ISSN:2994-5569

Research Article

World Journal of Forest Research

Assessment of Dimensional Stability, Mechanical Properties and Joint Bending Performance of *Zanthoxylum gilletii* (Okuo) for Furniture Applications

Delle Desire Domekyiir*

Lecturer, Tamale Technical University, Ghana

***Corresponding Author**
Delle Desire Domekyiir, Lecturer, Tamale Technical University, Ghana.

Submitted: 2026, Mar 28; **Accepted**: 2026, May 06; **Published**: 2026, Sep 01

Citation: Delle, D. D. (2026). Assessment of Dimensional Stability, Mechanical Properties and Joint Bending Performance of *Zanthoxylum gilletii* (Okuo) for Furniture Applications. *World J Forest Res, 5*(2), 01-09.

Abstract

The depletion and rising cost of well-known commercial timbers such as Enthandrophragma cylindricum, Khaya ivorensis, Terminalia superba and Milicia excelsa highlights the need to promote lesser-used species (LUS) for utilization. This study assessed some properties of Zanthoxylum gilletii, an abundant but underutilized tropical hardwood in Ghana as a potential substitute for some near-extinct Well-known species. Three trees of each of Z. gilletii and E. cylindricum were harvested at the Bobiri Forest reserve in Kumasi, Ghana. Sample were prepared in axial directions (top, middle and bottom), and redial directions (heartwood and sapwood) of the stem portions. Test conducted were swelling, shrinkage, MOE, MOR and bending strength of two selected joints (splayed-mortise and mortise-tenon joints). At 12% moisture content, the mean modulus of rupture (MOR) and modulus of elasticity (MOE) for Z. gilletii ranged from 86.08 ± 4.52 to 132.25 ± 4 N/mm² and 8,474.10 ± 754.3 to 9,263.80 ± 494.1 N/mm², respectively. Corresponding values for E. cylindricum ranged from 84.15 ± 2 to 109.50 ± 3 N/mm² (MOR) and 8,292.90 ± 492.9 to 9,616.70 ± 705.9 N/mm² (MOE). Results revealed that Z. gilletii exhibits comparable shrinkage, swelling, mechanical properties and joints performance and workability, confirming its suitability as an alternative to WKS for furniture and structural applications, thereby supporting sustainable forest resource management.

Keywords: Lesser-Utilized Species, Modulus of Rupture, Modulus of Elasticity

1. Introduction

The incessant depletion and high cost of the commercially well-known timber species such as *E. cylindricum, T. grandis, K. Ivorensis, T. grandis,* and *M. excelsa* which are maximally used due to their natural durability. There are over 500 lesser-utilised species in Ghana but about 70 WKS are relied on causing their depletion because of their known properties and commercial value [1]. Therefore, it requires the promotion of the abundant LUS timber to mitigate this canker and sustain the furniture and timber industry [2].

Thus, intensive research into the properties of LUS. such as *Z. gilletii* in this study would be needed in order to increase the number of utilizable timber species for domestic supply and reduce the overexploitation of traditional timbers that have great export markets. In Uganda, several LUS, including *Podocarpus latiflius* R.Br. ex Mirb., *Funtumia elastica* (P. Preuss) Stapf. and *Trichilia dregeana* E. Mey. Ex Harv. & Sond.) are being progressively used to substitute many of the traditional timbers such as *Milicia spp.* and *Khaya spp*) for furniture production [3]. Timber is a highly preferred structural material for both building and furniture production. Wood furniture is sound and thermal-resistant, which makes residential homes cool and very serene as compart to their counterparts made of metal and plastics [4]. The natural grain pattern and texture of wood reveal an appealing product and provides some therapeutic enhancement such as spinal and support to distress patience [4].

Z. gilletii is a tropical LUS in Ghana but it lacks information in Trade Statistics. *Z. gilletii* has a great strength and attractive grain pattern; it saws well, dress to smooth finish. It is relatively abundant with a mean value at basal area of 1077 m^2 km^{-2} in Ghanaian [5]. It grows up to 120 -150 cm in diameter and 45-50 m tall with straight and cylindrical bole with sharp sprinkle on stem, which could be branchless for up to 25 m from ground level. However, the depth of knowledge on its properties could hinder its utilization.

This chapter sought to examine some physical (swelling and shrinkage) and mechanical (MOE and MOR) properties of *Z. gilletii* as a potential substitute to the threatened WKS such as *E. cylindricum* wood so as to increase its prospects of utilization. Furthermore, it would also contribute to the widening of the pool of 'candidate' timber species from the tropical forest for domestic supply. It would further reduce the overexploitation of the traditional timbers, which have potential export markets. Timber swelling and shrinkage are the principal causes of dimensional instability in wood products, driven by its hygroscopic property of gaining or losing moisture with variations in environmental relative humidity [6]. Shrinkage and swelling are generally regarded as undesirable physical properties of wood, as they are responsible for many of the major problems encountered in wood-based products. During service, wood and wood products particularly furniture joints are exposed to varying climatic conditions. Wood shrinkage occurs when its moisture content falls below the fiber saturation point and when environmental factors such as relative humidity and temperature fluctuate [7]. Dimensional stability is one of the wood properties that differs markedly along the three principal fiber directions. Variations in shrinkage and swelling along the longitudinal, radial, and tangential directions can affect different furniture components, leading to joint failure, cracking of connected parts, damage to surface coatings or protective finishes, and other forms of deterioration [6,8]. The mechanical properties of wood are more complex than those of most other construction materials because of its anisotropic structure [9]. Furthermore, owing to its hygroscopic nature, these properties are influenced by ambient air conditions and, consequently by the moisture content of the wood [9]. The study sought to examine the some physical and mechanical of *Z. gilletii* and the bending strength of splayed joint made from *Z. gilletii* to compare to the counterpart from *E. cylindricum.*

