Content list available at http://epubs.icar.org.in, www.kiran.nic.in; ISSN: 0970-6429

Indian Journal of Hill Farming

December 2021, Volume 34, Issue 2, Page 130-137

Physical Properties of Some *Dendrocalamus* Species of Manipur

D. Laishram* • C.L. Sharma • M. Sharma

Wood Science and Forest Products Laboratory, Department of Forestry, North Eastern Regional Institute of Science and Technology (NERIST), Nirjultertei-791109, Arunachal Pradesh, India

ARTICLE INFO

Article history:
Received: 07 November, 2021
Revision: 22 November, 2021
Accepted: 28 November, 2021

Key words: Bamboo, Dendrocalamus, moisture content, specific gravity, shrinkage.

ABSTRACT

Dendrocalamus is one of the most important densely tufted, clump forming and sympodial bamboos with tropical and sub-tropical in distribution. The present study was carried out in four *Dendrocalamus* species namely *D. asper* Backer, *D. latiflorus* Munro, *D. sericeus* Munro and *D. strictus* Nees to investigate the important physical properties namely moisture content, specific gravity, water absorption, shrinkage and their variations within and among the selected species. Five mature culms of each species were harvested at 30cm above the ground from the clumps. Each culm was divided into bottom, middle and top height positions. Moisture content and water absorption percentages decreased and specific gravity increased from bottom to top in all species. *D. sericeus* exhibited highest moisture content (69.02%) and specific gravity (0.63). Water absorption was maximum in *D. asper* (81.44%). Radial shrinkage was higher than longitudinal and tangential shrinkage in all species. Radial, longitudinal, tangential and volumetric shrinkage did not exhibit a definite trend. Radial shrinkage was maximum in *D. asper* (1.65%) while *D. latiflorus* exhibited maximum tangential (11.85%), longitudinal (7.53%) and volumetric shrinkage (20.03%). All physical properties except moisture content exhibited significant variations among species. This study will help in characterization of physical properties of *Dendrocalamus* species for different end uses.

1. Introduction

Bamboos are the fastest growing plants and belong to sub-family Bambusoideae of family "Poaceae" with over 1200 species under 90 genera (Anon, 2021). They are generally tall grasses with evergreen culms having distinct nodes and internodes and found extensively in the tropical, sub-tropical and temperate regions of the world. These perennial grasses are capable of thriving in extreme climatic and edaphic conditions because of their hard and vigorous nature (Lobovikov *et al.,* 2007). Bamboos play an important role in socio-economic and ecological development of a region. They play a significant role in the reclamation of degraded lands, maintenance and improvement of physical, chemical and biological properties of soil. Also, they have high potential for carbon sequestration (Lou *et al.,* 2010). Like wood, bamboos are also ligno-cellulosic in nature. They are considered as the best alternative raw material for wood based composites because of their fast growing nature, quick maturity, high productivity and have comparable physical and mechanical properties to wood (Chaowana, 2013).

Moisture content, specific gravity, water absorption and shrinkage are the important physical properties which affect the strength, durability and dimensional stability of bamboos (Sattar *et al.*, 1990; Kamruzzaman *et al.*, 2008; Qisheng *et al.*, 2001). These properties determine the possibility of bamboos for different end uses and also as a substitute for wood. Also, these physical properties are highly variable among species, genera and

*Corresponding author: laishrambi3211@gmail.com

even within a culm. Therefore, the information on these properties is required for appropriate end-use (Yohannis and Dessie, 2018).

India ranks second in bamboo resources after China with 125 indigenous and 11 exotic species under 23 genera (Anon, 2021). There are nearly 90 species of bamboos in states of Northeast India. Of which, 41 species are endemic to this region (Tewari *et al.,* 2019). *Dendrocalamus* is one of the largest genera and is represented by 18 species in India (Sharma and Nirmala, 2015) and 12 species in Manipur (Anon, 2015). It grows well in diverse region and habitats. The available literature on *Dendrocalamus* reveals that Ahmad and Kamke (2005) evaluated the technical feasibility of *D. strictus* for the production of structural composite by comparing its physical and mechanical properties with commercial timber species. Kamthai and Puthson (2005) evaluated the fibre morphology, physical properties and chemical composition of *D. asper*, whereas Wakchaure and Yute (2012) examined the effect of moisture content on physical and mechanical properties of *D. strictus* at regular intervals of 1, 3, 6 and 12 months. Narasimhamurthy *et al.* (2013) compared the physical and mechanical properties of *Dendrocalamus membrances* with *Thyrostachys siamensis* and reported better mechanical properties in *T. siamensis.* However, there is hardly any information on important physical properties of *Dendrocalamus species* of Manipur. Therefore, the present study was an attempt to obtain basic information on physical properties of four *Dendrocalamus* species and their variation from bottom to top along the culm height.

