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Variation in some anatomical and physical properties of stems of five rattan palm species of Ghana

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Abstract—Selected anatomical and physical properties of stems of *Calamus deeratus, Eremospatha dransfieldii*, *Eremospatha macrocarpa*, *Laccosperma acutiflorum* and *Laccosperma secundiflorum* in the natural forest of Ghana were investigated to aid in understanding their quality and to promote their efficient utilization. Fibre lumen diameter, double fibre wall thickness (fibre diameter minus fibre lumen diameter) and proportion of fibres exhibited a more definite pattern of variations within and between all the five species than other anatomical properties. Generally, proportion of fibre and double fibre wall thickness decreased, whereas fibre lumen diameter increased from base to top internodes. Initial moisture content increased consistently from base to top internodes whilst relative density decreased in the same direction. Simple regression analysis of physical properties on anatomical properties revealed that fibre lumen diameter, double fibre wall thickness and proportion of fibre are important parameters likely to influence initial moisture content and relative density along the stems and between all species investigated. Stem quality of all five species is also discussed.

Key words: Stem anatomy; rattan palms; fibres; *Eremospatha*; *Calamus*; *Laccosperma*; Ghana.

INTRODUCTION

"Rattan" is a collective term commonly used for spiny climbing palms belonging to the subfamily Calamoideae of the family Palmae. This subfamily comprises 13 genera with more than 600 species [1]. Ten genera with their species occur in the Southeast Asian region and four genera with about 19 species occur in the West and Central Africa region. Of these, three genera, *Laccosperma*, *Eremospatha* and *Oncocalamus*, are endemic to the African region and *Calamus* is native to both regions [2, 3].

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Many forest communities are dependent on rattans as a means of income. In Ghana rattans are used for the production of household and commercial goods. Currently the rattan sector in Ghana contributes about 20% to total revenue from non-timber forest products (NTFPs); the global trade and subsistence value of rattan and its products is estimated to be US$ 6.5 billion [4]. The market for rattan furniture in Ghana is increasing [5, 6].

Considerable information has been recently generated on various aspects of rattans, including anatomy of the stem to broaden and improve their utilization [7–27]. Except for the work of Weiner and Liese [18, 21] and Ebanyenle and Oteng-Amoako [27], which dealt with the anatomy of some African rattans, almost all anatomical investigations have focused on Asian rattans. The physical and mechanical properties of three rattan species of Nigeria have recently been evaluated to assess their potential as construction materials [28].

The rattan industry in Ghana as in tropical Africa is beset with many technical problems which include misidentification, poor processing, poor harvesting techniques and over-exploitation of rattans leading to scarcity of economic rattan species like *Eremospatha* spp. [6]. Consequently, the future of the rattan industry, upon which so many rural people depend, appears to be threatened. This is a major cause for concern, particularly in view of the paucity of information on African rattans.

The primary objective of this study, therefore, was to determine the variation in selected anatomical and physical properties of five indigenous rattans species of Ghana to aid in understanding their stem quality to promote their efficient utilization.

MATERIALS AND METHODS

A total of five species comprising three genera, *Calamus*, *Eremospatha* and *Laccosperma*, were collected from three different forest types, namely Wet Evergreen (WE), Moist Evergreen (ME) and Moist Semi-deciduous (MS) (Table 1). At least, five matured stems were collected randomly for each species with each stem from a different growing clump in each forest type. Due to difficulty in collection, the entire length of stems could not be obtained, as the very top could not be reached. Both herbarium and stem samples collected for taxonomic identification are kept in the herbarium and xylarium, respectively, of Forestry Research Institute of Ghana (FORIG).

From each stem, a 4-cm-long sample was removed from the mid second basal, middle and top internodes for investigations (Fig. 1). The 4-cm-long sample was further divided into 1- and 3-cm-long samples for investigation of anatomical and physical properties, respectively. The 1-cm-long sample was sub-divided into two diameter flanks to serve as sectioning and maceration samples (Fig. 1).

A total of 165 samples for sectioning were softened by keeping them in a mixture of ethanol and glycerol (1:1) in labelled containers for an average period of about 20–30 days. Five transverse sections of 15–25 μm in thickness for each sample were

Table 1.
Mean diameter and length of rattan stems collected for the study

Species	Number of stems				Mean diameter (mm)	Mean length (m)
	WE	ME	MSD	Total		
Calamus deeratus G. Mann and H.Wendl	5	5	5	15	11.9	16.08
**Eremospatha dransfieldii* Sunderland	5	—	—	5	13	18.1
Eremospatha macrocarpa G. Mann and H. Wendl	5	5	5	15	11	19.7
**Laccosperma acutiflorum* (Becc.) J. Dranst	5	—	—	5	28	10.3
Laccosperma secundiflorum P. Beauv	5	5	5	15	25.5	9.9

* Species not readily available at MS and ME.

made using a sliding microtome. The sections were first washed in water and then stained in 1% safranin in 50% ethanol solution for about 10–20 min. The stained sections were then washed in water and dehydrated in increasing concentration of ethanol: 30, 50, 70, 85, 90 and 100% before being mounted in Canada balsam on a glass slide. All prepared slides were dried at 60°C overnight and observed under a light microscope. From each maceration sample, splits of matchstick size were taken from the core and the periphery portions, and kept in vials containing mixtures of 6% hydrogen peroxide and 97% acetic acid. The specimens were then incubated at 60°C for 2 days to obtain complete macerations. The macerated samples were rinsed with water and mounted temporarily in dilute glycerol for determination of cell dimension.

Fibre, conducting tissue and parenchyma proportions were determined from each sample using a 10× objective lens and 10× eye-piece with a dot-grid scale of 20 points. The dot-grid scale was placed three times progressively from the periphery towards the centre of the central cylinder. At each placement the number of points covering any tissue was counted and expressed as a percentage of the total number of points. Fibre length, width, lumen and double wall thickness were measured on 50 straight fibres per macerated sample. Terminology for description followed the recommendations of the IAWA Committee [29] and Weiner and Liese [17].

