20 mm thick. The wood samples were selected from only the heartwood of the three sections and labelled for easy identification. The samples for the various tests were prepared in accordance with the requirements of the test protocol used.

2.2 PHYSICAL PROPERTIES TEST SAMPLES
2.2 VZORCI ZA TESTIRANJE FIZIKALNIH LASTNOSTI

The physical properties considered in this study were the moisture content (MC) and density (D) of the 12-year-old teak.

2.2.1 Moisture Content (MC)
2.2.1 Vlažnost lesa

After conversion and prior to air-drying the specimen groups, some samples of each group were randomly selected for the determination of their MC for the butt, middle and top sections using the oven-dry method. MCs were determined with sample sizes of 20 × 20 × 20 mm in accordance with the American Standard-ASTM D2395 (2017) protocol (test method D4442 where test specimens were cut from member ends). Only heartwood samples were used for MC determination. A total of 300 specimens were used for this (i.e. 10 trees x 3 sections x 10 replicates = 300). The specimens were weighed to ascertain their initial masses using an electronic digital balance with 0.001 g accuracy. The specimens were oven-dried, and MCs estimated with the relation expressed in equation 1 (ASTM D2395, 2017; Shmulsky & Jones, 2011).

$$MC\ (\%) = \frac{Initial\ Mass\ -\ Oven\text{-}dry\ Mass}{Oven\text{-}dry\ Mass}\ x\ 100 \qquad (1)$$

2.2.1 Density
2.2.2 Gostota lesa

The oven-dry density (Do) of the *Tectona grandis* was estimated using the same specimen used for the MC determination (with a total of 300 heartwood specimens), and was done in accordance with the ASTM D2395 (2017) Test Method D4442. The sizes were measured with a digital vernier calliper with a length of 150 mm, resolution of 0.01 mm and accuracy of ± 0.02 mm. Afterwards, the oven-dry volumes (Vo) of the samples were estimated as Lo x Bo x Wo, with Lo = oven-dry length, Bo = oven-dry breadth, and Wo = oven-dry width. After obtaining the masses and volumes, the oven-dry density was calculated using the relation expressed in equation 2 (ASTM D2395, 2017; Shmulsky & Jones, 2011).

$$\text{Oven-dry Density (Do)} = \frac{\text{Oven-dry Mass (Mo)}}{\text{Volume of Wood (Vo)}} \; x\ 100 \quad (2)$$

2.3 MECHANICAL PROPERTIES OF THE TEST SAMPLES
2.3 VZORCI ZA TESTIRANJE MEHANSKIH LASTNOSTI

The mechanical properties considered in this study were the static bending properties (MOE and MOR), and compression parallel to the grain for air-dry specimens of the wood.

2.3.1 Static bending (MOR and MOE) and compression stress test
2.3.1 Statični upogibni test in test tlačne trdnosti

In estimating the bending properties (MOE and MOR), 20 specimens were tested for each axial tree section, giving a total of 600 specimens (i.e., 10 trees x 3 sections x 20 replicates). The same quantity of samples was tested for compression strength parallel to the grain. The sizes of the bending test samples were 20 x 20 x 300 mm, whereas those of the compression samples were 20 x 20 x 60 mm in accordance with the British Standard BS 373 (1957) protocol. Only the heartwood samples were used in all the mechanical tests. The tests were carried out on a Universal Testing Machine (model, UTN-110). This machine is fitted with an automatic computerized system that captures all the results. The air-dry MC of all tested samples was measured with moisture meter model MO210 designed to measure the MC of wood up to 44% with an accuracy of ± 2%. Because the test specimens during testing had a variable MC ranging from 12.87 to 16.28%, the test results of all sample groups were adjusted to 12% MC using equation 3 (BS 373-1957) to enable better comparisons.

$$l_{12} = lw\,(1 + x\,(w - 12)) \quad (3)$$

Where: $l1_2$ is the strength property at 12% MC, *lw* is the calculated bending propriety, *w* is the MC of test specimen, and x is a constant with value of 0.04 (BS 373-1957).

2.4 DATA ANALYSIS
2.4 ANALIZA PODATKOV

Both descriptive statistics (means), and inferential statistics (Tukey multiple comparison test, and correlation) were used to analyze the data collected using SPSS 17.0 version at a 5% significance level. Two-way ANOVA was also used to ascertain the effects of moisture levels and tree position on the various properties studied.

