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Evaluation of Some Mechanical Properties of *Cola pachycarpa* (K. Schum.) Wood in the Tropical Rainforest Ecosystem of Rivers State, Nigeria

Procjena nekih mehaničkih svojstava drva *Cola pachycarpa* K. Schum. iz ekosustava tropske prašume u saveznoj državi Rivers, Nigerija

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ABSTRACT • *The wood mechanical properties of Cola pachycarpa K Schum. were investigated within one of the tropical rainforest ecosystems of Rivers State. Three mature wood stands of Cola pachycarpa were harvested and used for the study. Samples of wood were collected from each of the different sections of the tree: the base (10 % height), middle (50 % height), and top (90 % height) along the axial plane. These samples were then divided into innerwood, corewood, and outerwood based on their radial position. Afterwards, the samples underwent oven drying until they reached a moisture content (MC) level of 12 %. The study was conducted using a 3 × 3 nested design in a completely randomized design (CRD). In cases where there were significant differences, the Duncan multiple range test (DMRT) was employed to separate the means. The results revealed that the MOR mean value was 5.89 N/mm² with an increase from top to base along the axial plane and with an increase from outer to inner wood across the bole of the tree radially. The MOE mean value was 810.87 N/mm² and it showed an increase from the base to the top axially, with an increase from the outer to inner wood radially. The mean value of CS//G recorded 34.62 N/mm². It showed that there was an increase from base to top across the grain radially, and an increase from outer to inner wood. The findings of this study offer quantitative data on the potential use of Cola pachycarpa wood, which could be competitive with other well-known wood species and serve as a good replacement for commercially overexploited wood species.*

KEYWORDS: *Cola pachycarpa; mechanical properties; axial plane; radial plane*

SAŽETAK • *U radu su istražena mehanička svojstva drva Cola pachycarpa K Schum., uzetoga iz jednog od ekosustava tropske prašume u saveznoj državi Rivers. Tri zrela stabla drva Cola pachycarpa posječena su i iskorištena za istraživanje. Uzorci drva pripremljeni su iz različitih dijelova stabla: iz baze (na 10 % visine), sa sredine (na 50 % visine) i s vrha (na 90 % visine) duž aksijalne osi. Ti su uzorci na temelju njihova radijalnog*

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položaja zatim podijeljeni na uzorke iz unutarnje, srednje i vanjske zone. Uzorci su sušeni u sušioniku do sadržaja vode (MC) od 12 %.
Istraživanje je provedeno uz pomoć 3 × 3 potpuno randomiziranog dizajna (CRD) studije. Ako su postojale znatnije razlike, za razdvajanje srednjih vrijednosti primjenjivan je Duncanov test višestrukih raspona (DMRT). Rezultati su pokazali da je srednja vrijednost MOR-a iznosila 5,89 N/mm², s porastom od vrha prema dnu debla u uzdužnom smjeru i s porastom od vanjske prema unutarnjoj zoni u radijalnom smjeru debla. Srednja vrijednost MOE-a bila je 810,87 N/mm² i povećavala se od dna prema vrhu u uzdužnom smjeru te od vanjske prema unutarnjoj zoni u radijalnom smjeru debla. Srednja vrijednost CS//G iznosila je 34,62 N/mm², s porastom od dna prema vrhu u uzdužnom smjeru i od vanjske prema unutarnjoj zoni u radijalnom smjeru debla. Rezultati ove studije nude kvantitativne podatke o potencijalnoj uporabi drva Cola pachycarpa, koje bi moglo konkurirati drugim poznatim vrstama drva i poslužiti kao dobra zamjena za komercijalno prekomjerno iskorištavane vrste drva.

