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Evaluation of Physical Properties of Some Selected *Bambusa* Species of Manipur

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ABSTRACT

Background: *Bambusa* is one of the three largest genera of bamboo found in India. Physical properties have direct influence on mechanical properties of bamboo. This study was conducted to investigate the physical properties *viz.* moisture content, specific gravity, water absorption and dimensional shrinkage of some selected *Bambusa* species of Manipur in order to find their suitability for various end uses.

Methods: The culms were harvested at 30 cm above ground level. Each culm was divided into bottom, middle and top positions. Moisture content, specific gravity and dimensional shrinkage percentage were determined using Indian Standard Method IS 6874 (2008) while ASTM D 1034-72 method was used for water absorption test.

Result: Moisture content and water absorption decreased with the increase in culm height whereas specific gravity increased from bottom towards the top portion in all selected eight *Bambusa* species. Dimensional shrinkage percentages exhibited an irregular pattern. Radial and tangential shrinkages were higher than longitudinal shrinkage. Analysis of variance of the physical properties among the *Bambusa* species exhibited significant variations at all height positions. *B. kingiana* is the most desirable among the selected *Bambusa* species due to comparatively higher specific gravity and low moisture content, water absorption capacity, dimensional shrinkage and T/R ratio.

Key words: *Bambusa*, Density, Moisture content, Shrinkage, Water absorption.

INTRODUCTION

Bamboo is one of the most important Non Timber Forest Products of India and is the best substitute of wood these days due to depletion of wood resources. Bamboos belong to family Poaceae and subfamily Bambusoideae (Zakikhani *et al.*, 2017). They grow luxuriantly in the tropical and subtropical regions of the world except Europe and Antarctica. As compared to wood, it has fast growth, easy to propagate and has higher tensile strength. They are commonly exploited for multipurpose uses such as scaffoldings, basketry, handicrafts, furniture, cutlery, *etc*. (Chaowana, 2013).

Physical properties are known to determine the strength and desirability of bamboos. Mechanical characteristics of a bamboo are directly proportional to its physical properties. Few authors have worked on the physical properties of some *Bambusa* species. Kamruzzaman *et al.* (2008) studied moisture content, density and shrinkage of different ages of *Bambusa balcooa*, *B. tulda* and *B. salarkhanii* at different height positions. Kumar *et al.* (2015) also studied the above physical properties such as moisture content, specific gravity and dimensional shrinkage of *Bambusa mizorameana* along and across the culm height. Abdullah *et al*. (2017) examined the density and its relation to morphology and macro structures *viz.* vascular bundle and parenchyma of *Bambusa vulgaris* Schrad var. Vittata. Krishnakumar *et al.* (2017) analyzed and compared the moisture content, basic and bulk density of *Bambusa balcooa* and *Bambusa vulgaris* harvested from five agro-climatic regions of Tamil Nadu, India. Nordahlia *et al*. (2019) investigated the density and shrinkage of *B. blumeana*, *B. heterostachya*, *B. vulgaris* and *B. vulgaris* cv. Vittata along culm height for determining their suitability for end uses.

A total of 125 indigenous and 11 exotic species under 23 genera of bamboos are reportedly spread in the deciduous and semi-evergreen forests of North-eastern region and tropical moist deciduous forests of Northern and Southern India (Anonymas, 2021). *Bambusa*, *Dendrocalamus* and *Ochlandra* constitute the three largest bamboo genera in India (Sharma and Nirmala, 2015). There are 130 species of *Bambusa* genus in the world (Das *et al.*, 2013), out of which around 37 species and 2 varieties of *Bambusa* are available in India (Sharma and Nirmala, 2015). In Manipur, genus *Bambusa* is represented by 9 species (Naithani *et al.*, 2015). Bamboo has been an integral part of people's lives of Manipur. The most common uses of bamboo in the

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state are house constructions, roofing, bamboo reinforced mud wall, flooring, doors and windows, *etc*. *Bambusa tulda* and *B. kingiana* are commercially important species in the valley used as scaffolding, pandal making, agricultural implements and baskets. Fine bamboo splits or "Peiya" which are made from *B. nutans* are used in many ritual practices by the Meitei people of Manipur. *B. ventricosa* and *B. vulgaris* are cultivated as ornamental plants due to its aesthetic value. Although, there has been some investigations carried out on bamboos of Manipur (Rajkumari and Gupta, 2013; Naithani *et al.*, 2015), information on physical properties of *Bambusa* species of the state is very limited. Therefore the present evaluation was executed in order to provide the detailed account of physical properties of some selected *Bambusa* species of Manipur and their variations along the culm height.