Initial moisture content and relative density were determined as described in British Standards 373:1957 [30]. Qualitative anatomical features were presented in descriptive form with photomicrographs. StatView software was used to perform analysis of variance (ANOVA) and Fisher's Protected Least Significant Difference (PLSD) post-hoc test to evaluate the variation in quantitative anatomical and physical properties among species (species effect) and between three different positions (position effect). Simple regression analysis was used to evaluate the

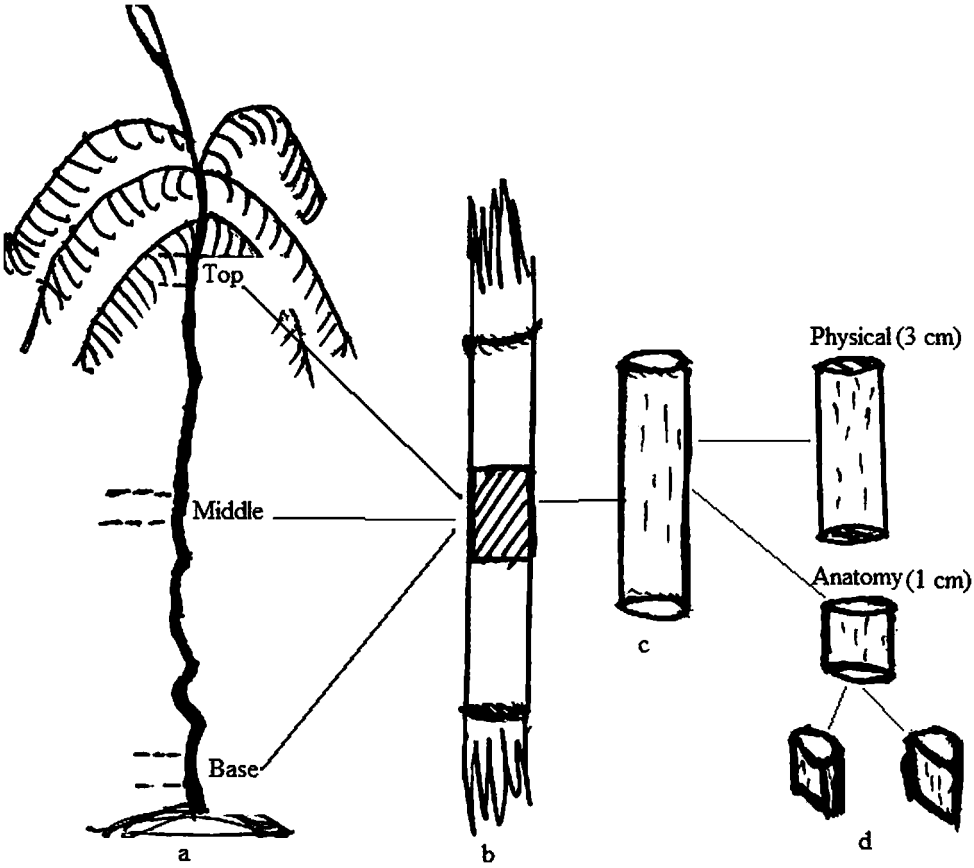

Figure 1. Schematic diagram of (a) rattan stem showing three levels: second basal, middle and top internodes, (b) internode showing mid portion (shaded portion), (c) 4-cm-long sample and (d) sample for physical and anatomical investigations.

relationship between anatomical and physical properties of all species. Before the regression analysis, a preliminary analysis was conducted to check if the data for each species from all three sites could be pooled. In all cases, stem position and its interaction with site and the variables (e.g., fibre length) were not significant ($P > 0.05$), so simple regression analysis was performed for each species on their pooled data from all three sites of WE, ME and MSD forests.

RESULTS AND DISCUSSION

Anatomical properties

All five rattan species investigated showed a common monocotyledonous stem structure [7]. Also, the general stem anatomy of the species investigated is similar to some West and Central African rattan species [18, 20, 21, 31].

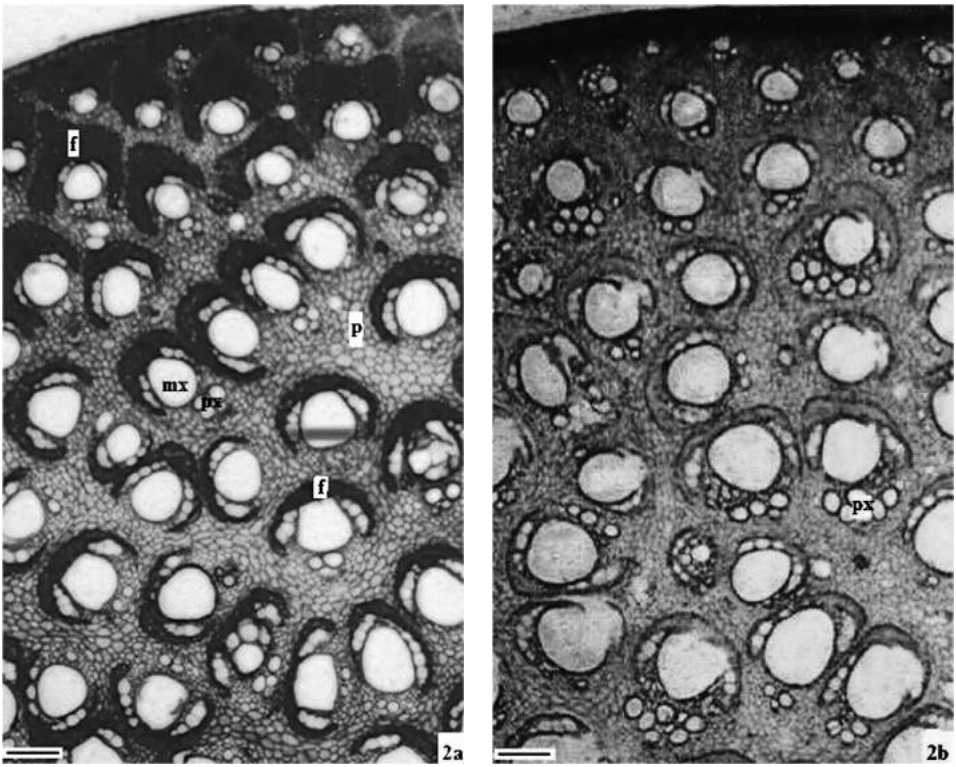

Figure 2. Cross-section of *Calamus deeratus*. (a) Basal internode and (b) top internode. Non-uniform and unevenly distributed vascular bundles. Vascular bundles at the periphery and basal internodes have a more extensive fiber sheath than inner vascular bundles and top internodes (f = fiber sheath; P = ground parenchyma; px = protoxylem vessels; mx = metaxylem). Scale bar = 25 μm.