KLJUČNE RIJEČI: Cola pachycarpa*; mehanička svojstva; aksijalna ravnina; radijalna ravnina*

1 INTRODUCTION
1. UVOD

Wood is a biological structure whose complexity is based on several cell kinds and chemistries working together to meet the demands of living plants (Wiedenhoeft, 2010). Wood has been used for centuries and decades for so many things ranging from furniture, structural, construction, acoustics, biofuel, etc. It is an indispensable material for people, and as such it is used for many utility and industrial purposes. Wood has a variety of qualities/properties originating from different wood species and within the same wood species due to varying factors and/or characteristics of wood. This is why wood species are classified based on their mechanical/strength properties thus providing timely information to science, wood-based industries, etc. Kretschmann (2010) opined that due to the dissimilarity of structural traits in wood, it helps to ascertain the mechanical attributes which in turn affect its potential for use. The modulus of rupture (*MOR*), which is also known and called the flexural strength of wood, is the load-carrying capacity (LCC) of a member. It measures the wood ability to resist deformation under bending. This property is essential in determining the structural integrity and suitability of wood for various applications. In contrast, the modulus of elasticity (*MOE*) quantifies the stiffness and stress-resiliency of wood. This property is crucial for figuring out how wood behaves under load, and whether it is appropriate for a given structural application. The resistance of wood to deformation when force is applied along the direction of the wood fibres is known as wood compressive strength parallel to the grain.

The African tropical sub-regions are home to many important edible tree species that have vast utilitarian potential and are rarely tapped. *Cola pachycarpa* happens to be one of them. *Cola pachycarpa* belongs to the Cola genus in the Malvaceae family and is a lesser-known plant species. In Nigeria, its fruits are recognized as edible, although it should be noted that the seeds within the fruit are not suitable for consumption like the commonly known "Kolanut" from the Cola genus (Jonny and Bassey, 2020). It is a forest tree which is over 30 feet high, little-branched with pale red flowers and white within. It is also, known as and commonly called Monkey or Bush Kola. Ogbu and Umeokechukwu (2014) asserted that Monkey Kola, also known as *Cola pachycarpa, Cola lepidota*, and *Cola lateritia*, are native tree species in the tropics originating from West Africa.

Despite their abundance, these edible wild relatives are underutilized. This underutilized indigenous tropical edible tree species is commonly consumed and relished by Nigerians and the Cameroons. It was reported by Anya (1982) that the south-eastern part of Nigeria has a wide array and diversity of *Cola pachycarpa* and other Cola spps. They are regarded as one of the epicentres for the early domestication of these forest tree species.

The aim of this work is to fill the knowledge gap regarding the mechanical properties of wood in most fruit tree species, with a focus on *Cola pachycarpa.* The goal is to better understand this fruit and food tree characteristics, as well as the possibilities of its utilization in construction works and plantation establishment.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Study area
2.1. Područje istraživanja

The research was carried out in Rivers State, located in the South-South region of Nigeria (Figure 1). The state is primarily focused on agricultural activities and has a land area of approximately 11,077 km² (4,277 sq mi), which places it as the 26th largest state in Nigeria. It is situated along the coastal plain of the eastern Niger Delta, extending towards the ocean from the Benue Trough. Rivers State is primarily known for the many rivers that run through it, such as the Bonny River. It lies between 4°45′N 6°50′E North of the Equator.

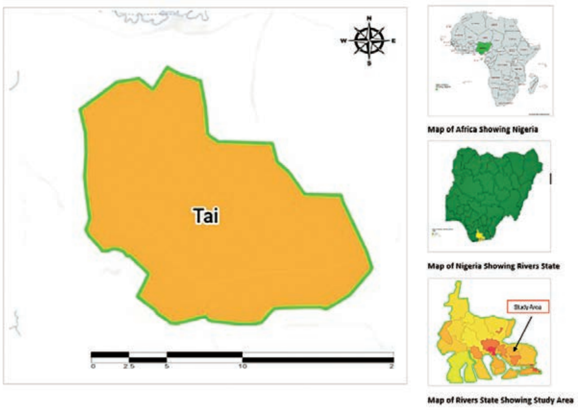

Figure 1 Map showing study area
Slika 1. Karta koja prikazuje područje istraživanja

Its surface geology consists of predominantly fluvial sediments. Rivers State experiences heavy, erratic, and seasonal rainfall. The average yearly temperature in the State stands at 26 °C.The hottest period is from February to May. For the majority of the year, relative humidity ranges from 90 % to 100 %, seldom falling below 60 % (Niger Delta Budget Monitoring Group, 2022). Specifically, wood species samples of Bush Kola (*Cola pachycarpa*) were obtained from Kpite, Bunu Tai in Tai LGA in Rivers State, Nigeria bordering between latitude: 4° 42' 59.99"N, longitude: 7° 17' 60.00" E.

