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RESEARCH ARTICLE

Anatomical and physical properties of *Bambusa mizorameana* Naithani

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Abstract

The present investigation was made in 3 years old culms of *Bambusa mizorameana* to evaluate anatomical and physical properties across and along the culm. There was decrease in vascular bundle frequency per mm^2 from bottom to top. Vascular bundles were larger in middle zone at all height positions. Along culm height, Type IV vascular bundles were present in middle zone of bottom and middle positions while Type III vascular bundles in middle zone of top position. The metaxylem vessel diameter decreased significantly from inner to outer zone across the culm. A non-significant variation in metaxylem vessel diameter was observed along culm height. Across the culm, fibre length varied significantly at bottom position only. Fibres were longer in middle zone across the culm at all height positions. Middle position had the longest fibres among all height positions. There was non-significant variation in fibre wall thickness both along and across the culm. Physical properties like specific gravity, moisture content, shrinkage in culm diameter and wall thickness decreased significantly from base to top in this species.

INTRODUCTION

India is one of the largest bamboo producing country in the world with 25 genera and ±130 species (Anon, 2010). The north-eastern region of India is considered as "Bamboo Paradise of India" and harbours 43% of total bamboo wealth of India (Madhab, 2003). Manipur, one of eight sisters of NE India is rich in bamboo species due to varied climatic conditions. There are about 10 genera and 35 species of bamboos growing in plains and hills of Manipur (Naithani, 2008; Anon, 2010). Recently, 15 genera and 45 species of bamboos are reported from this state. Bambusa is one of the most important genus having 13 species and one variety (Rajkumari and Gupta, 2013). Of these, *B. mizorameana* is endemic to both Manipur and Mizoram. It is known by its local name 'Khokwa' and 'Talan' in Manipuri and mizo dialects (Anon, 2010; Naithani, 2009). The word Khokwa consists of two words namely 'Khok' means handle and 'wa' means bamboo. It is widely used for making handles of agricultural implements, baskets and also as constructional material.

A perusal of literature reveals that physical and anatomical characteristics of bamboos can be used to determine its suitability for possible utilization as these are known to have significant effects on strength and durability (Liese, 1985; Latif and Tamizi, 1992; Wahab et al., 2010). Being a new species recorded from Manipur, there is no information on anatomical and physical properties of *B. mizorameana* so far. The present study is an attempt to investigate anatomical and physical properties of this species across and along the culm. The evaluation of these characteristics may be helpful to generate data for various end uses of this species.

Material and methods

Sample collection

The samples were collected from the area of Bamon Kampu Mathak Leikai located in foothills of Imphal-East district of Manipur (Fig.1). The geographical co-ordinates of the selected site are 24°46' N 93°59' E. Five matured culms of 3 years having more or less similar diameter were randomly selected and harvested 30 cm above the ground. All the physical characteristics like culm height, culm diameter, internode length, culm wall thickness at various heights were measured in green condition at the time of felling (Table1). The culms were then converted into three portions according to the height (bottom, middle and top) leaving the top lofty branches. The cut ends were painted to minimize sap evaporation. They were then brought to the laboratory for further processing and preservation.

Determination of anatomical characteristics

Samples from middle of internodes from each height were cut into 1cm×1cm×culm wall thickness and preserved in FAA solution for 24 hrs. and then in 70% alcohol. The samples were boiled in water for 4-6 hrs. and 25-30 µm sections were cut with the help of a sliding microtome. Permanent slides were made by following standard method. Number of vascular bundles per mm^2, their radial and tangential diameters were measured at 40 X along the culm height and across the culm wall from cross-sections. Types of vascular bundles were classified according to classification of vascular bundles given by Grosser and Liese (1971). 10 fields from each zone (inner, middle and outer) at different height positions were selected to study these parameters.

Match stick size of bamboo splints were taken from each zone at different height positions. These were macerated with Franklin's solution to measure dimensions of fibres and vessels. A total of 50 fibres and 30 vessels were measured randomly from each zone. Length of fibres and vessels was taken at 40X and other dimensions like fibre diameter, fibre wall thickness and vessel diameter were taken at 400 X.

Determination of physical properties

Blocks of 2.5cm×1cm×culm wall thickness were taken from middle portion of internodes at different heights (bottom, middle, top) to determine moisture content and specific gravity. Moisture content was determined by following Indian standard method (1973). For specific gravity, water displacement method was followed. A total of 10 replicates (10×3) were taken at each height position for each culm.

