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WATER ABSORPTION EVALUATION OF *Eremospatha macrocarpa* AND *Calamus deërratus* FROM MANGROVE SWAMP FOREST, DELTA STATE, NIGERIA

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Abstract:

The evaluation of the water absorption rate of rattan species majorly determines their behavior in service and suitability for various structural and non-structural utilization, especially in wet environment and outdoor applications. This study, therefore, provided an understanding through the evaluation of the water absorption characteristics of two prominent rattan species, Eremospatha macrocarpa, and Calamus deërratus from mangrove swamp forest, Delta State, employed by the manufacturers of rattan products.

Five rattan stands were purposively collected from each species with samples taken across the tripart axial length positions (butt, middle and top of the plant). The samples were cut to the dimension in accordance with the specified physical properties tests standard of 60mm long with modifications due to the cylindrical form of the samples. The samples were oven dried in an oven at 103±2^{o}C until constant masses were attained and recorded. Thereafter, they were soaked in four different intervals (24 hours, 48 hours, 7 days, and 14 days) to determine the water absorption rate.

At 24 hours, 48 hours, 7 days and 14 days, water absorption in Eremospatha macrocarpa ranges from 28.487 - 83.679%, 41.234 - 95.227%, 53.399 - 111.478%, and 62.833 - 119.744% while in Calamus deërratus it ranges from 55.242 - 181.661%, 61.464 - 194.674%, 74.046 - 229.153%, and 80.796 - 243.484% respectively. The water absorption rate of the two species differs from one another with the Eremospatha macrocarpa species recording a lower mean value of 72.439 ± 23.005 than that of Calamus deërratus with mean value of 109.240±11.090. Water absorption as observed in the two species, increased from the base to the top. This implies that the butt could be employed for various outdoor applications while other positions could be utilized for indoor applications. For overall effective utilization of mangrove swamp forest rattan, sealant should be applied for prolonged service life due to high affinity for water uptake.

Key words*: Rattan; Water absorption; Eremospatha macrocarpa; Calamus deërratus.*

INTRODUCTION

The increased pressure and a decline in the availability of timber resource to meet up with the ever-increasing demand for wood utilization necessitates the need for the search of alternative (Micheal *et al.* 2017, Olayanu *et al.* 2022). This compelled efforts to be directed to the easily accessible non-timber forest species, such as rattan, serving as alternative (Zziwa *et al*. 2012).

Rattan species, a resilient natural material, thrive in mangrove areas due to the humid and tropical environment which offers optimal conditions for its growth. The soil quality, moisture levels, and support from surrounding vegetations within mangrove forests facilitate rattan development. In terms of biodiversity, the global landscape hosts around 22 genera and over 650 species of rattan (Govaerts *et al.* 2014). In Africa, a total of twenty-two rattan species, representing four genera, are known to inhabit lowland tropical forests. In Africa, rattans are predominantly distributed in the wild. They are recognized as a versatile and multipurpose resource, found primarily in tropical rainforests (Akpenpuun et al. 2017). Three genera *Laccosperma, Eremospatha*, and *Oncocalamus* are endemic to the continent, while *Calamus,* predominantly found in Asia, is represented by a single species in Africa (Sunderland 2007). These genera demonstrate unique climbing mechanisms, distinguishing them within the Calamoideae subfamily. There are four genera and ten species

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in Nigeria (Dahunsi 2000). The four genera identified in Nigeria are *Laccosperma, Calamus*, *Oncocalamus,* and *Eremospatha,* with ten species distributed across various locations in the country.