2.2 Sample preparation
2.2. Priprema uzoraka

Three trees of *Cola pachycarpa* were selected due to their good quality. Measurements were taken for both the length and diameter of the chosen trees. Three samples of bolts (logs) were taken from the base (10 % height), middle (50 % height), and top (90 % height) of the trees along the axial plane or merchantable height (Figure 2). Bolts were taken to the sawmill workshop for conversion and divided into six equal zones: labelled 1 to 6 from bark to bark. Sections 1 and 6 formed the outerwood portion, section 2 and 5 formed the corewood, and 3 and 4 formed the innerwood portion in-line with the recommendations of Aguda *et al*., (2020). The sawn wood samples were further cut and trimmed to the specified dimensions of 20 mm × 20 mm × 60 mm and 20 mm × 20 mm × 300 mm for testing the mechanical properties. The blocks were prepared for testing by undergoing a process of drying and sterilization in an oven until reaching a constant weight at (103±2) °C for a duration of 24 hours. The weight of each wood sample was first measured, both when wet and dry in an oven, before being placed in a sealed nylon bag to avoid moisture absorption. 45 test samples were taken from each tree, with dimensions of 20 mm × 20 mm × 60 mm, totalling 135 samples. An additional 45 test samples were collected with dimensions of 20 mm × 20 mm × 300 mm, also totalling 135 samples, resulting in a grand total of 270 test samples (ASTM, 2014 and BS, 2012).

2.3 Determination of some mechanical test properties
2.3. Određivanje nekih mehaničkih svojstava

2.3.1 Modulus of rupture (*MOR*)
2.3.1. Modul loma (*MOR*)

The static bending tests were conducted using British standard BS: EN 408 (2012) and ASTM (2014) standard for small clear specimens of wood. The experiment was carried out at the Structural Unit of the Civil Engineering Laboratory, Rivers State University, Port Harcourt, using an improvised wood bending strength frame with a digital dial gauge (Improvised Universal Testing Machine) as shown in Figure 3. The dimensions of the test specimens are shown in Figure 4. The test specimens were loaded on a radial face, and the force applied to the sample at the point of failure was noted. The load carrying capacity (LCC) or bending strength was determined. This is typically expressed as the MOR, which is equivalent to the fibre stress in extreme fibres of the specimen at the point of failure.

$$MOR = \frac{3 \cdot P \cdot L}{2 \cdot b \cdot d^2} \ (\mathrm{N/mm^2}) \qquad (1)$$

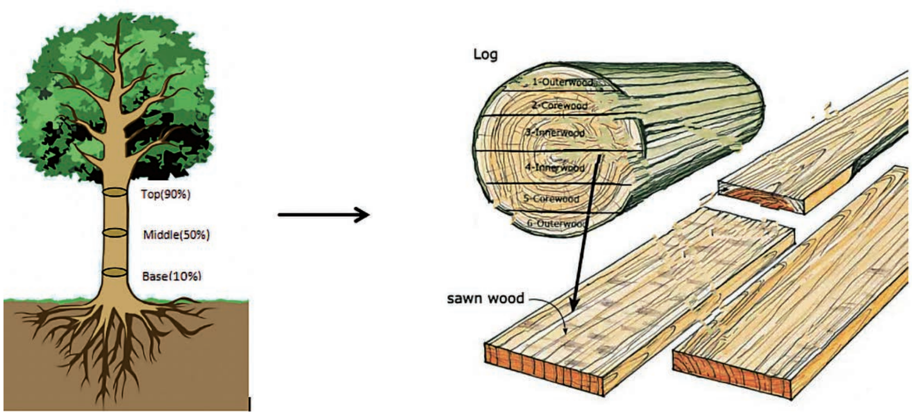

Figure 2 Selected parts of tree samples
Slika 2. Odabrani dijelovi uzoraka stabala