2. Materials and Methods

2.1. Study Area and Sampling of Wood Species

Three (3) trees of *Z. gilletii* and *E. cylindricum* each were purposively obtained from Bobiri Forest Reserve and Butterfly Sanctuary in the Juaben Municipal and Sekyere-East District in the Ashanti region of Ghana (Latitude 6°40''S and 6°44'N; Longitudes 1°15''E and 1°23''W) as marked on Ghana Survey Department Topographical Field Sheets 0602B3 and 0602B4 [10,11]. The forest is in the Moist Semi-Deciduous South-East sub-type ecological zone with an area capacity of 54.65m^2 (21.10 square miles). A careful selection of the wood species in the forest were made in order to select a straight, defect free stems and trees at their felling limits. Each tree was fell at 1.5m above ground level to avoid the fluted portions. Chain saw operator cutting down one of the selected timbers for further processing (Figure 1).

Figure 1: Chain Saw Operator Cutting down a Selected

Tree one (1) of *Z. gilletii* was fell 128.6 cm Diameter at Breast Height (DBH) and height of 32 m from compartment GISP 68. Tree two (2) of *Z. gilletii* was also fell at 121.9 cm DBH and height of 32 m from compartment GISP 68. Tree three (3) was fell from compartment 8 at of 93.1 cm DBH and height of 92.4 m. Tree one (1) of *E. cylindricum* tree was also sawn (127cm) DBH with height (33m) and location at compartment 72 near GISP 8, Tree two (2) was fell (93.7cm) DBH, height (33m) at compartment 72 near GISP 23 and trees three (3) was fell (95.48cm) DBH at height (38m) at compartment 1 near GISP 23. The wood species were selected because of their availability in the Ghanaian forests, large stem sizes, export characteristics, neglect in extraction especially in the case of *Z. gilletii* and their potential uses in the furniture industry and constructional work in Ghana.

Figure 2 shows the Bobiri Forest Reserve and Butterfly Sanctuary [12]. Each tree stem was crosscut into logs, 250 cm long and into three portions (bottom, middle and top) respectively and were further sawn using the through and through method into cants of 250 x 30 x 20 cm using a chain saw for easy transportation from the forest (Figure. 3).

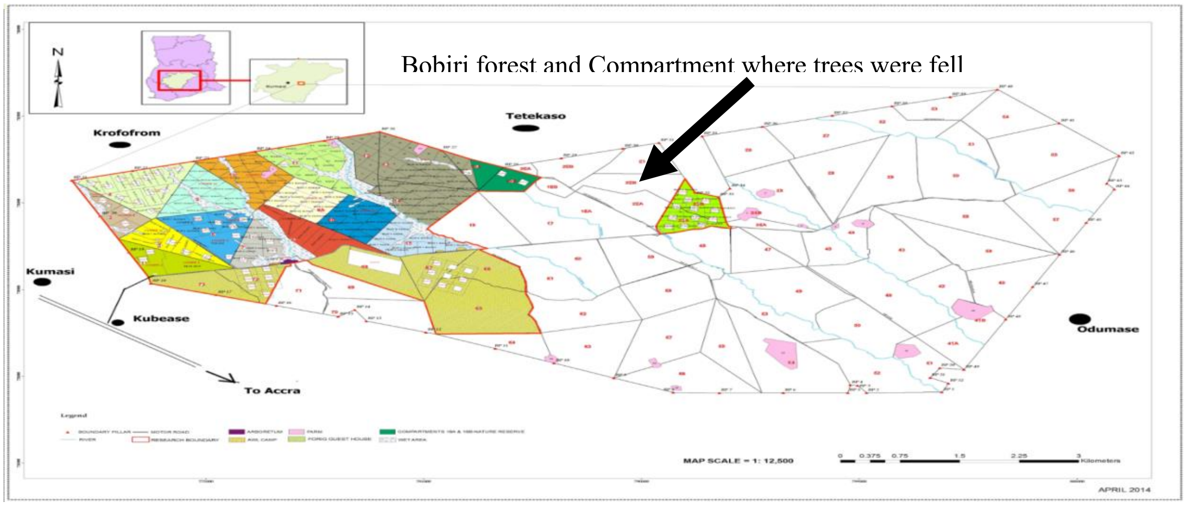

Figure 2: Bobiri Forest Reserve and Butterfly Sanctuary. (Resource Management Support Centre of the Forestry Commission of Ghana, 2007)

Figure 3: E. Cylindricum Stem Cross-Cut into Logs (A), Logs sawn into cants for Easy Transportation (B)

The cants were further processed into lumber, 250 x 30 x 5 cm thick using a wood mizer at Forestry Commission Training Centre (FCTC) at Akyaakrome and transported to CSIR-FORIG, Fumesua – Kumasi, Ghana. The lumber was stacked under an open shed to air-dry and processed into heartwood and sapwood samples from bottom, middle and top portions of the lumber from each the trees. Small, clear, straight-grained heartwood and sapwood samples were processed into the actual sizes into bottom, middle and top portions at the Wood and Furniture Testing workshop at CSIR-FORIG, for the various sizes for test on some physical and mechanical properties and joints construction.