Nigerian rattan species are primarily endemic to mangrove and high forest vegetation, with concentrations notably observed in the Niger Delta Area (Sunderland 2007). The abundance and diversity of species correlate closely with rainfall distribution, with regions like Cross River, Delta, Bayelsa, and River State exhibiting higher species richness. In Nigeria, *Calamus deërratus, Eremospatha macrocarpa, Oncocalamus mannii,* and *Laccosperma secundiflorum* are among the most prevalent species, with *Calamus deeratus* being the most abundant (Obiukwu and Igboekwe 2020). These species exhibit varying stem diameters and stock densities per plot. Rattan stems exhibit considerable variation across species, with some featuring solitary stems, clustered stems, or even being "stem-less." Stem diameter ranges widely, from as small as 3mm for certain species to approximately 20cm for others (Olorunnisola 2002). Interestingly, stem diameter remains relatively consistent throughout a rattan's lifespan, while stem length can vary significantly, with some species reaching lengths of up to 175 meters (Burkill 1966). The growth rate of rattan canes averages around 0.70 meters per year, although this rate is subject to variation based on species and environmental factors (Razali *et al.* 1992; Sunderland *et al*. 2012). With its long, tough stems, rattan is a promising valuable material for the construction industry. The high moisture content of freshly harvested rattan cane, as observed in green samples, has implications for weight, dimensional stability, and susceptibility to pests and fungi (Lucas and Dahusi, 2004; Steckel *et al.* 2007). It is recommended to season fresh rattan canes before transportation to mitigate these issues and optimize their usability (Severa *et al.* 2003). Similar to wood materials, the rate of water uptake in rattan species signifies their water absorption capacity and resistance, which in turn can influence mechanical performance. Ogutuga *et al.* (2023) found significant differences in water absorption among different rattan species, with implications for their suitability in various applications. Lucas and Dahusi (2004), Liese (2001) observed differences in moisture content among green rattan samples, with *E. macrocarpa* exhibiting higher average moisture content compared to *C. deërratus.* Ogutuga *et al.* (2023) conducted studies on water absorption after 24 hours and 48 hours, highlighting differences between the two rattan species *Laccosperma secundiflorum* and *Eremospatha macrocarpa*. They noted that the position within the rattan cane (base, middle, top) affects water absorption, with implications for outdoor functions and water resistance. High water absorption, as observed, may negatively affect quality and increase susceptibility to microorganism attacks, thereby impacting mechanical performance in service Baronas and Ivanauskas (2004). The affinity for water uptake varies among rattan species, with *Laccosperma Secundiflorum* demonstrating higher water absorption compared to *Eremospatha macrocarpa* (Ogutuga *et al.* 2023). This suggests differences in water resistance between rattan species, influencing their suitability for various applications.

In spite of the potential benefits of rattan in terms of sustainability and effectiveness, there is insufficient research on the water absorption of different rattan species to know their suitability for diverse applications (Yang *et al.* 2020; Ogutuga *et al.* 2023). This study, therefore, provided significant insights on temporal water absorption rate of *Eremospatha macrocarpa* and *Calamus deërratus* rattan species, with a view to helping forest product users make informed decisions for diverse utilization purposes of indoor and outdoor applications.

OBJECTIVE

The objective of this study is to evaluate the water absorption of the non-timber forest product rattan species of *Eremospatha macrocarpa* and *Calamus deërratus,* with a view to knowing their behavior in service when employed for outdoor applications and in moist environment.

MATERIALS AND METHODS

SAMPLES PREPARATION

Five matured rattan plants were purposively selected from each of the two species of *E. macrocarpa*, and *C. deërratus* based on the superior phenotypic characteristics from mangrove swamp forest, Delta State, Nigeria. Samples were taken at the butt, middle and top of the stem of the plants in accordance with ASTM D143-52 (ASTM, 1972). The total samples of 45 were used for each species to make a total of 90 samples for the study.

DETERMINATION OF WATER ABSORPTION RATE OF *E. macrocarpa*, AND *C. deërratus*

Specimens of 60mm long with diameter range of 18mm to 26mm were cut from each selected samples and replicated five times with modifications based on the round shape of rattan canes according to ASTM D143-52 (ASTM, 1972). The specimens were placed in an oven at 103±2^{o}C until constant mass was attained. The oven-dried weights were recorded, there after, the samples were soaked in distilled water at four different intervals (24 hours, 48 hours, 7 days, and 14 days) to determine the water absorption rate. The water absorption percentage was calculated in accordance with ASTM-D1037 (1993) as stated in equation 1:

$$MA = \frac{mt - mo}{mo} \times 100\% \qquad (1)$$

where:
MA = the moisture absorption percentage
mo = the oven dry weight of the specimen (g)
mt = the weight of specimens after immersion in water (g)

EXPERIMENTAL DESIGN

The data collected for the study was analysed with 2 x 3 factorial experiment in a Completely Randomized Design (CRD). This was adopted to facilitate the interpretation and interacting effect of the result (Akindele 2004).