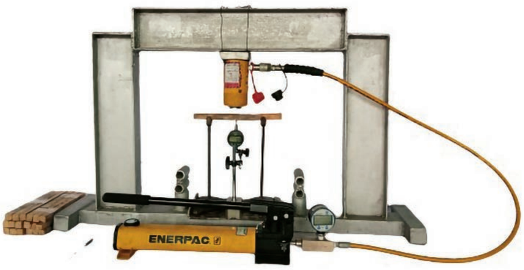

Figure 3 *MOR* test sample setup
Slika 3. Oprema i postavljanje uzorka pri ispitivanju modula loma

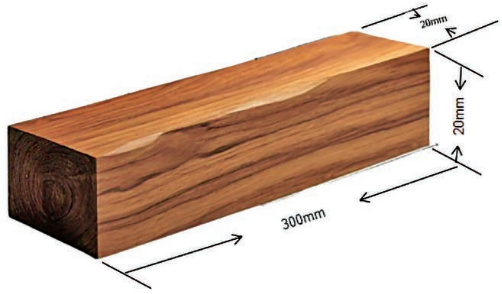

Figure 4 Wood sample geometry for *MOR* and *MOE* test
Slika 4. Geometrija uzorka drva za ispitivanje *MOR-a* i *MOE-a*

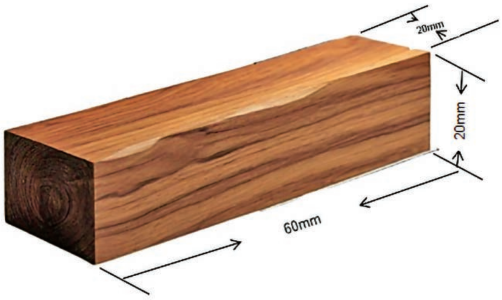

Figure 5 Wood sample geometry for compressive strength test
Slika 5. Geometrija uzorka drva za ispitivanje čvrstoće na tlak

Where:

MOR – Modulus of Rupture
P – load (N)
L – length of the sample (mm)
b – width of the sample (mm)
d – thickness of the sample (mm)

2.3.2 Modulus of elasticity (*MOE*)
2.3.2. Modul elastičnosti (*MOE*)

The values obtained at the point of failure and recorded during the *MOR* test were used to calculate the *MOE*. This made it possible to compute the deflection, which was then used to estimate the *MOE* by the following formula:

$$MOE = \frac{P \cdot L^3}{4 \cdot \Delta b \cdot d^3} (\mathrm{N/mm^2}) \qquad (2)$$

Where:

P – load (N)
L – span (mm)
b – width (mm)
d – depth (mm)
Δ – deflection at the beam centre at a proportional limit (mm)

Figure 6 Compression stress parallel to grain test setup
Slika 6. Oprema za ispitivanje čvrstoće na tlak paralelno s vlakancima

2.3.3 Compressive strength parallel to grain (*CS*//*G*)
2.3.3. Čvrstoća na tlak paralelno s vlakancima (*CS*//*G*)

The maximum compressive strength parallel to the grain was ascertained in line with the guidelines of BS: EN 408 (2012) method of testing small clear specimens of timber with test samples measuring 20 mm × 20 mm × 60 mm (Figure 5). At a rate of 0.01 mm/sec, wood samples were loaded, and the corresponding force was measured directly at the point of failure. The maximum compressive strength parallel to the grain was calculated by dividing this by the test specimen cross-sectional area. The CRB machine was used for this task (Figure 6).

(3)

Where:

CS//*G* – compressive strength parallel to grain
F – force at failure (N)
L – length of specimen (mm)
b – width in (mm)
Note: $L \cdot b$ – Cross-sectional area of specimen ($\mathrm{mm^2}$)

2.4 Experimental design and data analysis
2.4. Dizajn eksperimenta i analiza podataka

The experiment was laid out in a Completely Randomized Design (CRD), and the samples were replicated three (3) times and data was analyzed using Minitab statistical software version 16. One-way analysis of variance (ANOVA) was carried out to determine the level of significance among the various treatment means at a 0.05 % probability level. Duncan Multiple Range Test (DMRT) was used to separate the means.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