3 RESULTS AND DISCUSSION
3 REZULTATI IN RAZPRAVA

3.1 PHYSICAL PROPERTIES
3.1 FIZIKALNE LASTNOSTI

The average MC of 39.8% for the 12-year garden teak wood after felling and conversion before air-drying was found to be higher at the treetops (39.8%) compared to the middle (31.6%) and the base (28.2%) (Figure 1A, Table 1).

The oven-dry density of the 12-year-old teak averaged 628 ± 43 kg/m³ and varied with different axial positions in the stem. Wood density was the highest at the top of the tree (643 kg/m³) and smallest in the middle part (612 kg/m³) (Figure 1B, Table 1).

The top section of the teak trees was found to have denser wood than the base. The average oven-dry density (628 kg/m³) found in this study is within the range reported in the selected literature. For instance, Rizanti et al. (2018) reported oven-dry density ranging from 559 to 606 kg/m³ for 12-year plantation teak from Panama. Thulasidas and Bail-

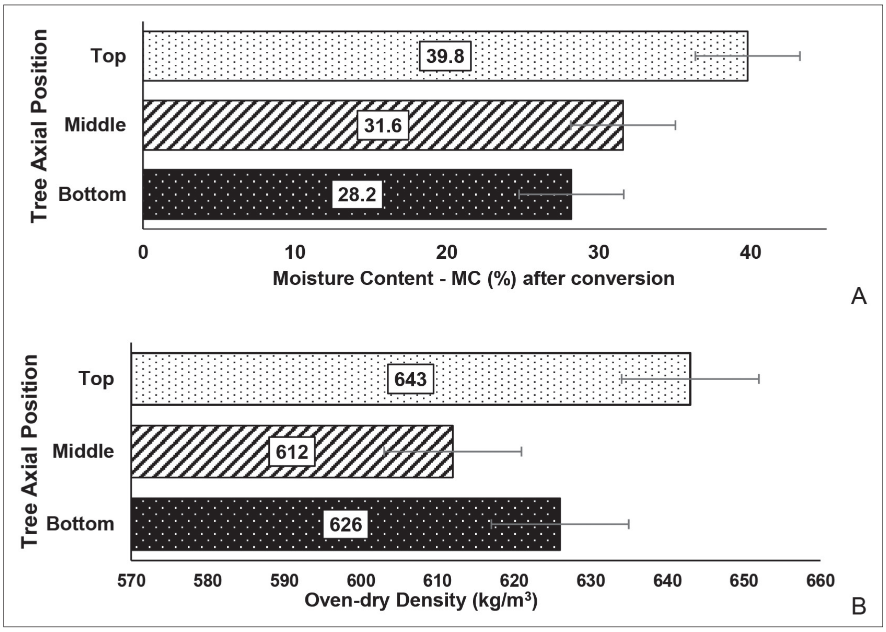

Figure 1. Moisture content (A), and oven-dry density (B) of teak wood from different axial positions of the trees. N = 300.

Slika 1. Vlažnost (A) in gostota absolutno suhega lesa (B) tika z različnih mest vzdolž dreves. N = 300.

Table 1. Statistical analysis of the physical properties of the 12-year-old garden teak.

Preglednica 1. Statistična analiza fizikalnih lastnosti lesa 12 let starega vrtnega tika.

Tree axial section Nivo v drevesu	N	Moisture content MC (%) ± SD Vlažnost MC (%) ± SD	Oven-dry Density (kg/m³) ± SD Gostota r_0 (kg/m³) ± SD
Top	100	39.8 ± 10.3 b	643 ± 38.71 a
Middle	100	31.6 ± 8.8 a	612 ± 45.21 b
Bottom/Base	100	28.2 ± 10.2 a	626 ± 40.77 b
F-Value		14.321 **	28.046 **

Note: ** = significant at P ≤ 0.05; SD = Standard Deviation.

Opomba: ** = značilno pri P ≤ 0,05; SD = standardni odklon.

leres (2017) found that 13-year-old teak from India had an oven-dry density of 630 kg/m³, while 65-year-old plantation and natural teak had an oven-dry density of 640 kg/m³, whereas Wannang et al. (2014) reported that 10-year-old teak from Laos had an oven-dry density of 634 kg/m³. Bhat and Priya (2004) reported that the air-dry density of 65-year- old teak was 655 kg/m³.