The shrinkage in wall thickness was determined at four perpendicular positions to each other and diameter shrinkage was measured along two diameters perpendicular to each other with digital calliper according to Kamruzzaman et al. (2008). The percentage shrinkage in wall thickness and diameter were calculated by formula given by Panshin and deZeeuw (1980).

Statistical analyses were performed by using SPSS 16.0 software.

Results and Discussion

The cross-section of culm at different positions (bottom, middle and top) along the culm height showed that numbers of vascular bundles were embedded in parenchymatous tissue like other bamboo species. The innermost 4-5 layers of culm lining the cavity were made of radially flattened parenchyma cells whereas rest of layers of parenchyma cells have round shaped cells. There was variation in number, size and types of vascular bundles along and across the culm (Fig.3). The culm was divided into three zones namely inner, middle and outer across the culm. At all height positions, the inner zone of culm had Type III vascular bundles. Some of vascular bundles were inverted in this zone. The middle zone had Type IV bundles in bottom and middle positions while top position had Type III bundles in this zone (Fig.4). The vascular bundles were smaller, more or less ellipsoid shape in outer zone. The sclerenchymatous sheath of phloem was fused with fibrous strand in this zone. The outermost layers of vascular bundles were circular in shape with one or two metaxylem vessels and few phloem cells. The number of vascular

bundles per mm^2 was one in inner and middle zones at all height positions. But, the number varied from bottom to top in outer zone (Fig. 5).The decrease in number of vascular bundles per mm^2 along the culm height might be due to decrease in culm wall thickness. The present results are contrary to the findings of Maya et al. (2013) and Wahab et al. (2006, 2010) who report uniform vascular bundles frequency from bottom to top of culm in other bamboo species.

Ratio of radial diameter/ tangential diameter (R/T) was taken to measure vascular bundle size of this species. A perusal of literature reveals increase in this ratio from inner to outer zone in bamboo species like *Fargesia yunnanensis* (Wang et al., 2011), *Bambusa rigida* (Xing et al., 2015). On the other hand, Mustafa et al. (2011) measure length and width of vascular bundles separately in *Gigantochloa species* and report longest vascular bundles in middle zone and widest vascular bundles in inner zone. In the present study, R/ T ratio was maximum in middle zone at all height positions (Fig. 6) which might be due to higher radial diameter of vascular bundles in this zone. The present result is in agreement with the findings of Lõndõno et al. (2002). Along the culm height, there was decrease in R/T ratio from base to top and corroborates the findings of Latif and Tamizi (1992), Liese (1998), Lõndõno et al. (2002) and Xing et al. (2015).

Determination of tissue proportion at different height positions is an important parameter for characterization of any bamboo species. According to Liese (1998), *Bambusa polymorpha* and *B. tulda* have 44-45% fibres, 47-48% parenchyma and 8% conducting tissue. The selected species had higher percentage of fibres and low percentage of parenchyma than these species (Fig.7). The percentage of fibres increased from bottom to top, while percentage of parenchyma decreased from bottom to top. Condensation of vascular bundles due to decrease in culm wall thickness at top position might be attributed to increase in fibre and decrease in parenchyma percentage.
The results in Table 2 showed that vessel diameter decreased significantly from inner to outer zone across the culm wall. There was non-significant variation in vessel diameter along culm height. The largest vessel diameter in inner and middle zones might be due to main conduction of water through these zones in bamboos and is supported by the findings of other workers (Liese, 1985; Wang et al., 2011 and Xing et al., 2015).

The fibres are present in the form of sclerenchymatous sheath around the vessels and isolated strands (Grosser and Liese, 1971). The fibres are long and slender with pointed ends. Duncan multiple range test showed significant variation in fibre length at bottom position and non-significant variation at middle and top positions across the culm wall. It increased from bottom to middle and then decreased towards top along culm height (Table 2). The present study is in agreement with the findings of Wang et al. (2011, 2012). There was significant variation in fibre diameter at bottom and top positions across culm wall. While, non-significant variation existed in fibre wall thickness both across culm wall and along culm height (Table 2). The present results are comparable to other *Bambusa* species (Xing et al., 2015).