3.1 Modulus of rupture (*MOR*)
3.1. Modul loma (*MOR*)

MOR is the load-carrying capacity (LCC) of a member. As shown in Table 1, the *MOR* mean values range from 5.81 N/mm^2 to 6.03 N/mm^2 with an increase from top to base along the axial length and with an increase from outer to inner wood across the bole of the tree radially with mean values ranging from 5.43 N/mm^2 to 6.64 N/mm^2, respectively. The findings align with the studies conducted by Aleru and David-Sarogoro (2016) on *Mangifera indica*, Izekor (2010) on *Tectona grandis*, Aguda *et al*. (2014) on *Funtumia elastica*, Oriowo *et al*. (2015) on *Terminalia superba,* Kiaei and Farsi (2016) on *Albizia julibrissin* (Persian silk wood), and Ojo (2016) on *Borassus aethiopum*, as well as the recent research by Aguda *et al*. (2020) on *Ficus vallis-choudae* wood. However, the mean values are far less than those of the above authors but agree with the mean *MOR* range values (1.6067±0.62 to 5.5133±2.33 N/mm^2) of the work conducted by David-Sarogoro, and Emerhi (2021) on *Ficus exasperata*. The addition of more mature wood, an increase in annual growth rings, and the ageing of the cambium as the tree grows in girth could all be contributing factors to the axial increase of *MOR* from top to base (Izekor and Fuwape, 2010). The radial increase from the outerwood to the innerwood of the tree bole could be a result of the formation of annual growth rings, wherein the innerwood seems older than the core and outerwood. Accumulation of wood extractives at the heartwood area tends to boost the wood weight-bearing ability, and this may also have contributed to the increase from the outerwood to the innerwood (Aguda *et al*., 2020). In accordance with BS 5268-2 (2002) wood strength grading as reported in the BVRIO Guide by Blackham *et al.* (2020), the mean *MOR* (5.89 N/mm^2) falls under the deciduous class (D40), making it a very weak wood in terms of bending. This is also corroborated according to MS 544 Part 2 (2001), which falls under the strength group (SG-7).

3.2 Modulus of elasticity (*MOE*)
3.2. Modul elastičnosti (*MOE*)

MOE is the ability of a material, in this case wood, to exhibit its level of retention to its original size and shape before deformation. As such, the evaluation of the wood elastic modulus has great significance in determining its suitability for specific end uses. The mean data of the *MOE* is presented in Table 2. The mean values range from 756.72 N/mm^2 to 878.41 N/mm^2 with an increase from base to top (axially). Radially, there was an increase from outer to inner wood with mean values ranging from 761.96 N/mm^2 to 869.32 N/mm^2, respectively. The results at the axial position agree with the results of Fasiku and Ogunsanwo (2020) in the work carried out on *Anogeissus leiocarpus* (DC.) Guill & Perr and with the work of Aguda. *et al.* (2020.) on *Ficus vallis-choudaea* wood in their radial position. The increase in MOE at the top of the tree could be attributed to the dynamic nature of the tree canopy area. Wood from the canopy zone is often prone to wood defects because the area is gnarled (i.e., filled with knots). This zone is where photosynthetic activity is predominantly carried out and it is impacted more when compared to the base region of the wood. This report corresponds with the work carried out by Sanwo (1983) in the study of the plantation-grown *Tectona grandis* and Aguma, and by Ogunsanwo (2019) on *Khaya grandifoliola.* Given that age in the cambium and the accumulation of extractives in the heartwood when compared to the outerwood are major determinants of wood mechanical properties, the increase in MOE from the outer to the innerwood may have resulted from the annual formation of growth rings. This report contradicts the study(ies) on *Tectona grandis* by Izekor (2010) and Aguda *et al.* (2020), Ojo (2016) on *Borassus aethiopum* and (2012, 2014, and 2015) on *Staudtia stipitata, Funtumia elastica, and Chrysophyllum albidum.* Consequently, a combination of juvenile wood properties, growth stresses, nutrient distribution, cell structure variation, environmental influences and

Table 1 Mean *MOR* (N/mm^2) values of Cola (*Cola pachycarpa*)
Tablica 1. Srednje vrijednosti modula loma (N/mm^2) drva *Cola pachycarpa*