The difference in MC levels and density recorded in the current study compared to the previous findings could be due to the differences in location and climate (Thulasidas & Baillères, 2017; Bhat & Priya, 2004). The current study's sample origin – Ejisu in Kumasi, Ghana – has an altitude of 240 to 300 m above sea level and annual precipitation of 1,200 mm, as against the sample origin in Dadzie et al. (2023) with an altitude of 60 to 200 m, and 1,750 mm annual precipitation (MOFA, 2024). Wannang et al. (2014) sampled their wood from Laos, an area lying on latitude 18° 00‘N and longitude 105° 00‘ E, with annual precipitation of 1,809 mm, in contrast to MOFA (2024) and Dadzie et al. (2023) who carried out their work in Ghana, with an approximate latitude of 8° 00‘ N and longitude 2° 00‘ W, and annual rainfall of 780 mm to 2,160 mm.

3.2 MECHANICAL PROPERTIES

3.2 MEHANSKE LASTNOSTI

The static Modulus of Elasticity (MOE) averaged 13,162 ± 1,468 N/mm² and increased from the bottom to the top. The bottom to middle increase was 1,226 N/mm² (10.22%) and significant (P ≤ 0.05), the bottom to top increase was 2,240 N/mm² (18.67%) and significant, while the middle

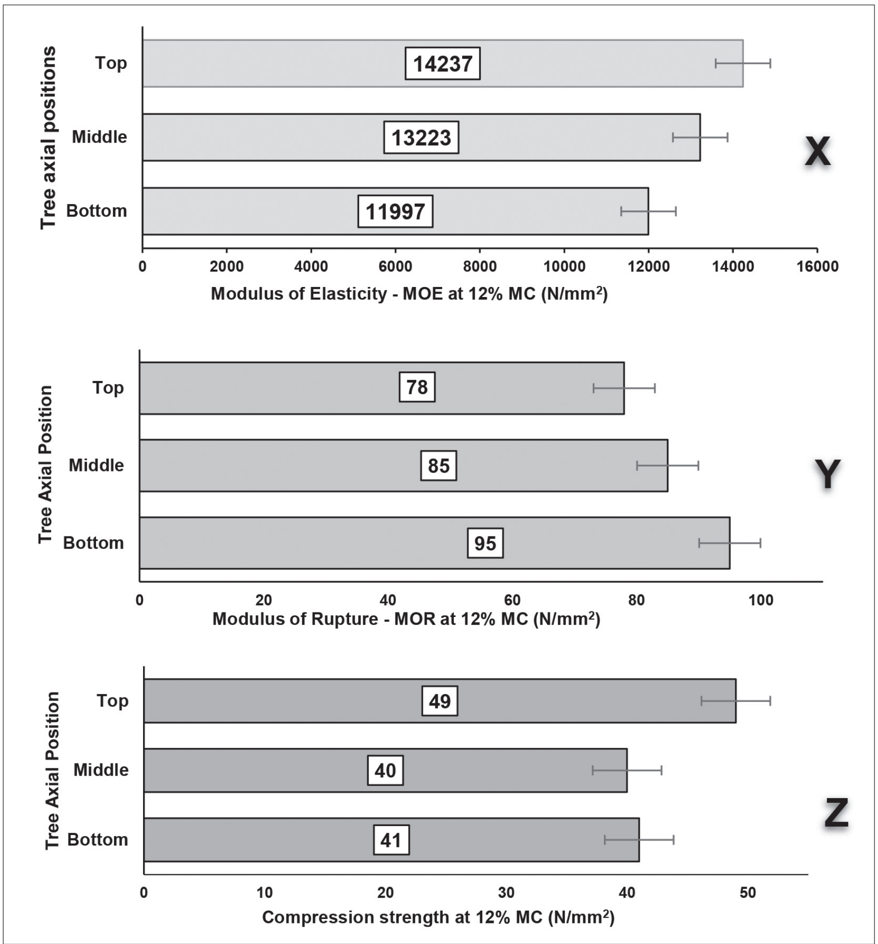

Figure 2. Mechanical properties (X = MOE, Y = MOR, and Z = compression II grain) of teak wood from different axial positions of the trees. N = 600.
Slika 2. Mehanske lastnosti (X = MOE, modul elastičnosti, Y = MOR, upogibna trdnost in Z = tlačna trdnost) tikovega lesa iz različnih aksialnih položajev dreves. N = 600.

Table 2. Statistical analysis of the mechanical properties of the 12-year-old garden teak.
Preglednica 2. Statistična analiza mehanskih lastnosti lesa12 let starih dreves tika.