2. Materials and Methods

The four *Dendrocalamus* species viz., *D. asper, D. latiflorus*, *D. sericeus* and *D. strictus* (Fig.1) were collected from Imphal West and Tengnoupal Districts of Manipur (Table 1). Five mature naturally grown culms of each species were harvested at 30cm above the ground level and the upper lofty portion was discarded. The length of culms, number of internodes, the lengths and diameter of internodes were measured from bottom to top in the field (Table 1). The culms were divided into bottom, middle and top height positions and their ends were painted black to reduce the sap evaporation before bringing to laboratory for further studies. For each culm, five internodes were selected at each height position and samples of size 2.5cm were taken in the form of rings. The rings were converted into strips of 25mm × 25mm × culm wall thickness size for determination of physical properties namely moisture content, water absorption, specific gravity and dimensional shrinkage. For each species, a total of 105 strips were taken separately for the determination of each physical property.

Moisture content, specific gravity and shrinkage percentage (longitudinal, radial and tangential) were determined according to Indian Standard Method IS 6874 (2008). Water absorption percentage was determined by following ASTM D 1034-72 (1998).

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 were carried out to compare the mean values of physical properties among the species.

3. Results and Discussion

Moisture content and water absorption are important physical properties of bamboos to determine their durability. The species with high moisture content and water absorption are highly susceptible to fungal and insect attack. Moisture content has also significant effect on biological properties of fibres for reinforced composite material. The results presented in Table 2 showed that moisture content was maximum in *D. sericeus* (69.02%) followed by *D. asper* and *D. latiflorus* (67.83%) and *D. strictus* (60.15%). On the other hand, water absorption was maximum in *D. asper* (81.44%) and minimum in *D. strictus* (56.24%). The moisture content and water absorption in bamboo species vary depending on geographical location, season of harvesting and species. The present study is in line with findings of Zakikhani *et al.* (2017). The moisture content was higher at bottom than middle and top positions and also there was statistically significant decrease from bottom to top in all *Dendrocalamus* species. On the other hand, the percentage of water absorption was maximum at the bottom position of *D. asper*, *D. latiflorus* and *D. strictus* whereas it was maximum in middle position of *D. sericeus*. Different pattern of variation in water absorption were observed in *Dendrocalamus* species. It decreased non-significantly in *D. asper* and *D. latiflorus*, uniform in *D. strictus* from bottom to top. There was no definite variation of water absorption in *D. sericeus* from bottom to top position.

A perusal of literature reveals that proportion, size and number of parenchyma cells are related with moisture content and water absorption percentage. Also, the water absorption depends on the percentage of porosity and presence of intercellular spaces which is different for every bamboo species. The present results corroborate the findings of Nahar and Hassan, 2013; Anokye *et al.,* 2014; Sharma *et al.,* 2017; Suthoni and Woravit, 2016; Zakikhani *et al,.* 2017.

The mean specific gravity was maximum in *D. sericeus* (0.63) and minimum in *D. asper* (0.44). Specific gravity is related to anatomical structure and chemical composition of bamboo culms which may be the probable reason for maximum and minimum specific gravity in these species. In all *Dendrocalamus* species except *D. asper,* a statistically significant increase in specific gravity from bottom to top position was found (Table 2). The decrease in culm wall thickness from bottom to top position results in compact vascular bundles with maximum percentage of thick walled fibres which attribute to increase in specific gravity. The obtained results are in good agreement with the findings of Kamthai and Puthson, 2005, Falayi and Soyoye, 2014; Sharma *et al.,* 2017, 2019; Selvan *et al.,* 2017)

The dimensional stability in bamboos is indicated by shrinkage which occurs due to loss of water molecules bound to cell wall (Aguinsatan *et al*., 2019). Like wood, it also shrinks in three planes (longitudinal, radial and tangential). The sum of radial and tangential shrinkage determines the volumetric shrinkage. The results given in Table 3 showed that the longitudinal shrinkage percentages were lower than radial and tangential shrinkages in all species. The maximum longitudinal shrinkage was observed in *D. asper* (1.95%) followed by *D. sericeus* (1.36%), *D. strictus* (0.79%*)*, and *D. latiflorus* (0.66%). Tangential shrinkage occurred maximum in *D. latiflorus* (7.53%) followed by *D. asper* (2.98%), *D. sericeus* (1.61%) and *D. strictus* (1.54%). The maximum radial shrinkage was in *D. latiflorus* (11.35%) followed by *D. asper* (6.06%), *D. strictus* (5.46%) and *D. sericeus* (2.33%). The higher radial shrinkage in bamboos is due to absence of rays. The longitudinal shrinkage varied non-significantly in all species. The tangential shrinkage showed a decreasing pattern of variation in all species except *D. strictus*. Radial shrinkage decreased significantly from bottom to top in *D. latiflorus* whereas other species did not show any consistent pattern with non-significant variation from bottom to top. Volumetric shrinkage is the sum of longitudinal, radial and tangential shrinkage. Volumetric shrinkage was maximum in *D. latiflorus* (20.03%) followed by *D. asper* (10.99%), *D. strictus* (7.79%) and *D. sericeus* (5.30%). It varied non-significantly from bottom to top in all *Dendrocalamus* species (Table 3). It increased from bottom to top in *D. sericeus* and *D. strictus*. In *D. asper*, the volumetric shrinkage was same at bottom and top positions whereas in *D. latiflorus*, it decreased along the culm height. The different patterns of volumetric shrinkage in *Dendrocalamus species* may be due to distribution pattern of fibres and parenchyma in the culms (Yu *et al.,* 2008). Also, all physical properties exhibited highly significant variations among *Dendrocalamus* species (Table 4) which indicate that these properties are species specific.