MATERIALS AND METHODS

The study was conducted in the year 2019-2021 at Wood Science and Forest Products Laboratory, Department of Forestry, North Eastern Regional Institute of Science and Technology (NERIST), Arunachal Pradesh. Eight species of *Bambusa viz*., *Bambusa balcooa* Roxb., *B. binghamii* Gamble, *B. kingiana* Gamble, *B. multiplex* (Lour.) Raeusch. ex Schult. f., *B. nutans* Wall, *B. tulda* Roxb., *B. vulgaris* Schrad. ex J.C. Wendl. and *B. ventricosa* McClure were collected from various parts of Bishnupur, Imphal East, Imphal West and Thoubal districts of Manipur (Fig 1). The geographical co-ordinates and elevations are given in Table 1. The mentioned districts are humid subtropical plain areas of the state. Rivers namely Nambul, Khuga, Imphal, Iril, Sekmai and Thoubal flow though this plain area. Many lakes and swamps are found in this region. Loktak Lake, the largest freshwater lake of India is located at Moirang of Bishnupur district. Climate is temperate with an average temperature ranging from 1 to 2°C in winter and 32 to 33°C in summer. Average annual rainfall ranges from 1200 to 1400 mm. Soil is fertile, well-drained, clayey loam, acidic (pH ranging from 4.5 to 5.5) in Bishnupur, Imphal West and Thoubal while it is slightly acidic in Imphal East. Vegetation consist of medicinal herbs, spices, rice crops, shrubs, bamboos and trees such as *Ficus religiosa* (Pipal), *Eucalyptus globulus* (Eucalyptus), *Phyllanthus emblica* (Amla), *Parkia roxburghii* (Yongchak), *Arundo donax* (yendhou), *Carica papaya* (papaya), *Citrus maxima* (Pomelo), *Mangifera indica* (Mango), *Prunus domestica* (plum), *Prunus persica* (peach), *Pyrus serotina* (pear), *Psidium guajava* (guava), *Tamarindus indica* (Tamarind), etc. Five matured culms of each species were harvested at 30cm above the ground level. The upper lofty portions were discarded; the end portions of the remaining culms were painted to reduce sap evaporation and brought to laboratory for further studies. The length of culms, number of internodes, their lengths and diameter were measured at the site itself. The morphological parameters of these selected *Bambusa* species are given in Table 2. These culms were further divided into equal lengths from bottom, middle and top height positions. Rings of 2.5 cm height were cut from the internodal regions of all the three height positions for each species. Further, sample strips were prepared from these rings. A total of 105 strips were taken separately for the determination of each physical property.

Determination of moisture content, specific gravity and dimensional shrinkage percentage (longitudinal, radial and tangential) were carried out using Indian Standard Method IS 6874 (2008).

Water absorption percentage was determined by following ASTM D 1034-72 method.

The data were analysed by using SPSS software 16.0 at $\alpha = 0.05$. One way analysis of variance (ANOVA) followed by Tukey's test was carried out to compare the mean values of physical properties among the selected species.

RESULTS AND DISCUSSION

Moisture content and water absorption capacity of bamboo are important parameters of bamboos which govern its durability/life span. Bamboos with high moisture content are susceptible to fungal and insect attacks. Both moisture content and water absorption percentages decreased from bottom to top along the culms in all the species. Similar observations were reported in other bamboo genera by different workers (Razak *et al.,* 2006; Kamruzzaman, *et al.,* 2008; Bhonde *et al*., 2014; Zakikhani *et al.,* 2014). Wakchaure and Kute, 2012 also found that the moisture content percentage and water absorption was not constant along the culm height. They further added that these parameters varied with age and height of bamboos. Among the species, the moisture content was observed maximum

Table 1: Geographical co-ordinates of the selected *Bambusa* species.