Tree axial section Nivo v drevesu	N	Modulus of Elasticity – MOE (N/mm²) ± SD Modul elastičnosti– MOE (N/mm²) ± SD	Modulus of Rupture – MOR (N/mm²) ± SD Upogibna trdnost (N/mm²) ± SD	Compression strength II (N/mm²) ± SD Tlačna trdnost II (N/mm²) ± SD	Moisture Content at test (%) ± SD Vlažnost (%) ± SD
Top	200	14,237 ± 4.88 b	78 ± 1.28 a	49 ± 3.21 a	17.08 ± 1.03 a
Middle	200	13,223 ± 6.80 b	85 ± 1.34 a	40 ± 2.65 b	14.95 ± 0.98 ab
Bottom/Base	200	11,997 ± 2.71 a	95 ± 0.92 b	41 ± 2.82 b	13.05 ± 1.42 b
F-Value		**345.163 ****	**226.408 ****	**89.267 ****	**102.542 ****

Note: Mean values with different letters indicate a significant difference at P ≤ 0.05; SD = standard deviation.
Opomba: Srednje vrednosti, označene z različnimi črkami, pomenijo statistično značilno razliko pri P ≤ 0,05; SD = standardni odklon.

to top increase was 1,014 N/mm² (7.67%) and not significant (Figure 2, Table 2).

These trends appear to be at variance with those reported in most of the literature, which show that the MOE in trees of many wood species is higher at the bottom than the top (Shmulsky & Jones, 2011; Tsoumis, 1991). This appears to be consistent with Amoah and Inyong (2019), who found the MOE of teak grown in a wet site of Ghana increased from the bottom to the top, and they attributed this trend to the longer mean fibre lengths and higher mean aspect ratio of the teak. Similar reasons could also account for the MOE trend found in this study, since fibres are responsible for providing strength in hardwoods. Thulasidas and Baillères (2017) found that the MOE of 65-year-old plantation teak was 12,335 N/mm², while that of 65-year-old natural forest teak wase 12,530 N/mm². Hadiyanto and Prayitno (2006) also reported an MOE of 9,184.2 to 11,537.8 N/mm² for mature teak from various locations in Java and Indonesia, and Miranda et al. (2011) reported MOE values of 13,200 N/mm² and 14,400 N/mm² for 50- and 70-year-old teak trees, respectively, from an unmanaged forest in East Timor. These suggest the 12-year-old garden teak from Ghana has MOEs comparable or superior to those of 50- to 70-year-old plantation and natural forest teak from East Timor and Nilambur, in India, among other places.

The static Modulus of Rupture (MOR) averaged 87.53 ±16 N/mm², with decreases from the bottom to the top, in contrast to the trend observed with MOE. The MOR of the bottom to middle decreased by 10 N/mm² (10.53%), that of the bottom to top decreased by 17 N/mm² (17.89%), and that of the middle to top decreased by 7 N/mm² (8.23%) (Figure 3). These trends also appear to corroborate those reported for many wood species in most of the literature, which show that the MOR is higher in the wood of tree bases than those of treetops (Shmulsky & Jones, 2011; Tsoumis, 1991).

The bending Modulus of Rupture (MOR) average of 86.53 N/mm², which also showed a decreasing trend in value from the bottom to the top, is lower than the 94.08 N/mm² reported by Sekhar and Rawat (1966) and 91.8 N/mm² reported by Bhat and Priya (2004), as well as the 93.7 N/mm² and 83.4 N/mm² reported by Hadiyanto and Prayitno (2006) for teak ≥ 20 years. However, this study's MOR (86.53 N/mm²) is higher than that reported in some previous studies, such as 75 to 88 N/mm² for 15- to 20-year-old plantation teak (Amoah & Inyong, 2019), and 74.48 to 84.34 N/mm² for 12-year-old plantation teak (Shulkla & Viswanath, 2014). However, the average MOR in the current study is beneath the 108 N/mm² and 100 N/mm² for 13- to 65-year-old plantation teak from India (Thulasidas & Baillères, 2017). Moreover, Miranda et al. (2011) recorded an MOR value of 141 N/mm² for 50- to 70-year-old teak from unmanaged forest in East Timor.