3. Methods

3.1. Determination of MOE and MOR

The strength properties, Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) were assessed for heartwood and sapwood samples taken from the bottom, middle and top portions of each tree of Z. gilletii and E. cylindricum. The aim was to evaluate variations along the axial (vertical) and radial (cross-sectional) directions of the trees. Samples were prepared to a standard size of 20 × 20 × 300 mm (Figure 7) for mechanical testing.

A total of 720 samples were tested across all portions and tree species to determine MOR and MOE values for comparative analysis (BS 373: 1957). The samples were horizontally positioned and simply supported at two points along their effective span with load applied at mid-point for strength properties (Figure 8). MOE and MOR were determined using a Universal Testing Machine (UTM), Inspekt 50-1, specifically designed for testing small clear wood and wood-based panel samples (Figure 4).

The UTM Inspekt 50-1 was configured with a start load of 30 kN and an initial crosshead speed of 10 mm/min for testing each sample [13,14]. A progressively increasing load was applied until each sample failed or ruptured.

Figure 4: Sample Placed Under Load

3.2. Shrinkage and Swelling Tests

Two-hundred and forty (240) samples of (150 x 70 x 5 mm) from each of bottom, middle and top portions of the trees from each tree were used. Using the water-soak method, Thus, dry weights of samples and dry dimensions of longitudinal, tangential and radial directions of also measured using a caliper. The samples were soaked in clean water for 24 hours and each weighted and dimensions recorded as wet-weight and wet dimension. Samples were air dried at 12 - 15% mc in accordance with ASTM D 1037-06a, 24: 2006 standards. Shrinkage/swelling and volumetric shrinkage/swelling of sample was calculated using Equation 1 and 2.

$$Shrinkage/Swelling\ (\%) = \frac{Wd-Dd}{Dd} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{Equation 1}$$

Where: Wd = Wet dimension (ie. Wood dimension after immersion); Dd = Dry dimension (ie. Wood dimension before immersion).

$$Volumetric\ Shrinkage/swelling = \frac{Sl \times St \times Sr - Dl \times Dt \times Dr}{Dl \times Dt \times Dr} \times 100 \ldots\ldots\ldots\ldots \textit{Equation 2}$$

Where: Sl, St and Sr = Longitudinal, Tangential and Radial dimension of samples in swollen condition; Dl, Dt and Dr = Longitudinal, Tangential and Radial dimension of samples in dry condition.

3.3. Bending Strength of Joints of *Z Gilletii* and *E. Cylindricum* Wood

Straight grain and defect-free wood heartwood samples of *Z. gilletii* and *E. cylindricum* only were used to construction a T-shaped joint representing the back-leg and seat rail of a chair. Two joints, mortise-tenon and splayed-mortise joint were constructed to compare their bending strength and suitability for furniture production. Polyvinyl acetate (PVAc) was utilized as commonly used glue in the furniture industry [15]. The joints were cramped using a sash cramp and allowed to air-dry at room temperature for 48 hours. The leg member of the T-shaped joint was each held/cramped to a test jig attached to the Instron Universal Testing Machine (UTM) Inspekt 50 - 1 whiles the rail member placed under the cross head of the UTM inspect 50-1. An initial load was applied at a rate of 5 mm/min at 40 cm distance (L) from the face edge of each leg rail [16]. The ultimate load (F) that cause separation or breakage of each joint was recorded from an attached computer to the UTM with a tolerance of 0.01 Mpa from a computer attached to the UTM (Inspekt 50-1) (Figure 5) [17]. The applied load created stress such as tension in fibres at upper part of rail, compression in fibres at bottom of rail and shear at neutral plane [Nm] were recorded [16].

Figure 5: Joints Prepared from Z. Gilletii (1), E. Cylindricum (2) and Sample Under Load on UTM

4. Results

4.1. Physical Properties

4.1.1. Shrinkage and Swelling

The axial volumetric shrinkage of only heartwood samples from *Z. gilletii* were that middle > top > bottom whereas samples from the *E. cylindricum* counterpart was top > middle > bottom respectively (Figure 23 & 45). These variations were the same with the swelling with the bottom, middle and top portions of the samples. The were of significant differences (p>0.05%) among portions and both trees. The longitudinal directions in all portions with both trees recorded as low mean between 0.45 - 0.71 above longitudinal class of < 0.1-.03% as generally negligible (Figure 6 & 7). Generally, shrinkage and swelling in the longitudinal directions is minimal or unnoticed. Tangential shrinkage and swelling of were top > middle > bottom for *Z. gilletii* tree whereas those with *E. cylindricum* were bottom > top > middle portions. Radial shrinkage and swelling recorded that middle> bottom>top for *Z. gilletii* whereas *E. cylindricum* counterparts were bottom>middle>top respectively (Figure 6 & 7). Both the tangential and radial shrinkage and swelling indicated significant difference. Wood that has lower tangential and radial shrinkage and swelling are preferred for furniture production because they indicate a promising dimensional stability. Therefore, *Z. gilletii* and *E. cylindricum* are potential wood for furniture production and structural applications.