Species name	Latitude	Longitude	Elevation (m)	Location name
Bambusa balcooa	24°82.577′N	93°86.078′E	779	Lamsang, Imphal West
Bambusa binghamii	24°77.409′N	93°92.637′E	775	Ningthemcha Karong, Imphal West
Bambusa kingiana	24°80.027′N	93°85.040′E	773	Salam Luker, Imphal West
Bambusa multiplex	24°49.153′N	93°51.083′E	804	Maharabi, Imphal East
Bambusa nutans	24°64.238′N	93°93.602′E	769	Nungei,Thoubal
Bambusa tulda	24°50.263′N	93°77.608′E	771	Moirang, Bishnupur
Bambusa vulgaris	24.83.858′N	93.84.212′E	782	Lamsang, Imphal West
Bambusa ventricosa	24°80.415′N	93°02.881′E	792	Nongpok Sanjenbam, Imphal East

Table 2: Morphological parameters of the selected *Bambusa* species.

Species Name	Height(m)	No. of internodes	Internode length (cm)	Girth(cm)	Culm wall thickness(mm)
B. balcooa	8.38±0.38	22.20±0.84	37.76±10.01	18.62±3.49	5.89±1.55
B. binghamii	7.79±1.85	18.00±2.44	43.27±11.57	10.78±2.40	6.07±2.00
B. kingiana	7.63±0.72	19.80±1.92	38.52±11.98	11.24±2.54	5.31±1.08
B. multiplex	6.32±0.84	16.00±1.87	39.5±10.53	9.13±1.57	5.04±1.28
B. nutans	7.21±1.58	16.6±3.05	43.48±11.83	13.11±2.61	5.51±1.81
B. tulda	8.26±0.67	22.20±0.45	37.22±10.18	16.67±4.23	5.00±1.69
B. vulgaris	6.02±0.36	26.20±1.30	22.97±4.44	19.16±5.30	6.61±1.64
B. ventricosa	3.96±0.56	31.80±3.27	12.47±7.48	17.84±5.95	5.91±1.18

in culms of *B. multiplex* (66.88%) whereas *B. vulgaris* showed maximum water absorption (84.60%). Both moisture content and water absorption were observed minimum in *B. nutans* (42.67% and 56.36%). These differences are also dependent on the species, geographical location of the collected bamboo as well as the season of felling. There are variations in anatomical structures of bamboo species which may be the probable reason for maximum and minimum moisture content and water absorption in these species. The culm wall thickness decreased from bottom to top in all bamboo species. Larger vascular bundles with higher percentage of parenchyma are generally present at the bottom and middle positions of culms. This results in the highest moisture content and water absorption at these heights. Water absorption depends on the percentage of porosity and presence of intercellular spaces which is different for every bamboo species.

Specific gravity or basic density of bamboo determines the strength of bamboo. It varies with age, vertical culm height as well as horizontally across the culm wall/ *B. ventricosa* (0.65) showed the maximum average specific gravity while the minimum average specific gravity was shown by *B. vulgaris* (0.52). Specific gravity increased from bottom towards the top in all species. The results are similar to the findings of Falayi and Soyoye, 2014; Sharma *et al.*, 2019 and Selvan *et al.*, 2017. The reason for the increase of the specific gravity at top height position is due to decrease in the culm wall thickness which results in compactness of highly thick walled sclerenchymatous fibrous tissue with less percentage of parenchyma (Sharma *et al.*, 2017). Santoshkumar and Bhat, 2014 reported that the increase in specific gravity/basic density along the culm height is indicative of higher proportion of fibrous tissues and higher frequency of vascular bundles at top position of bamboos. The relation of specific gravity with anatomical structure and chemical constituents influence the pattern in specific gravity in different bamboo species. The specific gravity also varies with variation in bamboo species (Abd. Latif and Jusoh, 1992).