All species exhibited a single layer of epidermis consisting of unlignified parenchyma cells. The epidermal cells of all five species were covered with wax layer interspersed with few stomata cells, except for *C. deeratus*, which was covered with silica. The cortex of all species consisted of fibre bands, rudimentary vascular bundles embedded in parenchyma cells of varying shapes and sizes lying ring-like around the central cylinder.

The central cylinder, depending on the species, was composed of vascular bundles of varying sizes, structure and distribution, embedded in ground parenchyma (Figs 2–6). Vascular bundles of *C. deeratus*, *L. acutiflorum* and *L. secundiflorum* were non-uniform in structure; unevenly distributed; larger and closely packed at the periphery and smaller and diffusely scattered at the inner portion (Figs 2, 5 and 6). Tomlinson *et al*. [32] have reported variations of vascular bundles in size and tissue arrangement along the longitudinal axis of *Calamus* spp. The vascular bundles of *Eremospatha* species were relatively uniform and evenly distributed (Figs 3 and 4). The vascular bundles of all five species consisted of conducting tissue (xylem and phloem), which was surrounded by a fibre sheath and parenchyma

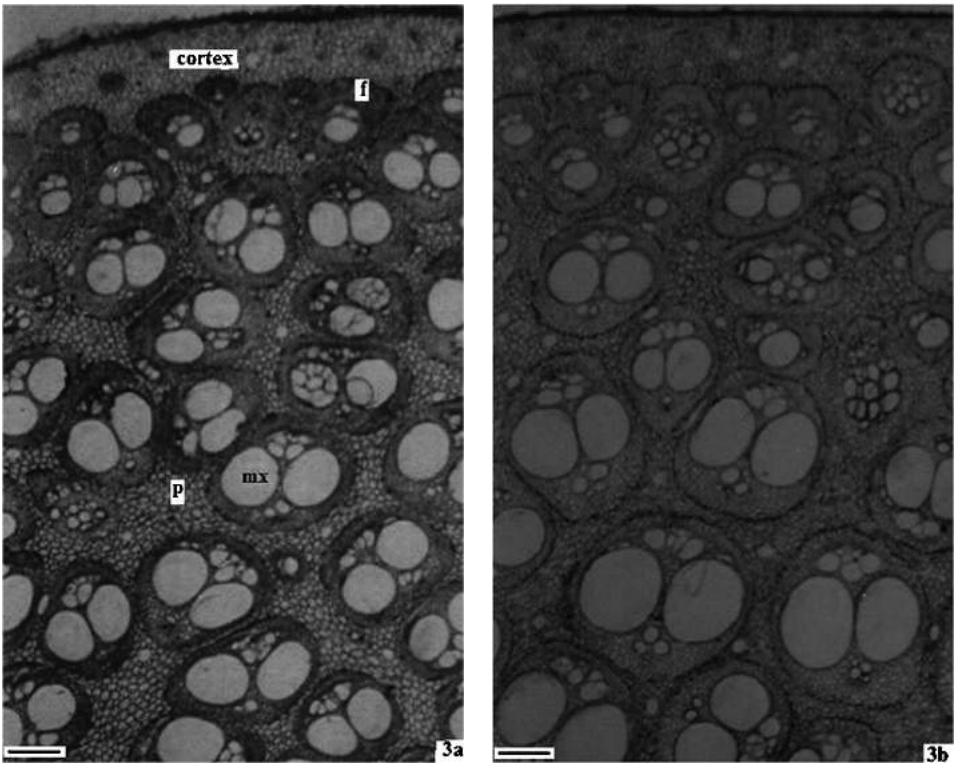

Figure 3. Cross-section of *Eremospatha dransfieldii*. (a) Basal internode and (b) top internode. Relatively uniform and evenly distributed vascular bundles. Fiber sheath more extensive in basal internode than top internodes. (f = fiber sheath; P = ground parenchyma; mx = metaxylem vessels). Scale bar = 25 μm.

(Figs 2–6). The mean proportion of conducting cells differed significantly between genera (*Calamus, Eremospatha* and *Laccosperma*) but insignificantly between species of the same genus (Table 2). Generally the proportion of conducting cells differed significantly with stem position, being relatively lower at the basal internodes than the middle and top internodes for all the species investigated (Table 2).

The mean proportion of parenchyma varied from 34% in *E. macrocarpa* to 48% in *L. secundiflorum* (Table 2). The mean values for all the species are in agreement with observations in similar species by Weiner and Liese [18]. Proportion of parenchyma was generally higher at the middle and top internodes than the basal internodes of all the species, which is in agreement with findings by Bhat *et al*. in *Calamus nagbettai, Calamus lacciferus* and *Calamus brandsii* [12].