The following are the variables representing the functions:

i. Species - *E. macrocarpa*, and *C. deërratus*
ii. Sampling height – butt, middle, and top

The statistical model is given by:

$Y_{ij} = \mu + A_i + B_j + (AB)_{ij} + \varepsilon_{ij}$

Where:
Y_{ij} = individual observation
μ = general mean
A_i = the effect of factor A (Species)
B_j = the effect of factor B (Sampling height)
$(AB)_{ij}$ = The effect of interaction AB
ε_{ij} = experimental error

RESULTS AND DISCUSSION

Table 1

Mean results of rattan species water absorption

Rattan species	Position on Stem	24hours	48hours	7days	14days
Calamus deerratus	Top	102.83±18.80	111.40±20.56	137.27±25.0	147.06±25.8
	Middle	99.68±20.21	103.45±23.06	132.02±21.97	143.23±26.0
	Base	92.81±22.89	102.68±23.22	127.96±27.4	136.69±28.06
	Mean	98.44±11.10	105.84±11.95	132.42±13.33	142.33±14.28
Eremospatha macrocarpa					
	Top	71.64±5.27	81.58±5.309	105.41±5.37	105.41±5.74
	Middle	64.34±7.03	71.23±6.89	93.38±81.01	99.35±8.01
	Base	47.77±7.18	59.40±7.79	77.22±8.86	84.57±8.56
	Mean	61.25±4.39	70.74±4.34	89.87±4.74	96.45±4.65

Mean ± Standard deviation of 5 replicate samples

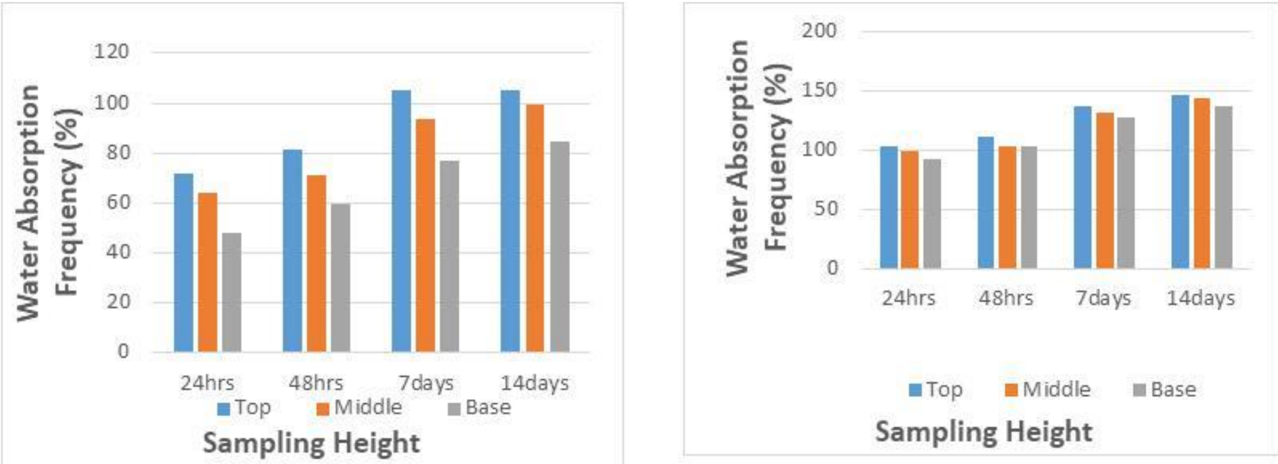
As shown in Table 1, at 24 hours, water absorption at the base in *Calamus deërratus* increased from 92.81% to 102.68% at 48 hours, to 127.96% at 7 days and to 136.69% at 14 days. At the middle, it increased from 99.68% to 103.45% at 48hours, to 132.02% at 7 days and to 143.23% at 14 days. At the top, it increased from 102.83% at 24 hours, to 111.40% at 48 hours, to 137.27% at 7 days and to 147.06% at 14 days. Whereas, at the base in *Eremospatha macrocarpa* at 24 hours, water absorption increased from 47.77% to 59.40% at 48 hours, to 77.22% at 7 days and to 84.57% at 14 days. At the middle, it increased from 64.34% to 71.23% at 48 hours, to 93.38% at 7 days and to 99.35% at 14 days. At the top, it increased from 71.64% to 81.58% at 48 hours, to 105.4% at 7 days and to 105.41% at 14 days.

In *Calamus deërratus,* the mean values of water absorption at 24 hours, 48 hours, 7 days and 14 days are 98.44%, 105.84%, 132.42% and 142.33% respectively. Whereas, in *Eremospatha macrocarpa* the average values at 24 hours, 48 hours, 7 days and 14 days are 61.25%, 70.74%, 89.87% and 96.45% respectively.