Loss of water molecules bound to cell wall of bamboos results in shrinkage which further determines its dimensional stability (Aguinsatan *et al.,* 2019). Bamboo, like wood is also an anisotropic material and its properties are different in longitudinal, radial and tangential directions. These variations in result may be due to difference in the size and proportion of xylem elements present at different height positions of these species. Longitudinal shrinkage was lesser than radial and tangential shrinkage in all *Bambusa* species (Table 3). Similar observation was reported in *Phyllostachys bambusoides* by Sharma *et al.* (2019). Longitudinal shrinkage was minimum in all species and ranged from 0.78% (*B. kingiana*) to 2.81% (*B. binghamii*). Radial shrinkage was higher than tangential shrinkage because bamboo is a monocotyledon and rays are absent. There is no specific pattern of variation in longitudinal, radial and tangential shrinkage from bottom to top in culms of *Bambusa* species. *B. binghamii* and *B. tulda* showed higher shrinkage towards the bottom and decreased gradually towards the top. Likewise, other workers reported higher shrinkage percentages at the bottom height position (Kamruzzaman *et al.*, 2008; Sompoh *et al.*, 2013). This may be probably due to the presence and loss of higher initial moisture content at the base portion. While the top portions of *B. balcooa, B. multiplex* and *B. ventricosa* exhibited higher shrinkages (radial, longitudinal and tangential) than the middle and bottom. On the contrary, *B. kingiana* and *B. vulgaris* showed that their middle portion had maximum dimensional shrinkages. These variations in result may be due to difference in the size and proportion of xylem elements present at different height positions of these species. The variation in tangential shrinkage can be related to the bamboo's anatomical structure and density (Anwar *et al.,* 2005). The dimensional stability in bamboo depends on its volumetric shrinkage and T/R ratio as in wood. Volumetric shrinkage is the sum of radial and tangential shrinkage. T/R is a good indicator of dimensional stability and measures the uniformity of shrinkage in bamboos (Panshin and de Zeeuw, 1980). Bamboos with good stability have low volumetric shrinkage and low T/R ratio. On the basis of volumetric shrinkage, Calderon (2012) classified bamboos into three categories namely low shrinkage (VS≤11.5%), medium shrinkage (VS 11.5%-14.5%) and high shrinkage (VS≥14.0%). According to this classification, *B. balcooa*, *B. kingiana*, *B. nutans*, *B. ventricosa* are low shrinkage bamboo, *B. multiplex* is medium shrinkage bamboo while *B. binghamii*, *B. tulda* and *B. vulgaris* are high shrinkage bamboos. The results given in Table 5 showed that T/R ratio in all *Bambusa* species varied from 0.61 (*B. balcooa*) to

Table 3: Physical properties of the selected *Bambusa* species.