The mean fibre length varied from 1.32 mm (*E. macrocarpa*) to 2.80 mm (*L. secundiflorum*), irrespective of position (Table 2). With the exception of *E. macrocarpa* which had insignificant longer fibres at middle and top internodes than the basal internodes, all the other species had their fibre length decreasing from

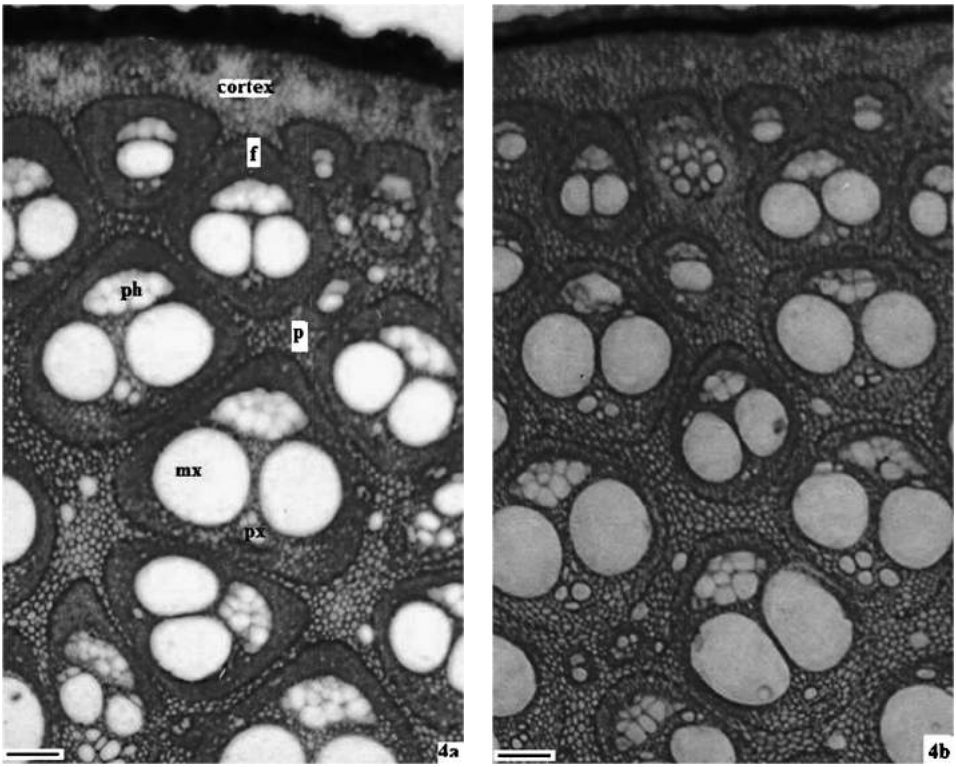

Figure 4. Cross-section of *Eremospatha macrocarpa*. (a) Basal internode and (b) top internode. Relatively uniform and evenly distributed vascular bundles. Fiber sheath more extensive in basal internode than top internodes. (f = fiber sheath; P = ground parenchyma; ph = phloem field; px = protoxylem vessels; mx = metaxylem vessels). Scale bar = 25 μm.

basal to top internodes (Table 2). Similar observations have been made in *Calamus nagbettai, Calamus lacciferus* and *Calamus brandsii* by Bhat *et al*. [12].

The mean fibre width regardless of position varied from 17.89 μm in *C. deeratus* to 22.20 μm in *E. dransfieldii*. Statistically there was no significant difference between fibre width of *C. deeratus* and *L. acutiflorum*. Mean fibre width of *C. deeratus*, *L. acutiflorum* and *L. secundiflorum* were wider at the basal internodes than at the middle and top internodes. However, *Eremospatha* spp. had wider fibre width at the top than the middle and basal Internodes (Table 2). Both type of observations have been made in *Calamus nagbettai*, *Calamus lacciferus* and *Calamus brandsii* [12].

Fibre lumen diameter, double fibre wall thickness and proportion of fibres exhibited more definite pattern of variations within and between all the five species. Generally, the proportion of fibre and double fibre wall thickness decreased whereas fibre lumen diameter increased from basal to top internodes (Table 2). This observation conforms to the findings of Bhat *et al.* [10, 12], Abasolo *et al*. [25] and Kadir [26] for some Asian rattans.