This shows that at 24 hours, 48 hours, 7 days and 14 days, *Calamus deërratus* had higher values of water absorption over *Eremospatha macrocarpa* with 37.19%, 35%, 42.55% and 45.88% difference for each time interval. Furthermore, in *Calamus deërratus* the difference in water absorption between the base and top of the stem at various intervals is about 10% whereas, it is about 20% in *Eremospatha macrocarpa.* This indicates that the later has wider sorption sites than the former.

The mangrove swamp forest *Eremospatha macrocarpa* rattan had higher rate of water absorption mean values with 61.25% after 24 hours and 70.74% after 48 hours, which are higher than the values reported by Ogutuga *et al.* (2023) for freshwater rattan species of 54.75% and rainforest of 47.15% after 24 hours as well as 65.045% and 54.57% after 48 hours respectively**.**

The results showed a consistent trend of increasing mean values of water absorption of the species over time, with the highest water absorption observed at 14 days. These descriptive statistics provide insights into the water distribution and variability of the species across different time zones. They help to characterize the central tendency, variability, and range of moisture absorption values, which are essential for understanding the behavior of these species in response to moisture over time. The increasing mean values over time suggest potential dimensional changes or instability in the species under study.



a. ***b.***

Fig. 1.
Water absorption rate of rattan species from Mangrove Swamp Forest, Delta State.
a. - Water absorption rate of E. macrocarpa; b- Water absorption rate of C. deërratus.

As shown in Fig.1, the two rattan cane species showed a similar trend of increasing water absorption with time, across the sampling heights (top, middle, and base). The absorption generally increased from 24 hours to 48 hours, thereafter to 7 days, and finally to 14 days as was observed in the two species. In both rattan species of mangrove swamp forest, variation in water absorption along the sampling heights was observed. An increase of water absorption was observed from the base to the top, which is in accordance with the pattern of variation reported by Ogutuga *et al*. (2023) for the freshwater and rainforest rattan species; *Laccosperma secundiflorum* and *Eremospatha macrocarpa*. Also, it follows a common pattern with the moisture content percentage of most tropical timber species that increased from base to the top of the stem due to the available sorption sites with the characteristics of being small at the base and increased to the top (Olaoye *et al*. 2016, Riki *et al*. 2019, Olayanu *et al*. 2022). The increment pattern from the base to the top may have been due to the fact that a high percentage of the matured rattan with low lumen diameter is found at the base than the top with large lumen diameter juvenile rattan. This contributes to the increase of resistance to the water uptake (Ogutuga *et al*. 2023). This implies that rattan products produced from the base of the stem will be more suitable for outdoor applications such as footstools, rattan umbrella for shade, outdoor chairs etc., while those of the top and middle will be better for indoor applications that do not have direct contact with water such as basket, cooking utensils, packaging materials, bedroom furniture etc.

The top section absorbed more water and at a faster rate than the middle and base sections. This may have been because of larger lumen or more sorption sites at the top region of lignocellulosic fibrous materials (Olaoye *et al*. 2016). However, higher rate of water absorption was observed for the two species within the 24 hours. Thereafter, the rate of absorption decreased over time in both species indicating a common trend of decreasing permeability or increasing saturation with time. This conforms with the findings of Kumar and Flynn (2006), Olorunnisola and Agrawal (2018) and Ogutuga *et al.* (2023) who reported a particular pattern common for wood known as 'the relaxation phase'. The relaxation phase is a two-step process whereby more than half of the final water to be absorbed by wood is absorbed within the first two days of the wood's contact with water (Khazaei 2008, Ogutuga *et al*. 2023). However, more than half of the final water absorption was observed in 24 hours for the two rattan species. This is in tandem with the findings of Ogutuga *et al*. (2023) on *Laccosperma secundiflorum* and *Eremospatha macrocarpa* rattan species. In spite of the two species exhibiting the similar absorption rate with the same time of relaxation phase, there are differences in their absorption values with *Calamus deërratus* absorbing more water than *Eremospatha macrocarpa.* These differences may be attributed to variations in the microstructure, the composition, and the properties of the two materials (Ebewele 2001, Baronas and Ivanauskas 2004). The higher affinity for water of *Calamus deërratus* may affect its appropriate use. This is because lignocellulosic fibrous materials effective utilization is being hampered with the poor water resistance characteristics (Ebewele, 2001).