	Axial position / *Pozicija u uzdužnom smjeru*				
Radial position *Pozicija u radijalnom smjeru*	**Top (90 %)**	**Middle (50 %)**	**Base (10 %)**	**Mean**	**COV, %**
Inner / *unutarnja zona*	6.19a±0.97	7.16a±0.60	6.56a±1.36	6.64±0.99	14.91
Core / *srednja zona*	5.44b±0.65	5.49b±0.97	5.91b±0.74	5.61±0.99	17.64
Outer / *vanjska zona*	5.81ab±1.29	4.86b±0.14	5.61b±0.73	5.43±0.55	10.13
Mean	5.81±0.86	5.84±0.19	6.03±0.85	5.89±0.12	2.04

The means in the same column that have the same superscript are not statistically significant ($p < 0.05$).
Srednje vrijednosti u istom stupcu koje imaju jednak indeks nisu statistički značajne (p < 0,05).

Table 2 Mean *MOE* (N/mm^2) values of Cola (*Cola pachycarpa*)
Tablica 2. Srednje vrijednosti modula elastičnosti (N/mm^2) drva *Cola pachycarpa*

Radial position / *Pozicija u radijalnom smjeru*	Axial position / *Pozicija u uzdužnom smjeru* Top (90 %)	Middle (50 %)	Base (10 %)	Mean	COV, %
Inner / *unutarnja zona*	977.16^a±168.17	871.12^a ±185.72	759.68^a±97.70	869.32 ±164.17	18.88
Core / *srednja zona*	880.55^b±91.06	766.54^b±127.65	754.80^c±38.89	801.34±99.64	12.43
Outer / *vanjska zona*	777.52^c±10.04	754.80^c±38.89	753.55^a±310.50	761.96 ±157.03	20.61
Mean	878.41±61.32	797.49 ±65.04	756.72±117.21	810.87±61.94	7.64

The means in the same column that have the same superscript are not statistically significant ($p < 0.05$).
Srednje vrijednosti u istom stupcu koje imaju jednak indeks nisu statistički značajne (p < 0,05).

Table 3 Mean *CS//G* (N/mm^2) values of Cola (*Cola pachycarpa*)
Tablica 3. Srednje vrijednosti *CS//G*-a (N/mm^2) drva *Cola pachycarpa*

Radial position / *Pozicija u radijalnom smjeru*	Axial position / *Pozicija u uzdužnom smjeru* Top (90 %)	Middle (50 %)	Base (10 %)	Mean	COV, %
Inner / *unutarnja zona*	38.98^a±3.60	33.37^a±3.54	35.26^a±4.23	35.87±2.86	7.97
Core / *srednja zona*	38.30^a±6.10	33.18^a±0.95	33.32^a±3.08	34.93±2.92	8.36
Outer / *vanjska zona*	35.02^b±6.81	33.11^a±7.67	31.02^b±2.11	33.05±2.00	6.05
Mean	37.43±4.55	33.22±2.33	33.20±0.77	34.62±2.44	7.04

The means in the same column that have the same superscript are not statistically significant ($p < 0.05$).
Srednje vrijednosti u istom stupcu koje imaju jednak indeks nisu statistički značajne (p < 0,05).

genetic factors can cause the wood at the top of the tree to grow harder and exhibit a higher MOE compared to the wood in the middle and base of the tree. In the same vein, the mean *MOE* (10.87 N/mm^2) also falls under the D30 and SG-7 category, making it a very weak wood in elasticity in line with BS 5268-2(2002) and MS 544 Part 2 (2001), respectively.