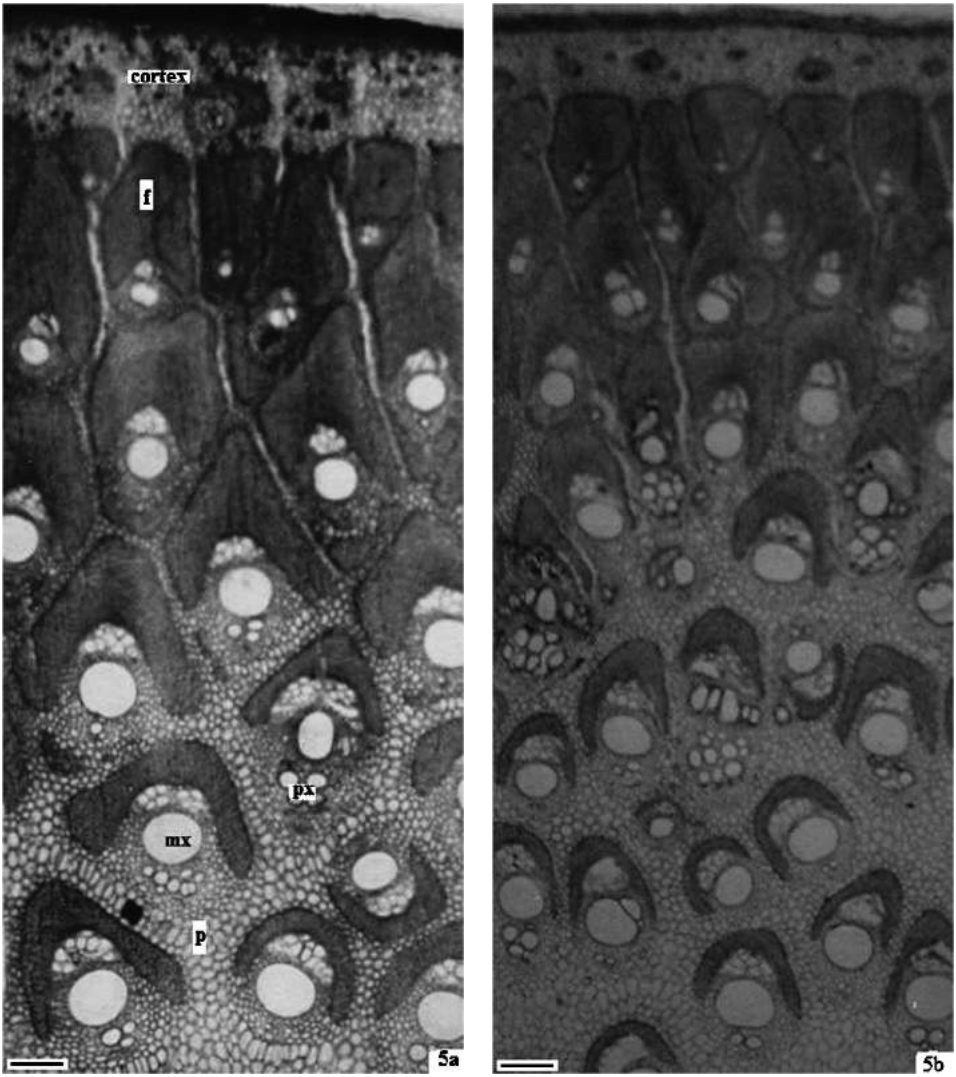

Figure 5. Cross-section of *Laccosperma acutiflorum*. (a) Basal internode and (b) top internode. Non-uniform and unevenly distributed vascular bundles. Vascular bundles at the periphery and basal internodes have more extensive fiber sheath than inner vascular bundles and top internodes. (f = fiber sheath; P = ground parenchyma; px = protoxylem vessels; mx = metaxylem vessels). Scale bar = 25 μm.

Physical properties

Internode diameter and length. Mean internode length varied from 24 cm in *E. dransfieldii* to 35 cm in *C. deeratus* (Table 3). Generally the middle internodes were longer than the base and top internodes of all the species (Table 3). The mean internode length did not differ among species, except *C. deeratus*, which had significantly longer internodes than the rest. The results suggest that

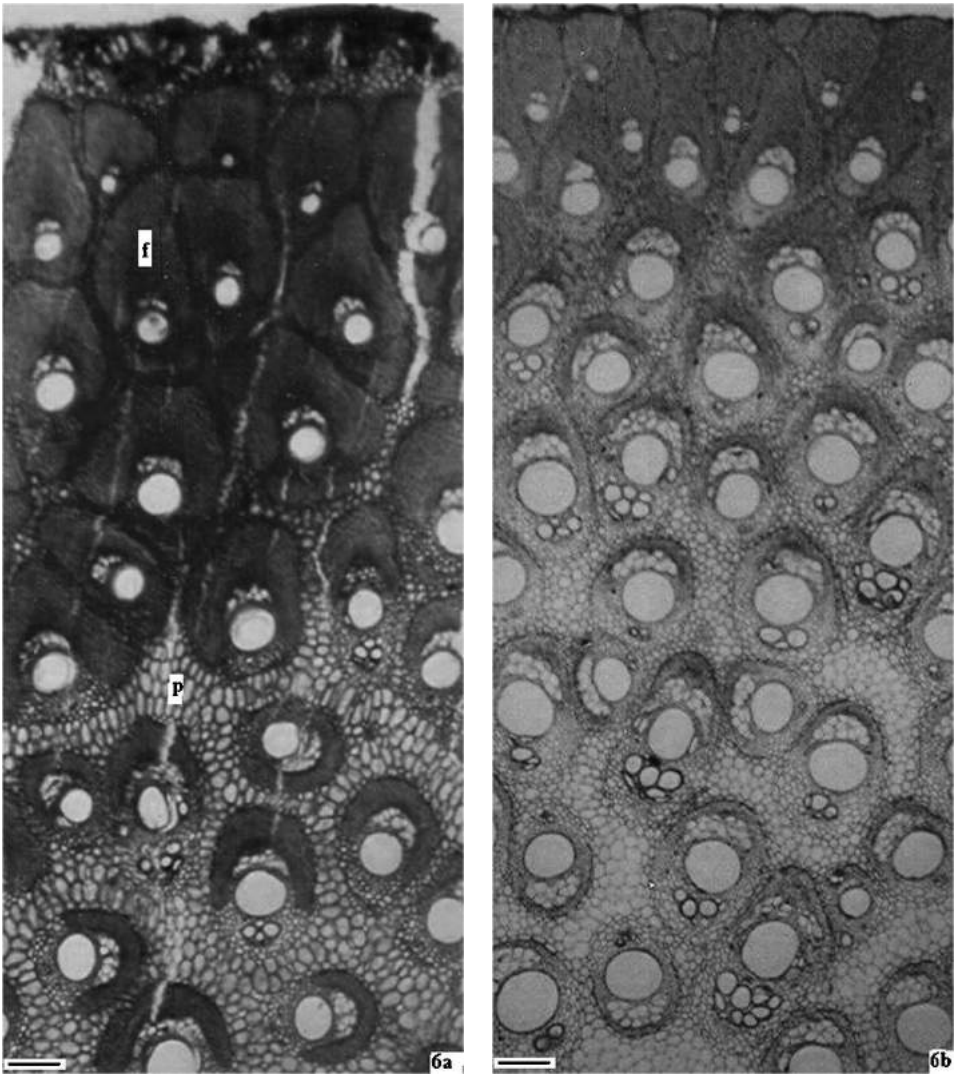

Figure 6. Cross-section of *Laccosperma secundiflorum*. (a) Basal internode and (b) top internode. Non-uniform and unevenly distributed vascular bundles. Vascular bundles at the periphery and basal internodes have more extensive fiber sheath than inner vascular bundles and top internodes (f = fiber sheath; P = ground parenchyma; px = protoxylem vessels). Scale bar = 25 μm.

internode length of all rattan species examined exhibit considerable variation within species but relatively stable between species. Yudodibroto [33] also reported of considerable variations of internode length in *Calamus* species from Indonesia.