Moisture content, specific gravity, shrinkage in culm diameter and wall thickness are important physical properties of bamboos. The moisture content of this species was significantly higher at bottom and decreases significantly from base to top along the culm height (Table 3). The present result is in agreement with the findings of other researchers (Sattar et al., 1990; Kamruzzaman et al. 2008; Kamthai and Puthson, 2005). The decrease in moisture content along the culm height might be associated with structural and chemical composition of bamboos (Liese, 1985). Likewise, specific gravity also decreased significantly from base to top (Table 3). Since number of vascular bundles per mm^2, fibre percentage and fibre wall thickness were higher at bottom position, therefore, these parameters may be the probable reason for increase in specific gravity at this position. This finding is in agreement with the results of Gnanaharan et al. (1995) and Kamruzzaman et al. (2008). Sattar et al. (1994) and Kamruzzaman et al. (2008) reported maximum proportion of shrinkage in culm diameter and wall thickness at bottom and minimum at top position in *B. balcoa, B. tulda* and *B. salarkhanii*. Similar results are obtained for the present study (Table 3). Since parenchyma cells are site for water storage in bamboos, therefore, decrease in shrinkage in culm diameter and wall thickness from bottom to top may be due to reduction in size and percentage of parenchyma cells with tapering of culm.

Table 1. Physical characteristics of *Bambusa mizorameana*

Culm height (cm)	990.60-1158.20 (1051.55±92.62)	
No. of internodes	19-22 (20.00±1.73)	
Internode length (cm)	Position	Range (Mean± S. D.)
	Bottom	30.25-32.0 (31.08±0.88)
	Middle	59.75-77.5 (65.80±10.13)
	Top	47.75-49.0 (48.42±0.63)
	Mean	45.58-52.67 (48.07±3.99)
Internode diameter (cm)	Bottom	13.50-14.75 (13.92±0.72)
	Middle	11.85-14.25 (12.82±1.27)
	Top	10.75-12.5 (11.58±0.88)
	Mean	12.28-13.42 (12.77±0.59)
Culm wall thickness (cm)	Bottom	1.36-1.66 (1.51±0.15)
	Middle	0.77-0.89 (0.62±0.86)
	Top	0.51-0.69 (0.62±0.10)
	Mean	0.93-1.05 (0.98±0.06)

Fig.1. Clump of *B. mizorameana* showing culm sheath (A), clump with leaves (B) and without leaves (C)