Species	Height position	Moisture content %	Water absorption %	Specific gravity	Longitudinal	Shrinkage (%)		
						Radial	Tangential	Volumetric
		Mean±SD						
B. balcooa	Bottom	86.51 ± 3.06^{c}	84.60 ± 1.44^{c}	0.59 ± 0.03^{c}	1.72 ± 0.46^{b}	4.88 ± 2.33^{a}	3.35 ± 2.15^{a}	10.20 ± 2.71^{a}
	Middle	67.85 ± 2.60^{b}	70.90 ± 4.89^{b}	0.60 ± 0.01^{ab}	1.06 ± 0.30^{a}	5.57 ± 2.32^{a}	3.14 ± 1.73^{a}	9.98 ± 3.64^{a}
	Top	41.99 ± 1.66^{a}	42.76 ± 5.10^{a}	0.67 ± 0.02^{a}	2.31 ± 1.76^{b}	5.95 ± 2.46^{a}	3.59 ± 1.75^{a}	11.40 ± 3.30^{a}
	Average	65.45 ± 1.45^{b}	66.09 ± 2.68^{b}	0.62 ± 0.04^{b}	1.70 ± 0.60^{b}	5.47 ± 1.60^{a}	3.36 ± 0.98^{a}	10.53 ± 1.91^{a}
B. binghamii	Bottom	84.77 ± 3.80^{c}	75.62 ± 2.43^{a}	0.53 ± 0.02^{a}	8.81 ± 2.09^{a}	8.29 ± 2.77^{a}	8.85 ± 2.78^{a}	17.95 ± 5.16^{a}
	Middle	63.96 ± 5.12^{b}	67.31 ± 1.67^{b}	0.54 ± 0.03^{a}	3.40 ± 3.53^{a}	7.33 ± 5.05^{a}	6.88 ± 3.08^{a}	17.62 ± 7.52^{a}
	Top	36.37 ± 1.30^{a}	60.31 ± 1.12^{c}	0.59 ± 0.03^{b}	2.21 ± 1.76^{a}	6.51 ± 3.18^{a}	6.57 ± 3.00^{a}	15.29 ± 3.49^{a}
	Average	61.70 ± 2.61^{b}	68.09 ± 6.60^{b}	0.55 ± 0.04^{a}	2.81 ± 1.79^{a}	7.38 ± 2.40^{a}	6.77 ± 1.89^{a}	16.95 ± 3.71^{a}
B. kingiana	Bottom	72.78 ± 3.37^{c}	82.46 ± 3.95^{a}	0.51 ± 0.01^{a}	1.27 ± 1.04^{b}	4.17 ± 1.63^{a}	4.17 ± 1.79^{a}	9.61 ± 2.42^{a}
	Middle	50.26 ± 2.01^{b}	64.03 ± 2.24^{ab}	0.63 ± 0.03^{ab}	0.60 ± 0.47^{a}	4.18 ± 2.74^{a}	4.29 ± 2.44^{a}	9.07 ± 3.93^{a}
	Top	36.03 ± 2.84^{a}	49.63 ± 4.09^{b}	0.66 ± 0.03^{c}	0.46 ± 0.39^{a}	4.11 ± 3.14^{a}	3.84 ± 2.29^{a}	8.41 ± 3.60^{a}
	Average	53.02 ± 15.73^{b}	65.37 ± 14.17^{b}	0.60 ± 0.05^{b}	0.78 ± 0.37^{a}	4.15 ± 1.64^{a}	4.10 ± 1.33^{a}	9.03 ± 2.11^{a}
B. multiplex	Bottom	91.25 ± 2.90^{c}	82.17 ± 3.58^{b}	0.54 ± 0.01^{a}	1.91 ± 1.48^{ab}	4.43 ± 3.64^{a}	3.97 ± 2.62^{a}	10.3 ± 3.63^{a}
	Middle	68.33 ± 3.17^{b}	78.02 ± 6.20^{a}	0.54 ± 0.02^{a}	1.07 ± 0.90^{a}	4.65 ± 3.11^{a}	6.08 ± 4.88^{ab}	13.59 ± 6.19^{b}
	Top	41.06 ± 1.99^{a}	72.54 ± 2.97^{a}	0.59 ± 0.04^{b}	2.87 ± 2.99^{b}	7.24 ± 5.64^{b}	6.59 ± 3.23^{b}	14.91 ± 6.12^{b}