4. Conclusion

Among all physical properties, moisture content, water absorption decreased and specific gravity increased significantly from bottom to top along the culms in all *Dendrocalamus* species. The longitudinal shrinkage was minimum and radial shrinkage was higher than tangential shrinkage in selected *Dendrocalamus* species. The tangential shrinkage decreased from bottom to top in all species except *D. strictus*. Radial shrinkage did not show any consistent pattern from bottom to top except *D. latiflorus*. There was highly significant variation in selected physical properties among all *Dendrocalamus* species. On the basis of present study, the culms of *Dendrocalamus species* may be considered for different end uses due to their desirable physical properties. However, *D. strictus* is the most suitable species due to low moisture content, water absorption, shrinkage properties and moderate specific gravity.

5. Acknowledgements

The first author is thankful to DST for financial assistance as an Inspire Fellow. The authors are thankful to Director, NERIST, Nirjuli-791109, Arunachal Pradesh for providing required laboratory facilities.

6. References

Ahmad M and Kamke FA (2005) Analysis of Calcutta bamboo for structural composites materials: physical and mechanical properties. Wood Science and Technology 39: 448-459.

Anokye R, Kalong RM, Baker ES, Ratnagingam J, Jawaid M and Awang K (2014) Variation in moisture content affect the shrinkage of *Gigantochloa scortechinii* and *Bambusa vulgaris* at different heights of bamboo culm. BioResources 9(4):7484-7493.

Anonymous (2015) ENVIS Hub, Status of Environment and Related Issues, Directorate of Environment, Govt. of Manipur Sponsored by Ministry of Environment and Forests, Govt of India. http://manenvis.nic.in/Database/BambooSpecies_2937.aspx.

Anonymous (2021) Indian State Forest Report, Forest Survey of India, Ministry of Environment and Forest, Government of India, Dehradun.

American society for testing materials (1998) ASTM D 1034-72. Standard Method of evaluating the properties of wood based fibre and particle panel material.

Chaowana P (2013) Bamboo: An Alternative for Wood and Wood-Based Composites. Journal of Material Science Research 2(2): 90-102.

Falayi FR and Soyoye BO (2014) The influence of age and location on selected physical and mechanical properties of bamboo (*Phyllostachys pubescens*). International Journal of Research in Agriculture and Forestry 1: 44-54.

Indian Standard 6874 (2008) Methods of test for bamboos. Bureau of Indian Standards, New Delhi.

Kamruzzaman M, Saha SK, Bose AK and Islam MN (2008) Effects of age and height on physical and mechanical properties of bamboo. Journal of Tropical Forest Science 20(3): 211-217.

Kamthai S and Puthson P (2005) The physical properties, fibre morphology and chemical compositions of sweet bamboo (*Dendrocalamus asper* Backer). Kasetsart Journal (Natural Sciences*)* 39: 581-587.

Lobovikov M, Shyam P, Piazza M, Ren H and Wu J (2007) World bamboo resources. Editions INBAR and FAO 18(1): 7-8p.

Lou Y, Li Y, Kathleen B, Henley G, Guomo Z (2010) Bamboo and Climate Change Mitigation: a comparative analysis of carbon sequestration. International Network Bamboo Ratan, Technical Report 32: 1-30.

Nahar S and Hassan M (2013) Effect of chemical composition, anatomy and cell wall structure on tensile properties of bamboo fiber. Engineering Journal 17(1): 61-68.

Narasimhamurthy, Maya C, Nadanwar A and Pandey, CN (2013) A study on physico-mechanical properties of *Thyrsostachys siamensis* (Kurz) Gamble and *Dendrocalamus membrances* (Munro) in Tumkur district, Karnataka. International Journal of Current Microbiology and Applied Sciences 2(2): 62-66.

Qisheng Z, Shenxue J, and Yongyu T (2001) Industrial utilization of bamboo, International Network For Bamboo And Rattan (INBAR).