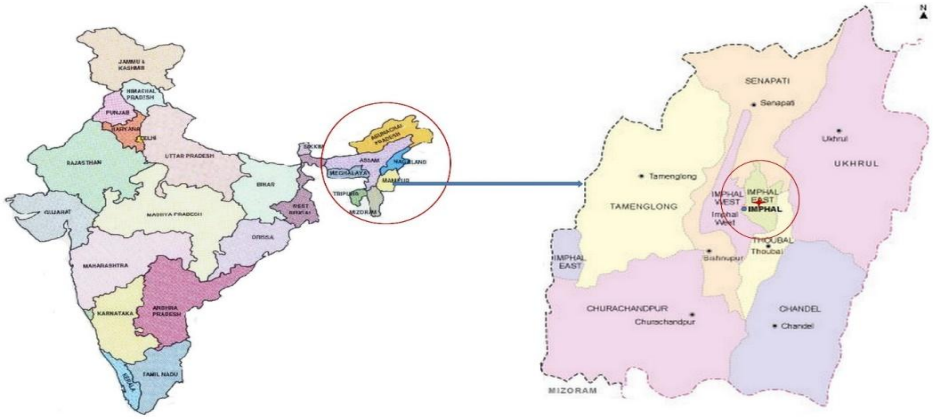

Fig. 2. Map showing selected study site

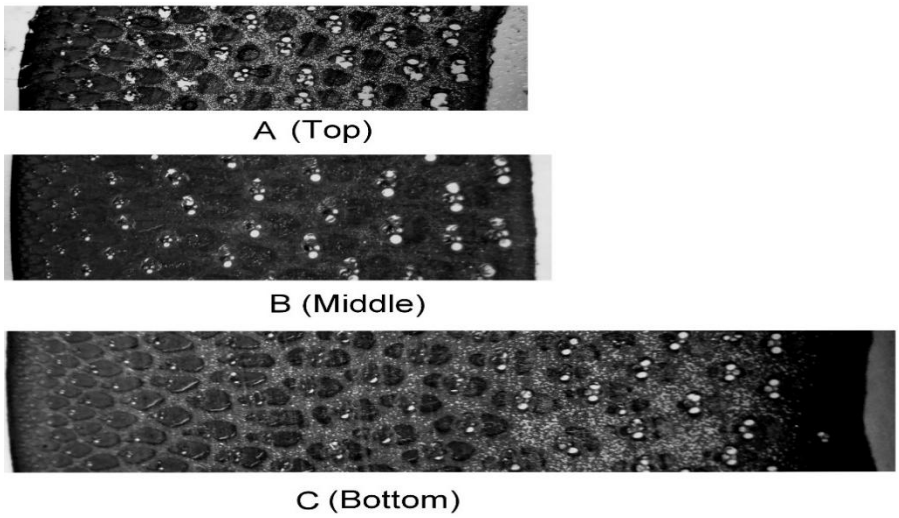

Fig. 3 (A-C). C. S. of culm at different height positions showing types and arrangement of vascular bundle

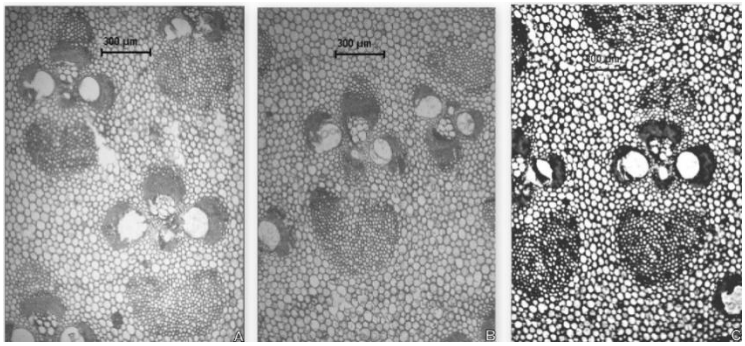

Fig. 4. (A-C). C. S. of culm showing Type III vascular bundle (A and B) inverted vascular bundle (B) and Type IV vascular bundles (A and C).