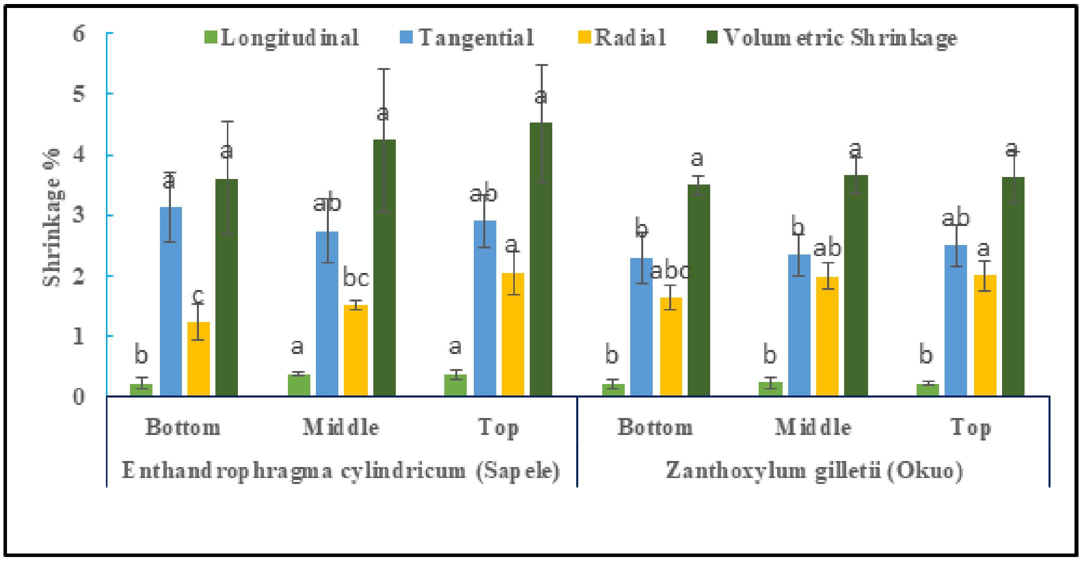

Figure 6: Timber Species X Axial/Radial Direction of Tree

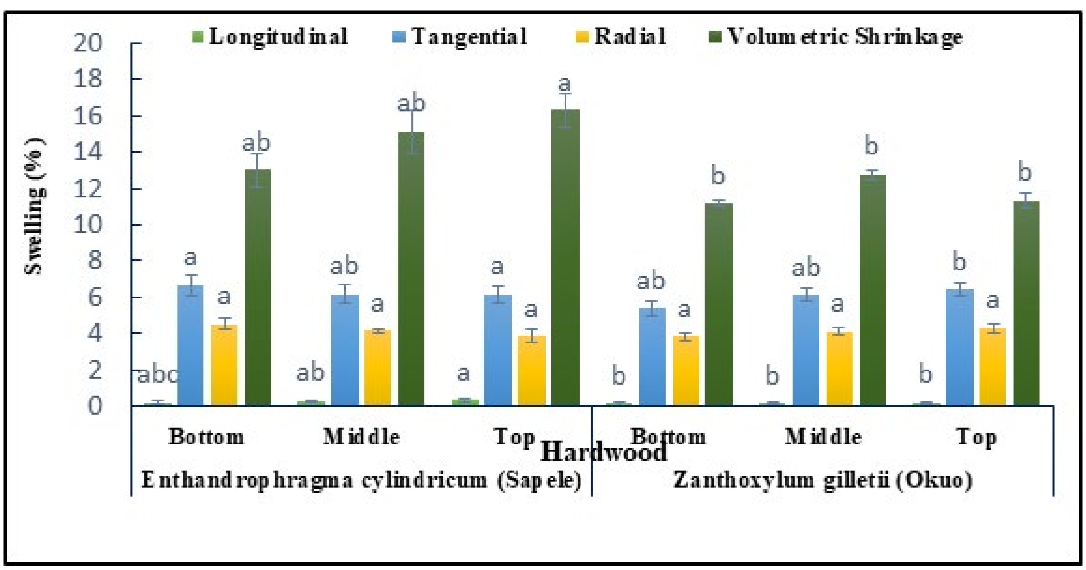

Figure 7: Timber Species X Axial/Radial Direction of Tree

4.1.2. MOE and MOR

The Modulus of Elasticity (MOE) for *Z. gilletii* and *E. cylindricum* followed the order in the axial (bottom, middle and top) and radial directions (Heartwood and sapwood) as Tree 1 > Tree 2 > Tree 3 for both species (Figure 8). The means of all radial sections indicated that, the heartwood samples *Z. gilletii* recorded the highest than those of *E. cylindricum* counterparts. (Figure 8). *Z. gilletii* exhibited highest mean MOE in both axial and radial directions compared to *E. cylindricum* (Figure 9), indicating that *Z. gilletii* strength is comparable to some well-known commercial wood species (WKS) such as Tectona grandis (Teak), Terminalia Ivorensis (Emire), Milicia excelsa (Odum), making it a potential alternative for furniture manufacturing. The results confirmed a significant difference ($p < 0.05$) between the MOE of *Z. gilletii* and *E. cylindricum*. The results for MOR for *Z. gilletii* also indicated the axial directions were bottom > middle > top portions as compared to those with *E. cylindricum* (Figure 10). However, there was no significant difference between the portions of the two trees species. Thus, the stiffness of the two trees had similarities which confirms that *Z. gilletii* is a potential substitute for furniture production (11). When compared to other local utility species (LUS) studied by LUS such as Albizia ferruginea [12,619 N/mm²], Blighia sapida [13,274 N/mm²], Sterculia rhinopetala [15,552 N/mm²] and Canarium schweinfurthii [9,209 N/mm²] [18]. This suggests that *Z. gilletii* is also suitable for heavy structural applications. Variations in MOE and MOR are likely influenced by genetic factors, density, fiber length, and environmental conditions like temperature and humidity.