3.3 Compressive strength parallel to grain (*CS//G*)
3.3. Čvrstoća na tlak paralelno s vlakancima (*CS//G*)

The mean compressive strength parallel to the grain of wood species is presented in Table 3. The values at their axial length range from 33.20 N/mm^2 to 37.43 N/mm^2 with an increase from base to top across the grain radially, and from 33.05 N/mm^2 to 35.87 N/mm^2 with an increase from outer to inner wood. The result agrees with the works carried out by Aguda *et al.* (2020) on *Ficus vallis-choudae* (Delile) wood and Fasiku and Ogunsanwo (2020) on *Anogeissus leiocarpus* (DC.) Guill & Perr wood. Conversely, the orientation trend goes contrary to the works of Izekor and Fuwape (2010) on *Tectona grandis* and Aguma and Ogunsanwo (2019) in both their axial and radial plan. This variation could also be a result of the top tree being close to photosynthetic activities as against the base of the tree, as seen in the *MOE* of the tree. Since age is one of the factors that determine wood strength properties, the radial variation that is highest in the innerwood may be the result of the annual growth ring formation, as the growth ring of the innerwood is older than that of the core and outerwood. Furthermore, these variations could be attributed to the fact that juvenile wood has a high density at the top due to rapid growth and high lignin content, which contributes to increased compressive strength (Larson *et al.*, 2001). The genetic composition and/or hormonal factors of the tree could also have resulted in this variation. Some tree species adapt to environmental conditions that favour stronger wood formation at the top for enhanced stability and resistance to mechanical forces (Wimmer and Downes,2003). The hormonal regulation of growth, particularly the influence of auxins produced at the apical meristem (top of the tree), can also cause this variation. These hormones can regulate cell division and differentiation, potentially leading to variations in wood strength along the tree height (Hoad *et al.*, 1981). Conversely, the wood in *CS//G* (34.62 N/mm^2) falls under SG-1 and D70 in line with MS 544 Part 2 (2001) and BS 5268 – 2 (2002) grading standards, respectively. This shows that the wood is stronger in *CS//G* and very weak in *MOR* and *MOE*.

4 CONCLUSIONS
4. ZAKLJUČAK

In conclusion, the research has provided baseline data on the suitability of *Cola pachycarpa* K Schum and its utilization potentials. Through meticulous analysis, the investigation results indicate that the *MOR* and *MOE* are low in line with the British and Malaysian Standard while *CS//G* wood is comparatively high. As such, having a relatively high compressive strength parallel to the grain, the wood will be suitable for applications where wood will be subjected to axial loads, such as columns, post, beams and joists (where the load is applied parallel to the grain), rafters and trusses and it could be competitive with other well-known wood species and be used as a good replacement for commercially overexploited wood species. Moving forward, further research is recommended to explore additional properties and applications of *Cola pachycarpa*, ensuring the conservation and responsible utilization of this valuable resource in the context of the rich biodiversity of the tropical rainforests of Rivers State, Nigeria.