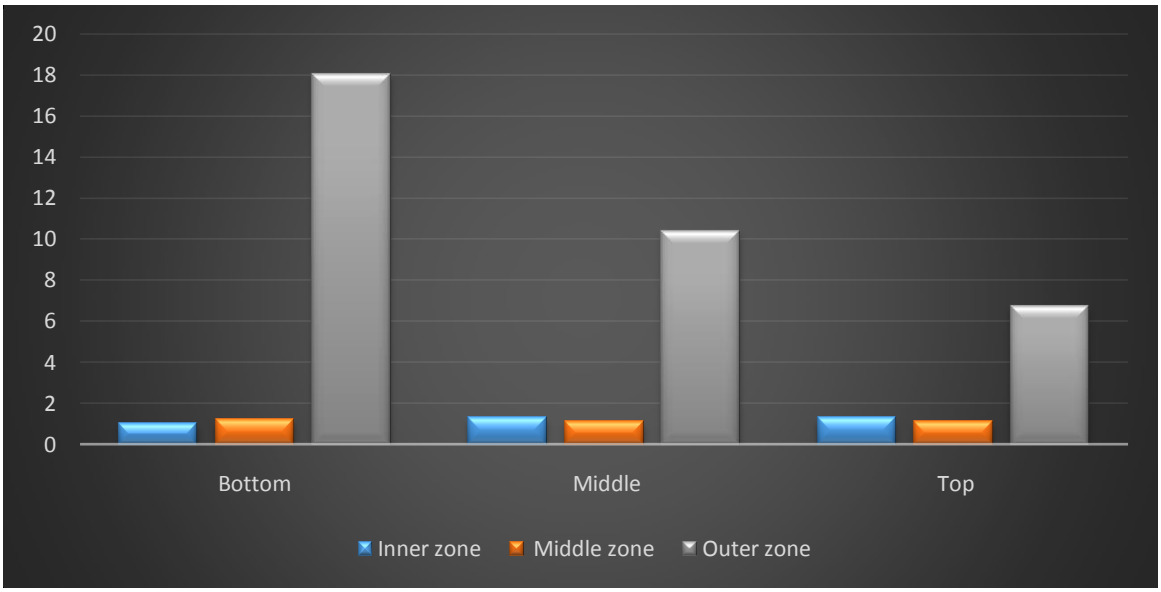

Fig. 5. Number of vascular bundles along and across the culm in *B. mizorameana*

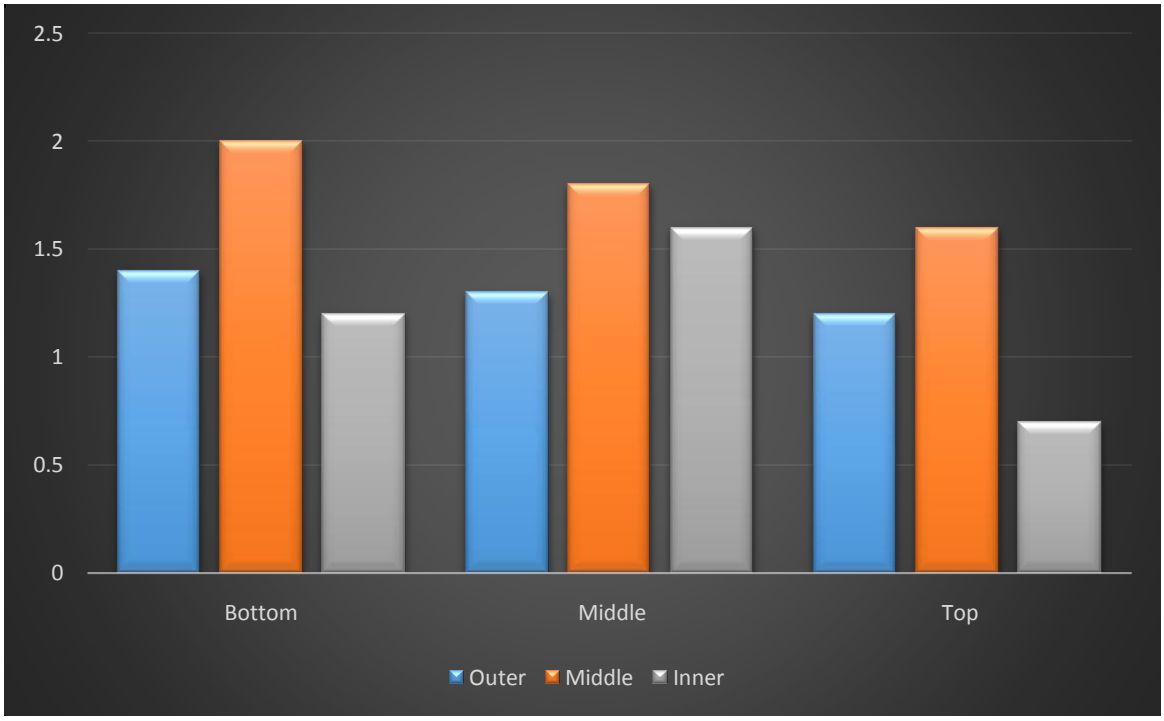

Fig. 6. Size (R/T ratio) of vascular bundles along and across the culm in *B. mizorameana*