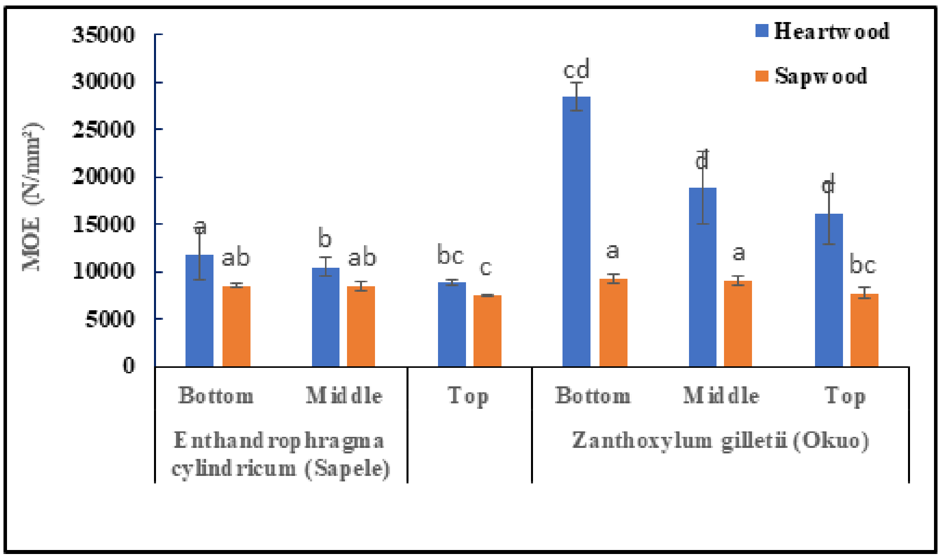

Figure 8: Timber Species X Axial/Radial Portions

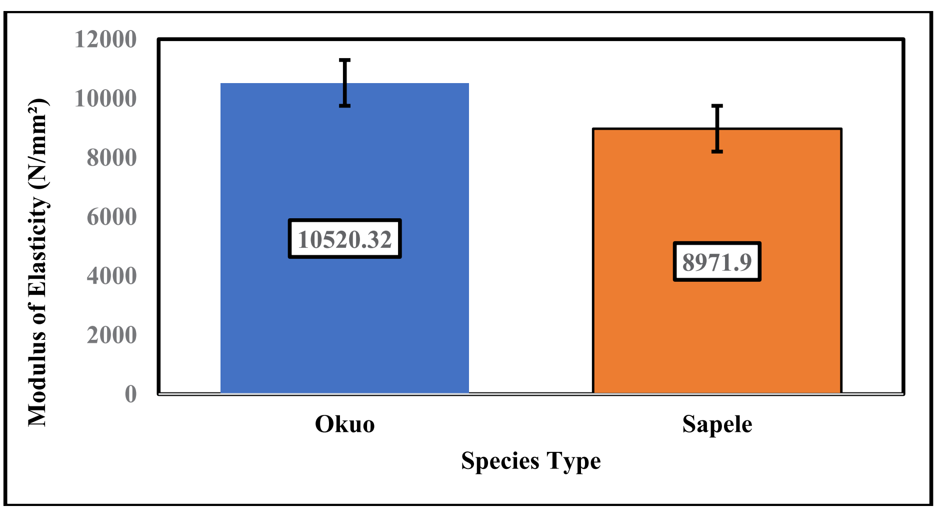

Figure 9: Mean Analysis of Modulus of Elasticity of the Tree Types

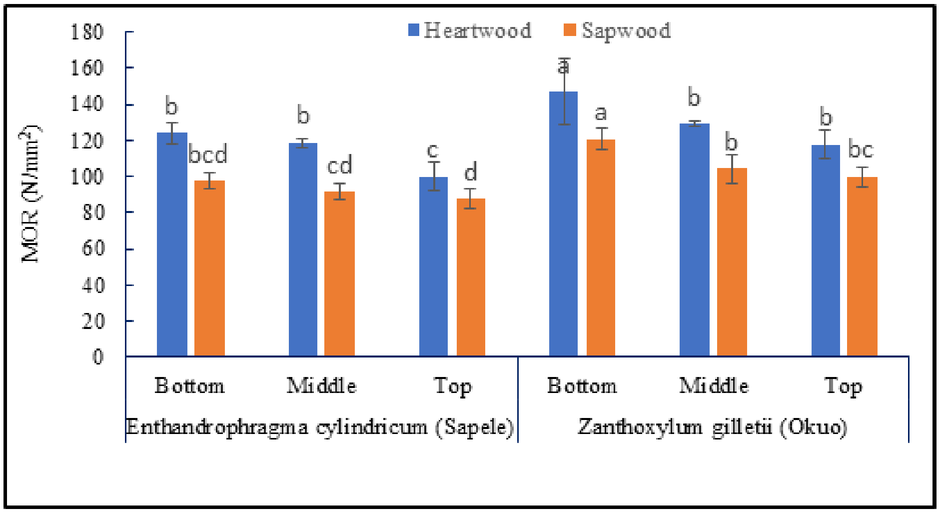

Figure 10: Timber Species X Axial/Radial Portions

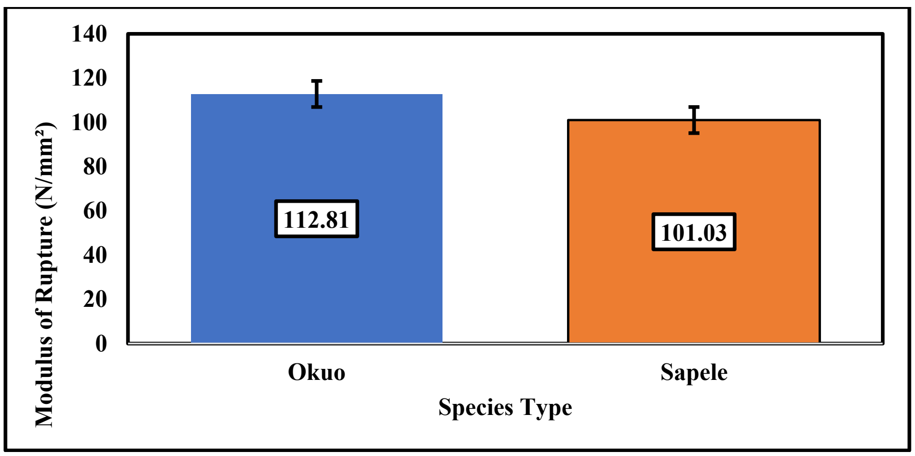

Figure 11: Mean Modulus of Rupture of the Species

4.1.3. Bending Strength of Joints of *Z Gilletii* and *E. Cylindricum* Wood

The strength of a furniture is highly hinged on the type of wood species and joint type for the selected construction [19]. Splayed-mortise joint made from *Z. gilletii* and *E. cylindricum* recorded an average of 9.32Mpa and 9.93Mpa respectively while mortise and tenon joint of made from both *Z. gilletii* and *E. cylindricum* recorded 11.28Mpa and 10.59Mpa. From results, both splayed joint and mortise and tenon joint exhibited a slightly lower strength capacity than counterpart joints made from E. cylindricum (Figure 12). It was revealed from the results from ANOVA, that there was significance between *Z. gilletii* and *E. cylindricum* and joint type ($p<0.05$). However, there was no significance between species type and joint type. It is found that the strength of both splayed joint and mortise joints made from *Z. gilletii* wood species is comparable to those of *E. cylindricum* species (Table 1). *Z. gilletii* wood species type indicated high potentials for utilization as a substitute to some WKS. There is a significant difference between the species type and joint type ($p>0.05$) than the species type and Joint-tree-types (Table 1). A study conducted on joint strength of mortise-tenon joint and dovetail joint made from *K. gabonensis* (3400 N) and 4915 N) respectively [20]. A study conducted by Boadu (2016) on the strength performance of dovetail joints made from heartwood (913±49.2 Nm) and sapwood (595.73±32.1) of *K. gabonensis* wood and its counterparts heartwood (842.9±39.5 Nm) and sapwood (556.6±38.9) of E. cylindricum. Comparatively, both the splayed joints and mortise and tenon joints made from *Z. gilletii* wood exhibited highest strength performance than those in other study conducted. It is therefore worth nothing that, *Z. gilletii* wood type is a viable LUS to augment the near-depleted WKS and to sustain the forests based on the results of this study.