Mean internode diameter differed significantly with species. Mean internode diameter ranged from 12 mm in *E. macrocarpa* to 28 mm in *L. acutiflorum* (Table 3). Although stem diameter differed with position, *Laccosperma* spp. showed relatively more uniform internode diameter from basal to top internodes than *C. deeratus* and

Table 2.
Comparison of some quantitative anatomical features of five rattan species of Ghana

Species and position	Anatomical features						
	Fibre length (mm)	Fibre width (μm)	Fibre lumen diameter (μm)	Double fibre wall thickness (μm)	Fibre (%)	Conducting cells (%)	Parenchyma (%)
Calamus deeratus							
Base	2.16 ± 0.02^{a}	18.69 ± 0.17^{a}	7.91 ± 0.13^{a}	10.79 ± 0.12^{a}	29 ± 1.53^{a}	27 ± 1.29^{a}	44 ± 2.45^{a}
Middle	1.96 ± 0.02^{b}	17.56 ± 0.15^{b}	9.24 ± 0.14^{b}	8.33 ± 0.10^{b}	19 ± 1.36^{b}	32 ± 1.10^{a}	48 ± 1.64^{a}
Top	1.69 ± 0.02^{c}	17.41 ± 0.16^{b}	9.88 ± 0.15^{c}	7.53 ± 0.09^{c}	20 ± 1.53^{b}	32 ± 1.40^{a}	48 ± 1.47^{a}
Mean	1.94 ± 0.01^{a}	17.89 ± 0.05^{a}	9.01 ± 0.08^{a}	8.88 ± 0.07^{a}	23 ± 1.08^{a}	30 ± 0.81^{a}	47 ± 1.12^{a}
n	2250	2250	2250	2250	45	45	45
Eremospatha dransfieldii							
Base	1.66 ± 0.03^{a}	21.41 ± 0.32^{a}	7.67 ± 0.28^{a}	13.75 ± 0.28^{a}	32 ± 4.77^{a}	38 ± 2.96^{a}	30 ± 3.22^{a}
Middle	1.56 ± 0.02^{b}	21.83 ± 0.34^{a}	11.79 ± 0.40^{b}	10.05 ± 0.26^{b}	$22 \pm 4.48^{a,b}$	41 ± 3.10^{a}	36 ± 3.27^{a}
Top	1.47 ± 0.02^{c}	23.35 ± 0.41^{a}	16.79 ± 0.43^{c}	6.56 ± 0.13^{c}	14 ± 1.62^{b}	40 ± 1.74^{b}	46 ± 2.01^{b}
Mean	1.57 ± 0.01^{b}	22.20 ± 0.21^{b}	12.08 ± 0.26^{b}	10.12 ± 0.17^{b}	23 ± 2.89^{a}	40 ± 1.49^{b}	37 ± 2.32^{b}
n	750	750	750	750	15	15	15
Eremospatha macrocarpa							
Base	1.26 ± 0.01^{a}	20.09 ± 0.19^{a}	8.09 ± 0.15^{a}	12.00 ± 0.13^{a}	34 ± 2.65^{a}	36 ± 1.33^{a}	31 ± 1.98^{a}
Middle	1.34 ± 0.01^{b}	19.41 ± 0.20^{b}	10.26 ± 0.18^{b}	9.16 ± 0.12^{b}	27 ± 2.16^{b}	42 ± 1.23^{a}	31 ± 1.89^{a}
Top	1.34 ± 0.01^{b}	20.28 ± 0.22^{a}	12.48 ± 0.22^{c}	7.80 ± 0.10^{c}	18 ± 2.10^{c}	43 ± 1.36^{b}	39 ± 2.38^{b}
Mean	1.32 ± 0.06^{c}	19.93 ± 0.12^{c}	10.27 ± 0.11^{c}	9.65 ± 0.10^{c}	$26 \pm 1.60^{a,b}$	40 ± 0.88^{b}	34 ± 1.31^{b}
n	2250	2250	2250	2250	45	45	45
Laccosperma acutiflorum							
Base	2.62 ± 0.05^{a}	19.12 ± 0.32^{a}	4.01 ± 0.18^{a}	15.11 ± 0.36^{a}	35 ± 1.62^{a}	23 ± 1.87^{a}	42 ± 1.78^{a}
Middle	2.44 ± 0.04^{b}	17.64 ± 0.25^{b}	5.71 ± 0.28^{b}	11.93 ± 0.26^{b}	29 ± 1.70^{b}	23 ± 1.90^{a}	48 ± 1.93^{a}
Top	2.14 ± 0.04^{c}	17.32 ± 0.24^{b}	6.49 ± 0.28^{c}	10.83 ± 0.26^{c}	27 ± 1.70^{b}	26 ± 2.09^{a}	47 ± 3.10^{a}
Mean	2.40 ± 0.03^{d}	18.03 ± 0.16^{a}	5.40 ± 0.15^{d}	12.63 ± 0.18^{d}	30 ± 1.31^{b}	24 ± 1.10^{a}	46 ± 1.44^{a}
n	75	750	750	750	15	15	15

Table 2.
(Continued)

Species and position	Anatomical features						
	Fibre length (mm)	Fibre width (μm)	Fibre lumen diameter (μm)	Double fibre wall thickness (μm)	Fibre (%)	Conducting cells (%)	Parenchyma (%)
Laccosperma secundiflorum							
Base	2.92 ± 0.03^{a}	21.26 ± 0.21^{a}	5.51 ± 0.15^{a}	15.75 ± 0.23^{a}	35 ± 1.88^{a}	20 ± 1.03^{a}	46 ± 2.04^{a}
Middle	2.91 ± 0.03^{a}	18.39 ± 0.16^{b}	6.34 ± 0.17^{b}	12.05 ± 0.16^{b}	29 ± 1.88^{b}	$23 \pm 1.40^{a,b}$	$48 \pm 1.96^{a,b}$
Top	2.58 ± 0.03^{b}	17.37 ± 0.15^{c}	7.90 ± 0.17^{c}	9.47 ± 0.15^{c}	23 ± 1.34^{c}	25 ± 1.34^{b}	51 ± 1.33^{b}
Mean	2.80 ± 0.02^{e}	19.01 ± 0.11^{d}	6.58 ± 0.10^{e}	12.42 ± 0.12^{d}	29 ± 1.19^{b}	23 ± 0.79^{a}	48 ± 1.08^{a}
n	2250	2250	2250	2250	45	45	45

Values followed by the same letter in the same column for a species are not significantly different ($P > 0.05$); means (for species) followed by the same letter in the same column are not significantly different ($P > 0.05$); n = total number of observations for mean determination.