	Average	66.88 ± 21.18^{b}	77.58 ± 5.86^{a}	0.53 ± 0.03^{ab}	1.95 ± 1.27^{ab}	5.44 ± 2.51^{ab}	5.55 ± 2.27^{ab}	12.94 ± 2.65^{ab}
B. nutans	Bottom	61.28 ± 9.08^{c}	66.55 ± 3.09^{a}	0.57 ± 0.02^{a}	1.13 ± 1.33^{b}	3.77 ± 1.9^{a}	4.09 ± 2.05^{a}	8.99 ± 3.11^{a}
	Middle	38.73 ± 2.41^{b}	52.36 ± 1.73^{b}	0.61 ± 0.02^{b}	1.07 ± 0.76^{ab}	4.15 ± 3.26^{a}	5.04 ± 2.59^{a}	10.26 ± 3.72^{a}
	Top	27.99 ± 2.58^{a}	50.16 ± 2.84^{b}	0.62 ± 0.02^{b}	0.56 ± 0.48^{a}	3.54 ± 1.83^{a}	5.61 ± 5.45^{a}	9.71 ± 6.47^{a}
	Average	42.67 ± 3.39^{b}	56.36 ± 7.85^{b}	0.60 ± 0.03^{ab}	0.92 ± 0.59^{ab}	3.82 ± 1.17^{a}	4.91 ± 1.89^{a}	9.66 ± 2.40^{a}
B. tulda	Bottom	83.85 ± 4.15^{c}	66.25 ± 2.77^{c}	0.57 ± 0.02^{a}	1.17 ± 1.27^{a}	10.21 ± 4.70^{a}	9.48 ± 2.38^{b}	20.86 ± 4.57^{b}
	Middle	70.56 ± 3.80^{b}	64.19 ± 4.82^{b}	0.61 ± 0.02^{b}	0.93 ± 7.62^{a}	8.8 ± 3.19^{a}	7.62 ± 1.79^{a}	17.45 ± 3.81^{ab}
	Top	39.79 ± 2.57^{a}	57.57 ± 2.10^{a}	0.62 ± 0.02^{c}	0.68 ± 1.05^{a}	9.02 ± 3.65^{a}	6.76 ± 3.65^{a}	16.47 ± 5.68^{a}
	Average	64.73 ± 1.99^{b}	62.54 ± 5.14^{b}	0.60 ± 0.03^{b}	0.93 ± 0.60^{a}	9.38 ± 0.60^{a}	7.95 ± 1.79^{ab}	18.26 ± 3.12^{ab}
B. vulgaris	Bottom	66.89 ± 2.30^{c}	79.53 ± 6.06^{c}	0.46 ± 0.01^{a}	0.98 ± 0.71^{a}	5.93 ± 2.55^{a}	4.79 ± 2.36^{a}	11.71 ± 4.07^{a}
	Middle	62.29 ± 4.75^{b}	70.96 ± 2.37^{b}	0.53 ± 0.02^{b}	2.38 ± 2.11^{b}	10.91 ± 5.48^{b}	7.81 ± 4.93^{b}	21.09 ± 7.63^{b}
	Top	47.32 ± 4.85^{a}	64.64 ± 3.40^{a}	0.57 ± 0.02^{c}	1.47 ± 1.59^{ab}	7.55 ± 4.15^{a}	4.95 ± 2.67^{a}	13.97 ± 5.96^{a}
	Average	58.83 ± 1.36^{c}	84.60 ± 1.44^{c}	0.52 ± 0.05^{b}	1.61 ± 0.93^{ab}	7.13 ± 2.94^{ab}	5.85 ± 1.99^{ab}	15.59 ± 3.82^{a}
B. ventricosa	Bottom	78.68 ± 5.98^{b}	70.90 ± 4.89^{b}	0.62 ± 0.03^{a}	1.02 ± 0.31^{a}	4.88 ± 2.33^{a}	3.88 ± 2.26^{a}	9.70 ± 2.91^{a}
	Middle	56.06 ± 3.45^{a}	42.76 ± 5.10^{a}	0.66 ± 0.04^{a}	1.06 ± 0.30^{a}	5.57 ± 2.32^{a}	3.35 ± 2.15^{a}	6.44 ± 2.55^{a}
	Top	36.72 ± 3.39^{b}	66.09 ± 18.28^{b}	0.68 ± 0.25^{a}	2.31 ± 1.76^{b}	5.95 ± 2.46^{a}	3.14 ± 1.73^{a}	11.40 ± 3.30^{a}
	Average	57.15 ± 2.97^{c}	75.62 ± 2.43^{a}	0.65 ± 0.14^{a}	1.47 ± 0.61^{a}	5.47 ± 1.60^{a}	3.45 ± 1.16^{a}	10.39 ± 2.02^{a}