Compression strength parallel to the grain appeared to be similar from the bottom to the middle section, and then increased significantly ($P \leq 0.05$) by about 22% for the wood from the top part of the trees. The mean compression strength (43 N/mm²) in the current study is within the range of 38.20 N/mm² to 42.13 N/mm² reported in Shulkla and Viswanath (2014), and just under the 44.6 N/mm² reported in Bhat and Priya (2004), but higher

Table 3. Two-Way ANOVA of the effects of stem position and moisture content on the properties of wood; CS – compression strength.

Preglednica 3. Dvosmerna ANOVA za vpliv položaja v drevesu in vlažnosti na lastnosti lesa; CS – tlačna trdnost.

	Density/Gostota		MOE/MOE		MOR/MOR		CS/CS	
	F-value/ F-vrednost	P-value/ P-vrednost	F-value/ F-vrednost	P-value/ P-vrednost	F-value/ F-vrednost	P-value/ P-vrednost	F-value/ F-vrednost	P-value/ P-vrednost
Stem position (S) / Nivo v deblu (S)	9.852	0.001	198.526	0.001	167.618	0.001	453.673	0.001
Moisture Content (MC) / Vlažnost (MC)	56.646	0.001	274.325	0.001	58.734	0.001	5.145	0.023
S × MC	3.432	0.084	6.879	0.001	6.127	0.001	7.149	0.001
	Adj. R^2 =0.386		Adj. R^2 = 0.523		Adj. R^2 = 0.498		Adj. R^2 = 0.584	

Table 4. Correlations among density and mechanical properties of teak wood (*Tectona grandis*).
Preglednica 4. Korelacije med gostoto in mehanskimi lastnostmi lesa tika (*Tectona grandis*).

	Density Gostota	**MOE** Modul elastičnosti	**MOR** Upogibna trdnost	**Compression II** Tlačna trdnost II
Density / Gostota	1			
MOE / Modul elastičnosti	0.657**	1		
MOR / Upogibna trdnost	0.739**	0.845**	1	
Compression strength II / Tlačna trdnost II	0.586**	0.187**	0.688**	1

**P≤0.05

than the 36 N/mm² for 10-year-old plantation teak in Dadzie et al. (2023). A high compression parallel to grain is required for wood to be used for tables, chair legs, columns in buildings, and parts of other interior products, among other uses. Twelve-year home grown teak could be used for furniture and other structures, as suggested for the agroforestry teak investigated by Shulkla and Viswanath (2024).

The results presented above indicate that the 12-year-old garden teak wood examined in the current study is of comparable quality to 65-year-old plantation and natural forest teak, as well as agroforestry teak. However, because the MOR fell below the threshold (>135 N/mm²) required for timber for heavy structural applications, it is recommended that garden teak is applied to lighter and less load carrying structures, such as furniture, sliced veneer, ceiling panels, door and window frames, and doors, among others.

Further analysis of the initial test results (prior to conversion to 12% MC levels) indicated that MC and tree axial position have significant effects on all the properties studied (Table 3), and the two factors explained approximately 39%, 52%, 50% and 58% of the variations in density, MOE, MOR and compression strength, respectively, as expressed by the R^2 values underneath Table 3.

3.4 CORRELATIONS AMONG DENSITY AND MECHANICAL PROPERTIES
3.4 KORELACIJE MED GOSTOTO IN MEHANSKIMI LASTNOSTMI

The parameters studied exhibited positive and significant correlations (P ≤ 0.05), with the strongest being between MOE and MOR (R = 0.845), though density also had significant correlation with both bending properties (MOE and MOR) and compression strength (Table 4). Such strong correlations recorded between MOE and MOR in this current study corroborate some previous reports (Tsoumis, 1991; Desch & Dinwoodie, 1996; Amoah & Inyong, 2019; Dadzie et al., 2023). However, whereas there was significant correlation between density and MOE in the current study, the opposite was shown by Amoah and Inyong (2019) and Dadzie et al. (2023).

4 CONCLUSIONS AND RECOMMENDATIONS
4 SKLEPI IN PRIPOROČILA

This current study assessed selected physical and mechanical properties of garden teak in Ghana with the objective of promoting its utilization with environmental and economic benefits.

The 12-year-old garden teak has a density that varies from tree base to the top, and is within the ranges for mature teak (>30 years old) reported in the literature, and it has significant influence on the mechanical properties of the wood.