Table 3.
Comparison of physical properties of five rattan species

Species and position	Physical properties			
	Internode length (cm)	Internode diameter (mm)	Moisture content (%)	Relative density ($\times 10^{-2}$)
Calamus deeratus				
Base	$34 \pm 1.1^{a,b}$	11 ± 0.3^{a}	112 ± 7.9^{a}	45 ± 1.8^{a}
Middle	41 ± 3.8^{a}	15 ± 0.8^{b}	179 ± 12.3	34 ± 1.6^{b}
Top	29 ± 2.9^{b}	16 ± 0.6^{b}	186 ± 12.3^{b}	32 ± 1.7^{b}
Mean	35 ± 1.8^{a}	14 ± 0.5^{a}	159 ± 7.9^{a}	37 ± 1.3^{a}
Eremospatha dransfieldii				
Base	18 ± 1.2^{a}	11 ± 1.0^{a}	84 ± 14.9^{a}	44 ± 3.2^{a}
Middle	35 ± 3.4^{a}	$15 \pm 1.9^{a,b}$	$161 \pm 35.8^{a,b}$	$36 \pm 5.9^{a,b}$
Top	20 ± 3.1^{a}	17 ± 1.9^{b}	225 ± 32.7^{b}	28 ± 2.4^{b}
Mean	24 ± 2.4^{b}	14 ± 1.1^{a}	$157 \pm 21.9^{a,c}$	36 ± 2.8^{a}
Eremospatha macrocarpa				
Base	28 ± 2.1^{a}	11 ± 0.5^{a}	72 ± 3.4^{a}	53 ± 1.8^{a}
Middle	33 ± 2.4^{a}	11 ± 0.5^{a}	113 ± 8.7^{b}	42 ± 1.8^{b}
Top	22 ± 1.5^{b}	14 ± 0.7^{b}	144 ± 11.1^{c}	37 ± 2.2^{c}
Mean	27 ± 1.3^{b}	12 ± 0.4^{b}	110 ± 6.5^{b}	44 ± 1.5^{b}
Laccosperma acutiflorum				
Base	25 ± 6.4^{a}	29 ± 1.2^{a}	90 ± 14.7^{a}	52 ± 5.2^{a}
Middle	30 ± 3.9^{a}	28 ± 1.0^{a}	111 ± 7.8^{a}	38 ± 0.8^{b}
Top	24 ± 2.2^{a}	28 ± 2.7^{a}	152 ± 13.5^{b}	33 ± 1.9^{b}
Mean	27 ± 2.5^{b}	28 ± 1.0^{c}	$118 \pm 9.6^{b,c}$	$41 \pm 2.8^{a,b}$
Laccosperma secundiflorum				
Base	22 ± 2.0^{a}	27 ± 0.7^{a}	105 ± 7.9^{a}	51 ± 2.2^{a}
Middle	33 ± 3.4^{b}	25 ± 1.0^{a}	148 ± 9.9^{b}	38 ± 1.7^{b}
Top	25 ± 1.8^{a}	28 ± 1.0^{a}	217 ± 20.4^{c}	31 ± 2.3^{c}
Mean	27 ± 1.6^{b}	26 ± 0.5^{d}	156 ± 10.5^{a}	$40 \pm 1.7^{a,b}$

Values followed by the same letter in the same column for a species are not significantly different ($P > 0.05$). Means (for species) followed by the same letter in the same column are not significantly different ($P > 0.05$).

E. macrocarpa which had larger internode diameter at the top than the middle and base.

Stem initial moisture content and relative density. Mean initial moisture content varied significantly with species and position. It varied from 110% in *E. macrocarpa* to 159% in *C. deeratus* (Table 3). The results obtained in this study for *C. deeratus* and *L. secundiflorum* conforms to values obtained by Lucas and Dahunsi [28] for the same species from Nigeria except *E. macrocarpa*. The difference in values for *E. macrocarpa* might be due to differences in methodology. Mean initial

moisture content increased consistently from basal to top internodes for all species investigated (Table 3). Bhat [34] reported similar observations in some India rattans.

Generally mean relative density differed significantly with species. Relative density of species varied from 0.37 in *C. deeratus* to 0.44 in *E. macrocarpa* (Table 3). Although mean relatively density of *C. deeratus*, *E. dransfieldii*, *L. acutiflorum* and *L. secundiflorum* differed, the differences were not statistically significant. Also, the differences between mean relative density of *E. macrocarpa*, *L. acutiflorum* and *L. secundiflorum* were not statistically significant (Table 3). With regards to position, mean relative density of all species decreased consistently from basal to top internodes. The differences between the middle and top internodes were often less than those between the basal and middle internodes of the stem (Table 3). This trend was consistent with the density distribution in some other rattans observed by Abasolo *et al*. [25].

Anatomical and physical properties relating to stem quality

Fibre lumen diameter had a significant positive correlation with moisture content in all species investigated ($P < 0.05$). In contrast double fibre wall thickness and proportion of fibres had a significant negative correlation with moisture content in all species studied ($P < 0.05$), except *L. acutiflorum,* which exhibited an insignificant ($P > 0.05$) negative correlation between proportion of fibres and moisture content (Table 4). This means that as fibre lumen diameter increased from basal to top internodes there was a corresponding increase in moisture content in all species studied. Likewise, as double fibre wall thickness and proportion of fibres decreased from basal to top internodes, there was a corresponding increase in moisture content.

There was a significant negative correlation between fibre lumen diameter and relative density in all five species ($P < 0.05$). Also, double fibre wall thickness and

Table 4.
Regression analysis

Species	Parameter	Fiber lumen	Double wall thickness	Fiber proportion
C. deeratus	Moisture content	0.623*	−0.75*	−0.385*
	Relative density	−0.662*	0.829*	0.435*
E. dransfieldii	Moisture content	0.928*	−0.923*	−0.721*
	Relative density	−0.906*	0.921*	0.812*
E. macrocarpa	Moisture content	0.834*	−0.850*	−0.482*
	Relative density	−0.812*	0.828*	0.563*
L. acutiflorum	Moisture content	0.838*	−0.727*	−0.352^{ns}
	Relative density	−0.868*	0.873*	0.561*
L. secundiflorum	Moisture content	0.817*	−0.828*	−0.484*
	Relative density	−0.813*	0.912*	0.565*

* Significant ($P < 0.05$); ns = not significant ($P > 0.05$).

proportion of fibres showed a significant positive correlation with relative density in all species investigated ($P < 0.05$, Table 4). This implies that as fibre lumen diameter increased from basal to top internodes of all the species there was a proportional decrease in relative density.