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

Table 4: Analysis of variance among the selected species of *Bambusa.*

Height position	Moisture content (%)	Water absorption (%)	Specificgravity	Shrinkage(%)			
				Radial	Longitudinal	Tangential	Volumetric
	(F value)						
Bottom	31.545**	96.075**	58.735**	22.107**	8.450**	26.360**	41.068**
Middle	52.825**	26.987**	21.492**	14.480**	9.729**	8.482**	19.378**
Top	28.811**	91.502**	1.829*	7.711**	14.011**	7.840**	9.632**
Average	84.769**	47.588**	8.701**	23.267**	17.661**	25.773**	39.311**

The level of significance used are ns=Non-significant, *= Significant at P≤0.05 level, **= Highly significant at P≤0.01 level.

Table 5: T/R ratio of the selected *Bambusa* species.

Species	Height position	T/R	Species	Height position	T/R
B. balcooa	Bottom	0.69	*B. nutans*	Bottom	1.08
	Middle	0.56		Middle	1.21
	Top	0.60		Top	1.58
	Average	0.61		Average	1.29
B. binghamii	Bottom	1.07	*B. tulda*	Bottom	0.93
	Middle	0.94		Middle	0.87
	Top	1.01		Top	0.75
	Average	0.92		Average	0.85
B. kingiana	Bottom	1.00	*B. vulgaris*	Bottom	0.81
	Middle	1.03		Middle	0.72
	Top	0.93		Top	0.66
	Average	0.99		Average	0.82
B. multiplex	Bottom	0.90	*B. ventricosa*	Bottom	0.80
	Middle	1.31		Middle	0.60
	Top	0.91		Top	0.53
	Average	1.02		Average	0.63

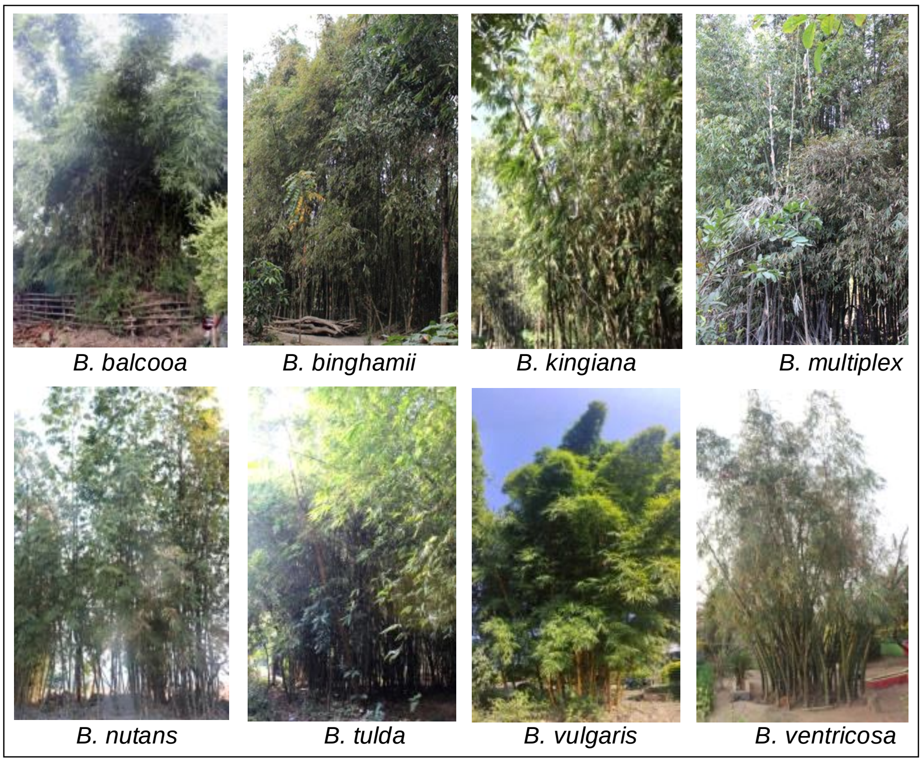

Fig 1: Clumps of the selected *Bambusa* species.

1.29 (*B. nutans*). Whereas in case of wood, T/R ratio varies from 1-3. The present study reveals that all *Bambusa* species shrink uniformly and are dimensionally stable.

The results for analysis of variance (ANOVA) for all physical properties among eight *Bambusa* species tabulated in Table 4 exhibited a significant variations at all height positions.

CONCLUSION

Moisture content and water absorption percentages decreased along the culm height in all species. Specific gravity of all Bambusa species increased from bottom to top portion. Radial and tangential shrinkages were higher than longitudinal shrinkage. Longitudinal shrinkage did not exhibit a definite pattern. All the physical properties showed significant variations at bottom, middle and top positions. B. kingiana is the most desirable species based on the study results considering the comparatively higher specific gravity and low moisture content, water absorption capacity, dimensional shrinkage and T/R ratio.

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