5 REFERENCES
5. LITERATURA

1. Aguda, L. O.; Adejoba, O. R.; Areghan, S. E.; Ogunleye, M. B.; Aba, O. D., 2014: Mechanical properties of *Funtumia elastica* wood. In: Proceedings of 4th Biennial National Conference of the Forests and Forest Products Society, Abeokuta, Nigeria, pp. 351-356.
2. Aguda, L.; Ajayi, B.; Areghan, S.; Olayiwola, Y.; Kehinde, A.; Idowu, A.; Aguda, Y., 2020: Mechanical properties of *Ficus vallis-choudae* (Delile), a lesser utilized species in Nigeria. BioResources, 15 (3): 6550-6560. https://doi.org/10.15376/biores.15.3.6550-6560
3. Aguma, Q.; Ogunsanwo, O. Y., 2019: Variations pattern in selected mechanical properties ofstem and branch woods of *Khaya grandifoliola* (Welw.). C. DC. Journal of Research in Forestry, Wildlife & Environment, 11 (1): March, 2019.
4. Aleru, K. K.; David-Sarogoro, N., 2016: Mechanical strength properties of *Mangifera indica* in axial direction at different moisture regimes. International Journal of Advanced Research, 4 (11): 1520-1526. https://doi.org/10.21474/ijar01/2242
5. Anya, A. O., 1982: The Ecology and Sociology of Igbo Cultural and Development.1982 Ahiaojku Lecture Series. Owerri, Nigeria. Government Press.
6. Blackham, G.; Núñez del Prado, I.; Parker, J.; Tavares de Bastos, C., 2020: Lesser-known & lesser-used timber species utilizing ghana's sustainable timber resources. BVRio Responsible Timber Exchange.
7. David-Sarogoro, N.; Emerhi, E. A., 2021: Correlation between density and other mechanical wood properties of *Ficus exasperata* (Vahl) along axial plane. African Journal of Wood Science and Forestry, 9 (6): 001-007.
8. Fasiku, O. O; Ogunsanwo, O. Y., 2020: Selected physico-mechanical properties of wood of *Anogeissus leiocarpus* (DC.) Guill & Perr. International Journal of Research Studies in Science, Engineering and Technology, 7 (1): 9-17.
9. Hoad, G. V.; Lenton, J. R.; Jackson, M. B.; Atkin, R. K., 1981. Hormone Action in Plant Development – A Critical Appraisal. Butterworth-Heinemann Ltd.
10. Izekor, D. N.; Fuwape, J. A., 2010: Variations in mechanical properties among trees of the same and different age classes of teak (*Tectona grandis* L.F) wood. Journal of Applied Sciences Research, 6 (4): 562-567.
11. Izekor, D. N., 2010: Physico-mechanical characteristics and anatomy of teak (Tectona grandis L. F.) wood grown in Edo State, Nigeria. PhD Thesis, Federal University of Technology, Akure, Nigeria.
12. Jonny, I. I.; Bassey, M. E., 2020: Pharmacognostic and taxonomic studies of cola *Cola pachycarpa* K. Schum. (Malvaceae). Asian Plant Research Journal, 6 (3): 33-45. https:doi.org/10.9734/aaaaprj/2020/v6i330132
13. Kiaei, M.; Fars, M., 2016: Vertical variation of density, flexural strength and stiffness of Persian silk wood. Madera y Bosques, 22 (1): 169-175. https:doi.org/10.21829/myb.2016.221484
14. Kretschmann, D. E., 2010: Mechanical properties of wood. In: Wood handbook – Wood as an engineering material. Chapter 4: General Technical Report FPL-GTR-190. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI. p. 508.
15. Larson, P. R.; Kretschmann, D. E.; Clark, A.; Isebrands, J. G., 2001: Formation and Properties of Juvenile Wood in Southern Pines. Forest Product Society.
16. Ogbu, J. U.; Umeokechukwu, C. E., 2014: Aspects of fruit biology of three wild edible monkey kola species fruits (*Cola* spp. Malvaceae). Annual Research and Review in Biology, 4 (12): 2007-2014. https:doi.org/10.9734/ARRB/2014/8066
17. Ojo, A. R., 2016: Intra-tree variation in physico-mechanical properties and natural durability of *Borassus aethiopum* Mart. Woods in Savanna Zones of Nigeria. PhD Thesis, University of Ibadan, Ibadan, Nigeria.
18. Oriowo, B. F.; Amusa, N. A; Aina, K. S., 2015: Evaluation of Mechanical Properties of the *Terminalia Catappa* Trees and Stems from South Western Nigeria. International Journal of Novel Research in Electrical and Mechanical Engineering, 2 (3): 132-138.
19. Sanwo, S. K., 1983: Variations in the wood characteristics of plantation grown teak *Tectona grandis* in Nigeria. PhD Thesis, University of Wales, Cardiff.
20. Wiedenhoeft, A., 2010: Structure and function of wood. Wood handbook: wood as an engineering material. In: Wood handbook – Wood as an engineering material. Chapter 3: General Technical Report FPL-GTR-190. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI, p. 3.1-3.18.
21. Wimmer, R.; Downes, G. M., 2003. Temporal and Spatial Variation of Climate-related Tree ring Growth. Springer Series in Wood Science.
22. ***ASTM D143-14, 2014: Standard Test Methods for Small, Clear Specimens of Timber, West Conshohocken, PA.
23. ***BS EN 408, 2012: Timber Structures – Structural Timber and Glued Laminated Timber-Determination of Some Physical and Mechanical Properties. British Standard Institute, London.
24. ***BS 5268-2, 2002: Structural use of Timber. Part 2: Code of Practice for Permissible Stress Design, Materials and Workmanship. British Standard Institute, London.
25. ***MS 544, 2001: Code of Practice for Structural Use of Timber. Part 2: Permissible Stress Design of Solid Timber (First Revision). Department of Standards Malaysia, Shah Alam.
26. ***Niger Delta Budget Monitoring Group. 2022: Overview of Rivers State.

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