On the other hand, as double fibre wall thickness and proportion of fibre decreased from basal to top internodes in all species investigated, there was a corresponding decrease in relative density. Bhat and Verghese [35, 36] reported of similar relationships when they identified that rattan density along the stem (base to top) was highly affected by proportion of fibres, fibre wall thickness, fibre lumen diameter ratio and metaxylem vessel diameter. Bhat *et al*. [10] and Abasolo *et al*. [25] also observed that proportions of fibres and fibre wall thickness were the most important parameters that influence density along the stem (base to top) of rattans. The presence of higher proportion of fibres with narrower fibre lumen diameter and thicker walled fibres may explain why the basal part of rattan stem is too hard to work with tools. Likewise, the top portion of even very old stems of rattans may break easily due to a lower proportion of fibres, wider fibre lumen diameter and thin walled fibres. Hence, shorter internodes which occur at the basal and top portions of rattan stems (Table 3) may be considered to be inferior in quality to longer internodes which occur in the middle portion and characterized by fibre proportion, fibre wall thickness and fibre lumen diameter which are intermediate between basal and top internodes. This may explain why rattan processors in Ghana use internode length as a criterion for determining quality of stems within the same species [6].

Comparison of the anatomical properties of the five rattan species to anatomical properties of 433 commercial rattan species [22], suggests that *E. dransfieldii* and *E. macrocarpa* exhibit commercial properties more than *C. deeratus* and *Laccosperma* spp. (Table 5). This may be the reason why processors in Ghana prefer *Eremospatha* spp. to *Calamus deeratus* and *Laccosperma* spp. [6]. Comparing *E. dransfieldii* and *E. macrocarpa*, the latter seems to have more preferred properties of a commercial rattan [22]. In addition, *E. macrocarpa* had the highest mean relative density value and lowest moisture content (Table 3). This implies that *E. macrocarpa* seem to possess better strength and may remain dimensionally more stable when in use than the other four species. Recent studies by Lucas and Dahunsi [28] on *C. deeratus*, *E. macrocarpa* and *L. secundiflorum* from Nigeria revealed that *E. macrocarpa* had the lowest shrinkage values. Although, the *Laccosperma* spp. appear to have less properties of a commercial rattan [22], their relatively high mean relative density (Table 3) which may be due to high proportion of fibres, thick-walled fibres with narrow lumen diameter (Table 2) and larger internode diameter (Table 3) suggest to make them stiffer and more rigid than *C. deeratus* and *Eremospatha* spp. This may explain why they are used as frames in chair legs, arms and table legs, etc. [6].

However, the relative higher moisture content of *Laccosperma* spp. (Table 3) coupled with their non-uniform distribution of vascular bundles (Figs 5 and 6) may promote warping, checking and splitting, especially at the middle and top

Table 5.
Comparison of some anatomical properties of commercial rattan species with five rattan species of Ghana

Rattan species	Anatomical properties						
	Distribution of vascular bundles	Fibre (%)	Conducting tissue (%)	Ground parenchyma (%)	Size of fibre cap/sheath	Structure of fibre wall	Size of ground parenchyma cells
Commercial rattan (Weiner and Liese, 1991)	Uniform	20–25	45	30–35	Equal	Polylamellate	Small
C. deeratus	Non-uniform	23	30	47	Unequal	Polylamellate	Large
E. dransfieldii	Uniform	23	40	37	Equal	Polylamellate	Small–large
E. macrocarpa	Uniform	26	40	34	Equal	Polylamellate	Small
L. acutiflorum	Non-uniform	30	24	46	Unequal	Polylamellate	Large
L. secundiflorum	Non-uniform	29	23	48	Unequal	Polylamellate	Large

internodes, when subjected to irregular or rapid drying. These defects have been observed by Lucas and Dahunis [28] on *L. secundiflorum* from Nigeria. The relatively higher moisture content, the low relative density (Table 3) due to lower proportion of fibres with relatively larger fibre lumen and thin-walled fibres (Table 2), the non-uniform distribution of vascular bundles (Fig. 2) and the high proportion of thin-walled parenchyma of *C. deeratus* place it further away from a commercial rattan. This may explain why *C. deeratus* is the least preferred commercial rattan species in Ghana because it breaks easily [6].

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be drawn from the study:

1. Fibre lumen diameter, double fibre wall thickness and proportion of fibres exhibited more definite pattern of variations within and between all the five species than other anatomical properties. Generally, proportion of fibre and double fibre wall thickness decreased, whereas fibre lumen diameter increased from basal to top internodes.
2. Initial moisture content increased consistently from basal to top internodes whilst relative density decreased from basal to top internodes.
3. Simple regression analysis of physical properties on anatomical properties revealed that fibre lumen diameter, double fibre wall thickness and proportion of fibre are important parameters likely to influence initial moisture content and relative density along the stems and between all species investigated.
4. Amongst the five rattan species investigated *E. macrocarpa* exhibited the most favourable anatomical and physical properties in terms of utilization because it had vascular bundles of uniform size with equal fibre sheath, which are evenly distributed across a section of the stem. In addition, it had the highest mean relative density value and lowest moisture content, implying that *E. macrocarpa* seem to possess better strength properties and will remain dimensionally more stable when in use than the other four species.

In the light of these observations the following recommendations are suggested:

1. Further investigations on the anatomical and physical properties of known age of rattans should be undertaken to confirm these findings.
2. Other technological properties (mechanical, chemical) of *C. deeratus*, *E. dransfieldii*, *E. macrocarpa*, *L. acutiflorum* and *L. secundiflorum* should be investigated with the aim of developing appropriate processing techniques to aid in diversification of their end-uses.
3. During processing and utilization of rattans, position of stem and species type should be considered to ensure uniformity of products.
4. The technological properties of *Laccosperma leave* which is currently not being utilized in Ghana should be undertaken to assess its utilization potential.

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