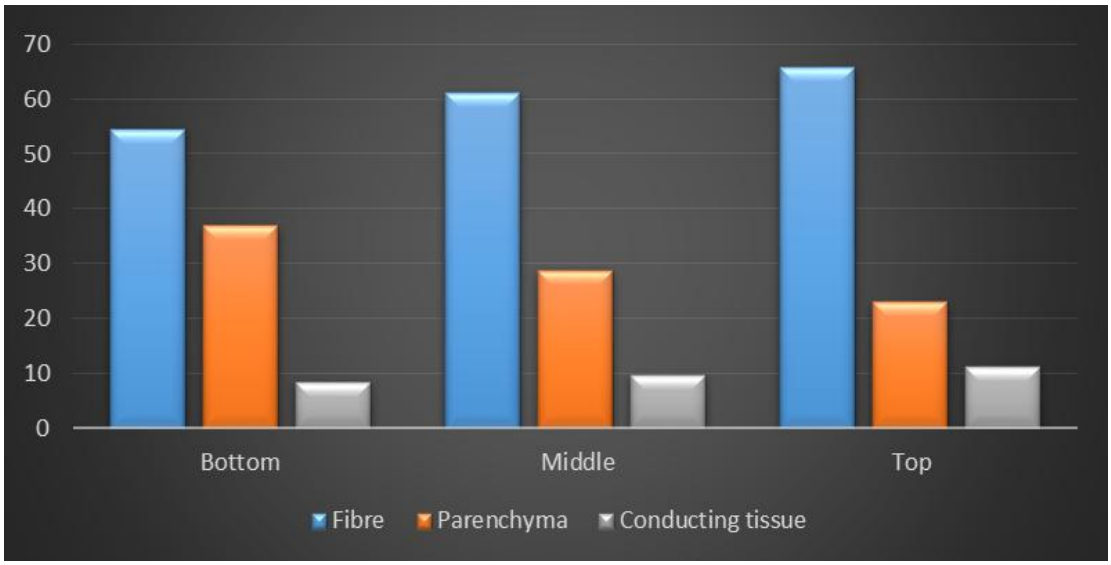

Fig. 7. Tissue Proportion at different positions along culm in *B. mizorameana*

Table 2: Anatomical properties of *Bambusa mizorameana*

Positions	Zone	Fibre length (µm)	Fibre diameter (µm)	Fibre wall thickness (µm)	Vessel length (µm)	Vessel diameter (µm)
Bottom	Outer	3586.23±95.51^{b}	18.67±1.58^{a}	7.50±0.80^{a}	839.55±19.02^{a}	118.79±16.81^{a}
	Middle	3350.29±238.82^{b}	20.51±1.99^{ab}	7.12±1.13^{a}	950.12±41.69^{ab}	182.76±13.75^{b}
	Inner	3016.19±239.25^{a}	21.23±0.78^{b}	7.29±0.27^{a}	867.89±48.52^{b}	202.42±10.78^{c}
Middle	Outer	4323.00±227.07^{a}	20.87±3.09^{a}	8.55±1.17^{a}	886.78±46.58^{a}	94.58±6.85^{a}
	Middle	4211.29±167.80^{a}	22.24±2.21^{a}	8.55±1.02^{a}	1155.70±31.46^{b}	164.72±9.34^{b}
	Inner	4249.95±105.76^{a}	22.12±3.04^{a}	7.95±1.02^{a}	1211.50±50.02^{c}	245.27±14.12^{c}
Top	Outer	3754.40±116.86^{a}	17.52±1.33^{a}	7.01±0.70^{a}	804.55±44.16^{a}	87.97±6.27^{a}
	Middle	3853.80±103.35^{a}	18.91±9.27$^{a\ b}$	6.65±0.79^{a}	1111.20±70.87^{ab}	183.95±10.83^{b}
	Inner	3809±110.07^{a}	19.22±0.99^{b}	6.71±0.60^{a}	1146.63±49.41^{b}	237.79±5.31^{c}

Values with same letter in the same row are not significantly different at 0.05 probability level

Table 3: Physical properties of *Bambusa mizorameana*

Height	Specific gravity	Moisture Content (%)	Shrinkage (%)	
			Culm Diameter	Wall Thickness
Bottom	0.66 ± 0.08^{c}	114.71 ± 20.4^{b}	9.22 ± 0.79^{b}	12.31 ± 1.07^{b}
Middle	0.61 ± 0.03^{b}	93.73 ± 14.75^{a}	8.88 ±0.72^{ab}	11.56 ± 1.36^{b}
Top	0.58 ± 0.04^{a}	90.55 ± 15.29^{a}	8.21 ± 0.94^{a}	10.21 ± 1.10^{a}

Values with same letter in the same row are not significantly different at 0.05 probability level

Conclusions

The present study on anatomical and physical properties of *B. mizorameana* shows that Type IV vascular bundles are present in middle zone at bottom and middle positions. Hence, this character may be used for identification of this species. Also, vascular bundles are larger in middle zone than outer and inner zones at all height positions. The size and number of vascular bundles decrease from base to top of culm. Across the culm wall, anatomical characteristics like vessel diameter, fibre length and fibre diameter show significant variation among inner, middle

and outer zones. Along culm height, vessel diameter and fibre wall thickness vary non-significantly from bottom to top. Physical properties namely specific gravity, moisture content, shrinkage in culm diameter and wall thickness show significant decrease from bottom to top along culm height.

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