However, in comparison of water absorption of *E. macrocarpa* of mangrove swamp forest of this study with those of freshwater forest and rainforest reported by Ogutuga *et al*. (2023), the mangrove swamp rattan species absorbed higher water and has higher affinity for water. This may have been due to the anatomical framework of the cells with high lumen diameter, developed to hold more water as a result of the waterlogged nature of mangrove swamp forest with more water than the freshwater and rainforest. This implies that ecological zone of rattan has effect on their permeability and water absorption rate.

Table 2

Water absorption Analysis of Variance results of Eremospatha macrocarpa and Calamus deërratus

	Variable	Sum of square	df	Mean Square	F	P-value
Control	Axial	10506.48	2	5253.24	1.04	0.371 ns
	species	10157.26	1	10157.26	2.001	0.17 ns
	Axial * species	4620.35	2	2310.17	0.45	0.64 ns
	Error	121844.1	24	5076.84		
	Total	147128.2				
24hrs	Axial	1506.37	2	753.18	0.64	0.535 ns
	species	10370.5	1	10370.5	8.84	0.007*
	Axial * species	252.67	2	126.33	0.11	0.898 ns
	Error	28141.37	24	1172.55		
	Total	40270.91				
48hrs	Axial	1207.02	2	603.51	0.44	0.645 ns
	species	9243.88	1	9243.88	6.84	0.015*
	Axial * species	257.41	2	128.71	0.09	0.909 ns
	Error	32420.53	24	1350.85		
	Total	43128.85				
7 days	Axial	1245.65	2	622.83	0.36	0.695 ns
	species	13578.81	1	13578.81	8.048	0.009*
	Axial * species	251.80	2	125.901	0.075	0.928 ns
	Error	40492.83	24	1687.201		
	Total	55569.09				
14 days	Axial	1272.76	2	636.38	0.33	0.72 ns
	species	15788.91	1	15788.91	8.26	0.008*
	Axial * species	151.968	2	75.98	0.04	0.961 ns
	Error	45855.31	24	1910.64		
	Total	63068.95				

*= significant (p< 0.05), ns= not significant (p > 0.05)

As shown in Table 2, the analysis of variance at 95% confidence level, showed that the moisture absorption significantly differs between the two species at 24 hours, 48 hours, 7 days and 14 days. Across all the time intervals (24 hours, 48 hours, 7 days, and 14 days), there were consistent significant differences in moisture absorption between *Eremospatha macrocarpa* and *Calamus deërratus,* with p-values (p<0.07, p<0.015, p<0.09 and p<0.08 respectively. This suggests that the water absorption increases with time for both species and a common pattern with other rattan species as the pattern of absorption is in conformity with that of *Laccosperma secundiflorum* and *Eremospatha macrocarpa* rattan species reported by Ogutuga *et al.* (2023). Along the sampling heights, there were no significant differences in water absorption across the various intervals. Also, the interaction between the sampling height and the species did not show any significant influence on moisture absorption across all the time intervals. This result is not in conformity with the findings of Ogutuga *et al.* (2023) who reported significant differences between the rattan species and their sampling heights. This may have been due to the variation in the species studied due to the anatomical characterization and the ecological zones from which the rattan species were collected.

However, the water absorption of rattan species affects their performance in several ways. High water absorption can weaken the mechanical strength and durability of rattan, leading to warping, cracking, and reduced longevity. Excess water uptake creates conducive environment for microorganisms such as mold and mildew growth, which affect quality by damaging the rattan and poses health risk (Baronas and Ivanauskas 2004). Moisture absorption can cause dimensional changes, such as expansion or contraction, which impact the structural integrity of rattan-based products.

CONCLUSION

Variations in water absorption across different sections of the rattan can limit potential applications and designs, necessitating careful selection and processing. Different water absorption rates may require specific approaches to preservation and maintenance. Managing these effects helps in improving the performance and longevity of rattan cane in various applications. The study of water absorption behavior of the two rattan species *Eremospatha macrocarpa* and *Calamus deërratus* revealed significant differences in absorption, with increased water uptake observed from the base to the top of the stem. This finding suggests that the basal portion of the rattan species may be more suitable for outdoor applications due to its reduced water absorption capacity. However, both rattans harvested from mangrove swamp forests exhibited a significantly higher affinity for water but *Eremospatha macrocarpa* had a lower rate of water absorption compared to *Calamus deërratus*. This suggests that for the effective utilization of rattan sourced from mangrove swamp forests, especially *Calamus deërratus* in outdoor and moisture-prone applications, the use of protective sealants such as polyurethane, epoxy resin, marine varnish, or spar urethane is essential to enhance the durability of the resulting products.

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