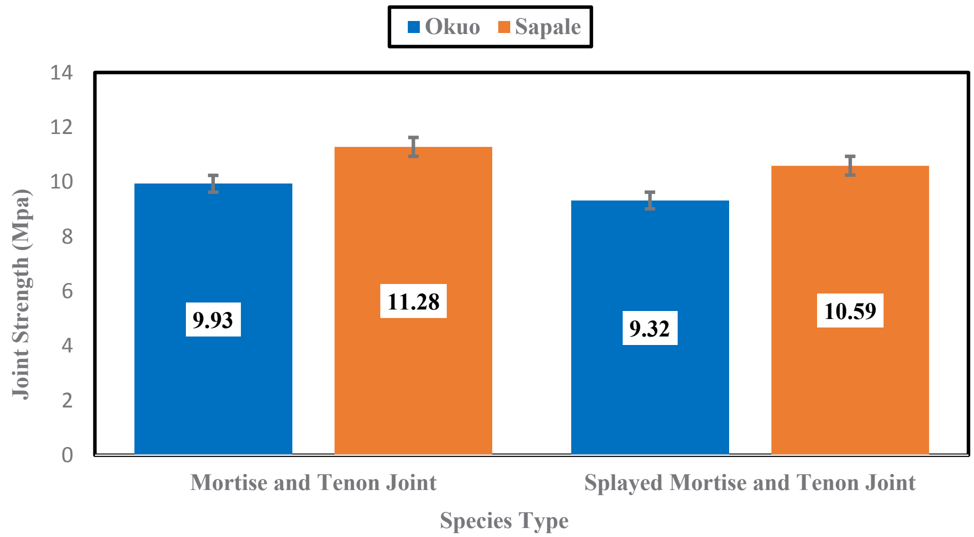

Figure 12: Mean of Joint Strength of The Species

Source	df	F-value	P-value	Var. (%)
Species Type (ST)	1	24.147	0.001**	24.1
Joint Type (JT)	1	5.971	0.017**	7.3
ST × JT	1	0.015	0.902ns	0

Table 1: ANOVA of Joints Strength for Tree Species

5. Discussion

The use of many timber species in engineering applications remains limited due to insufficient data on their properties [21,22]. Ozarska noted that the timber industry's growth is unsustainable because it relies too heavily on a few well-known traditional specie such as *Khaya ivorensis, Piptadeniastrum africanum, Tectona grandis and Milicia excelsa.* These species gained strong market prominence in Ghanaian and beyond largely because their properties were thoroughly studied [22-24]. In contrast, *Z. gilletii* remain underutilized due to a lack of information regarding its physical and mechanical characteristics. To evaluate its potential as a viable raw material or substitute for traditional timbers, a detailed investigation of its properties was necessary. Therefore, the some physical (shrinkage and selling) and mechanical (MOE and MOR) properties of both sapwood and heartwood of *Z. gilletii* were examined in this study.

6. Conclusion

This study evaluated into some physico-mechanical proprieties of *Z. gilletii* (LUS) and its bending strength of some joints and compared with those of *E. cylindricum* wood (WKS). There has been a sharp extinction of well-known commercial timbers (including *E. cylindricum*) and high demand for their exportation leading to reduction of furniture production and industry. Results obtained showed that properties of many non-exploited LUS including *Z. gilletii* with qualities for furniture production, are in abundance in the Ghanaian forests. Consequently, this affects demand by timber suppliers and furniture producers. In order to improve on the utilization of LUS, furniture producers must be abreast with adequate information on their properties and their commercial value. Therefore, it will prevent the over-dependence of the far extinct well-known timber species. *Z. gilletii* exhibited high promising values for replacement of WKS for furniture production [25-31].

References

1. Quartey, G. A. (2009). *Relationships between some anatomical, physical and durability properties of the wood of some lesser utilised Ghanaian hardwoods* (Doctoral dissertation).
2. Barany, M., Hammett, A. L., & Araman, P. A. (2003). Lesser used species of Bolivia and their relevance to sustainable forest management. *Forest Products Journal. 53* (7/8): 28-33.
3. Zziwa, A., Bukenya, M., Sseremba, O. E., & Kyeyune, R. K. (2006). Non-traditional tree species used in the furniture industry in Masaka District, central Uganda. *Uganda Journal of Agricultural Sciences, 12*(1), 57-66.
4. Phadke, A. (2012) Teak wood furniture – advantages and disadvantages.
5. Ghana Forestry Commission, (2012). Guidebook of some lesser-used timbers of Ghana. 38. Pp
6. Sejdiu, R., Topuzi, R., Sejdiu, M., & Jashari, B. (2022). The impact of climate conditions on wood shrinking and swelling