The Modulus of Elasticity (MOE, averaging 13,162 N/mm²) bending strength (MOR, averaging 86 N/mm²), and compression strength parallel to the grain (averaging 43 N/mm²) of the 12-year-garden teak are basically not much inferior to those of some mature plantation and natural forest trees (>30 and ≤65 years old) reported in the literature. While the MOR falls below the threshold for safe application in heavy construction, it can still be used for light construction and our hypothesis is proven.

Positive significant (P ≤ 0.05) relationships exist among density, bending strength and compression strength parallel to the grain for the wood of

12-year-old teak, as is also generally true for the wood of mature trees.

The wood of 12-year-old garden teak, with slightly lower strength properties than mature teak from plantations and natural forests, could be safely used for furniture, door and window frames, ceiling joists, ceiling panels, and sliced veneer, among other uses.

It is thus recommended that patrons in the timber and wood demand and supply chain should consider utilizing the wood of garden teak, and encouraging people in Ghana to plant more teak for both the economic and environmental benefits this would bring them.

Finally, it is suggested that the natural durability, finishing properties and other mechanical properties of this material should be studied to increase confidence in using the wood of short rotation teak.

5 SUMMARY
5 POVZETEK

Povpraševanje po lesu v Gani in po svetu še naprej narašča zaradi številnih dobrih lastnosti lesa in bistvenih vlog, ki jih ima les v človekovem življenju kot gradbeni material in material za druge uporabe, gorivo, proizvodnjo pohištva in tudi za uporabo v zdravstvu. To povzroča velik pritisk na gozdove ter ogroža obstoj naravnih gozdov, zaloge vode in biotsko raznovrstnost na splošno. V tej študiji smo uporabili eksperimentalne raziskovalne metode za raziskavo variabilnosti lesnih lastnosti v deblih 12-letnih dreves iz »vrtnih« nasadov tika (*Tectona grandis*) v bližini bivališč. Zbrali smo vzorce 12-letne vrtne tikovine, jih pripravili in ocenili nekatere izbrane fizikalne lastnosti v skladu s standardom ASTM 2395 (2007) ter mehanske lastnosti v skladu s protokoli BS 373 (1957). Mehanski testi so bili opravljeni z univerzalnim testirnim strojem (model UTN -110). Želeli smo ugotoviti, če so lastnosti lesa iz 12-letnih dreves iz »vrtnih« nasadov primerljive z lastnostmi lesa starejših plantažnih tikov in če je les uporaben za lažje konstrukcije. Za analizo pridobljenih podatkov so bile uporabljene uveljavljene statistične metode.

Ugotovljeno je bilo, da vlažnost (MC) in gostota lesa 12-letnega tika variirata od baze do vrha drevesa, njune vrednosti pa so bile v mejah vrednosti za les zrelega tika, starega nad 30 let, ki so navedene v literaturi. Modul elastičnosti (MOE), je v povprečju znašal 13162 N/mm², medtem ko je bila upogibna trdnost (MOR) v povprečju 86 N/mm². Tlačna trdnost vzporedno s potekom aksialnih elementov je bila v povprečju 43 N/mm². Tudi ta je bila primerljiva z vrednostmi za tikovino zrelih dreves iz različnih delov sveta, ki so navedene v literaturi. Samo vrednost MOR je bila pod pragom za varno uporabo v težkih konstrukcijah. Raziskana tikovina je zato primerna za lažje konstrukcije, kot je med drugim pohištvo.

Potrjeno je bilo tudi, da gostota pomembno vpliva na mehanske lastnosti lesa. Poleg tega je bila za 12-letno tikovino ugotovljena pozitivna in značilna ($P \leq 0{,}05$) povezava med gostoto, upogibnimi lastnostmi in tlačno trdnostjo vzporedno z aksialnimi elementi, kot je navedeno tudi v literaturi za les zrelih dreves številnih vrst.

Na podlagi navedenega je bilo ugotovljeno, da 12-letni vrtni tik ni bistveno slabši od zrelega tikovega lesa iz nasadov in naravnih gozdov, zato se lahko vrtni tik varno uporablja za pohištvo, vratne in okenske okvirje, stropne nosilce, stropne plošče in rezan furnir. Zato bi z vidika povpraševanja in ponudbe lesa v gozdno-lesni verigi lahko resno razmislili o uporabi lesa 12-letnega tika ter ljudi spodbudili k njegovemu sajenju. To bi pripomoglo tudi k boljši sekvestraciji ogljika in bi med drugim prispevalo tudi k blagodejnemu vplivu nasadov ter kakovosti zraka v domačem okolju.

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