and its effect on furniture damage (case study in the Republic of Kosovo). *International Journal of Ecosystems & Ecology Sciences, 12*(2).
7. Antwi-Boasiako, C., & Boadu, K. B. (2016). The level of utilization of secondary timber species among furniture producers. *South-east European forestry: SEEFOR, 7*(1), 39-47.
8. Boadu, K. B., & Antwi-Boasiako, C. (2017). Assessment of the bending strength of mortise-tenon and dovetail joints in leg-and-rail construction using Klainedoxa gabonensis Pierre Ex Engl. and Entandrophragma cylindricum (Sprague) Sprague. *Wood Material Science & Engineering, 12*(4), 242-250.
9. Mańkowski, P., Karwat, Z., & Laskowska, A. (2025). Assessment of the Modulus of Rupture and Modulus of Elasticity in Static Bending of Yellow Pine Earlywood and Latewood. *Forests, 16*(2), 265.
10. Hawthorne, W., & Abu-Juam, M. (1995). *Forest protection in Ghana: with particular reference to vegetation and plant species* (Vol. 15). IUCN.
11. Bobiri Forest Reserve Management Plan, (2021 unpubl).
12. Resource Management Support Centre of the Forestry Commission of Ghana, (2007).
13. Ohemeng, E. (2022). Functional Relationship between density and mechanical properties of Ricinidendron heudelotii. *Global Journal of Medicinal Plants Research, 9*(1), 09-17.
14. OHEMENG, E., MENSAH, P., de MELO, R. R., EBANYENLE, E., OWUSU, F. W., SEIDU, H., & MITCHUAL, S. J. (2023). Technological properties of Memecylon lateriflorum wood: a timber species from Ghana. *Nativa, 11*(3).
15. Demirci, S., Diler, H., Kasal, A., & ERDİL, Y. (2020). Bending moment resistances of L-shaped furniture frame joints under tension and compression loadings. *Wood research, 65*(6).
16. Erdil, Y. Z., Kasal, A., & Eckelman, C. A. (2005). Bending moment capacity of rectangular mortise and tenon furniture joints. *Forest products journal, 55*(12), 209.
17. Kasal, A., Kuşkun, T., Haviarova, E., & Erdil, Y. Z. (2016). Static front to back loading capacity of wood chairs and relationship between chair strength and individual joint strength.
18. Appiah-Kubi, E., Kankam, C. K., & Adom-Asamoah, M. (2012). Bending and modulus of elasticity properties of ten lesser-used timber species in Ghana using structural dimensions.
19. Smardzewski, J., & Majewski, A. (2013). Strength and durability of furniture drawers and doors. *Materials & Design, 51,* 61-66.
20. Su, W. C., & Wang, Y. (2007). Withdrawal properties of single dovetail joints. *Taiwan Journal of Forestry Science, 22*(3), 321-328.
21. Appiah-Kubi, E., Kankam, C. K., & Ansa-Asare, K. (2019, June). Mechanical properties of four lesser–known Ghanaian timber species. In *International conference on innovative practices in management, engineering and social sciences, Singapore* (pp. 20-23).
22. Wepia Apungu, J., Antwi, K., Appiah-Kubi, E., Kofi Bih, F., & Zakaria, J. (2025). Investigating Physical and Mechanical Properties of Mahogany Root Wood (Khaya ivorensis) for its Utilization. *Drvna industrija, 76*(2), 189-199.
23. Boadu, K. B. (2016). *Bio-mechanical properties of Klainedoxa Gabonensis and the strength performance of its Dovetail and Mortise-Tenon joints in leg-and-rail construction* (Doctoral dissertation).
24. Mohd-Jamil, A. W., Noor Azrieda, A. R., Roszaini, K., Ang, L. H., & Mohamad Fakhri, I. (2018). Mechanical properties and durability of fast-growing timbers cultivated on degraded lands. *Journal of Tropical Forest Science, 30*(4), 519-527. file:///C:/Users/HP/Downloads/519-527-MohdJamil.pdf.
25. Antwi-Boasiako, C., & Atta-Obeng, E. (2009). Vessel-fibre ratio, specific gravity and durability of four Ghanaian hardwoods. *Journal of Science and Technology (Ghana), 29*(3).
26. ASTM D 1037-06a, 24: (2006) Standard testing methods for evaluating properties of Wood-base fibre and particle panel materials. Expansion with change in moisture content. American Standard for testing materials.
27. EN 131831 – 1, (2002) European Standard EN 131831-1 (2002) Moisture content of a piece of sawn timber- part 1: Determination by oven-dry method. European Committee for standardization.
28. Forest Products Laboratory (US). (1999). Wood handbook: *wood as an engineering material* (Vol. 113). The Laboratory.
29. Angyalossy Alfonso, V., Baas, P., Carlquist, S., Peres Chimelo, J., Rauber Coradin, V. T., Détienne, P., ... & Wheeler, E. A. (1989). List of microscopic features for hardwood identification. *International Association of Wood Anatomists Bulletin new series, 10,* 219-332.
30. Ofori, J., Brentuo, B., Mensah, M., Mohammed, A. I., & Boamah-Tawiah, R. (2009). Properties of 10 Ghanaian high density lesser-used-species of importance to bridge construction–part 1: green moisture content, basic density and shrinkage characteristics. *Ghana Journal of Forestry, 25,* 67-77.
31. Wan-Mohd-Nazri Wan-Abd-Rahman, W. M. N. W. A. R., Jamaludin Kasim, J. K., Rudaini Mohd-Nawawi, R. M. N., Hazandy Abdul-Hamid, H. A. H., Rahim Sudin, R. S., & Nor Yuziah, M. Y. (2012). Anatomical properties of Leucaena leucocephala wood: effects on oriented strand board.