Sattar MA, Kabir MF and Bhattacharjee DK (1990) Effect of age and height positions of Muli (*Melocanna baccifera*) and Borak (*Bamboo balcooa*) bamboos on their physical and mechanical properties. Bangladesh Journal of Forest Science 19: 29-37.

Selvan RT, Parthiban KT and Khanna SU (2017) Physico-chemical properties of bamboo genetic resources at various age gradations. International Journal of Current Microbiology and Applied Sciences 6(9): 1671-1681.

Sharma MB, Sharma CL, and Laishram D (2017) Variation in anatomical and physical properties of some *Schizostachyum* species of Manipur, India. Journal of the Indian Academy of Wood Science 14(1):79-90.

Sharma MB, Sharma CL, Tado N and Laishram D (2019) Physical properties of Apatani bamboo (*Phyllostachys bambusoides* Siebold & Zucc.) in relation to age and height. International Journal of Advance Science Engineering and Technology 7(3): 76-78.

Sharma ML and Nirmala C (2015) Bamboo Diversity of India: An update.10th World Bamboo Congress, Korea.

Suthoni S and Woravit J (2016) Comparison of physical and mechanical properties of *Dendrocalamus asper* Backer specimens with and without nodes. European Journal of Wood and Wood products 74: 893-899.

Tewari S, Negi H and Kaushal R (2019) Status of bamboo in India. International Journal of Economic plants 6(1): 030-039.

Wakchaure MR and Kute SY (2012) Effect of moisture content on physical and mechanical properties of bamboo. Asian Journal of Civil Engineering (Building and Housing) 13(6):753-763.

Yohannis G and Dessie A (2018) Effect of Age and Height on some selected physical properties of Ethiopian Highland Bamboo (*Yushania alpina*). International Journal of Scientific Research and Management 6(8): 70-74.

Yu HQ, Jiang ZH, Hse CY and Shupe TF (2008) Selected physical and mechanical properties of Moso bamboo (*Phyllostachys pubescens*). Journal of Tropical Forest Science 20(4): 258-263.

Zakikhani P, Zahari R, Sultan MTH and Majid DL (2017) Morphological, mechanical and physical properties of four bamboo species. BioResources 12(2): 2479-2495.

Table 1. Morphological characteristics with geographical co-ordinates of the selected *Dendrocalamus* species

Sl. No.	Species Name	Culm height (m)	Culm diameter (cm)	Geographical co-ordinates	Locality	District
		Mean±SD				
1.	*D. asper*	8.53±0.59	6.92±2.13	24°77.222'N 93°92.580'E	Mongsangei	Imphal west
2.	*D. latiflorus*	10.86±0.74	8.43±2.97	24°51.476'N 94°14.350'E	Machi village	Tengnoupal
3.	*D. sericeus*	8.80±0.89	5.59±1.92	24°76.981'N 93°92.004'E	Kwakeithel Konjeng Leikai	Imphal west
4.	*D. strictus*	10.62±1.10	4.91±1.34	24°82.153'N 93°84.822'E	Haorang Sabal Leikai	Imphal West

Table 2. Physical properties of the selected *Dendrocalamus* species at different height positions

Species	Height position	Moisture content %	Water Absorption %	Specific gravity
		Mean±SD		
D. asper	Bottom	88.87±5.05[c]	85.38±9.41[b]	0.42±0.04[a]
	Middle	65.57±8.71[b]	80.83±7.07[a]	0.44±0.03[a]
	Top	49.07±5.61[a]	78.09±16.47[a]	0.44±0.02[a]
	Average	67.84±3.68[b]	81.44±6.49[ab]	0.44±0.02[a]

D. latiflorus	Bottom	85.69±5.95[c]	62.59±12.94[a]	0.46±0.02[a]
	Middle	68.68±6.68[b]	61.59±7.04[a]	0.51±0.03[b]
	Top	49.11±4.93[a]	59.19±4.18[a]	0.56±0.55[b]
	Average	67.83±4.08[b]	61.09±5.33[a]	0.61±0.06[b]
D. sericeus	Bottom	83.46±6.11[c]	63.71±7.77[a]	0.59±0.09[a]
	Middle	71.80±8.38[b]	68.42±10.95[b]	0.62±0.17[b]
	Top	51.80±6.09[a]	62.72±9.01[a]	0.70±0.07[b]
	Average	69.02±5.32[b]	64.95±6.95[ab]	0.63±0.08[b]
D. strictus	Bottom	74.37±13.72[c]	55.43±12.61[a]	0.57±0.05[a]
	Middle	57.78±15.50[b]	56.74±14.88[a]	0.62±0.08[b]
	Top	48.31±12.83[a]	56.56±11.88[a]	0.65±0.07[b]
	Average	60.15±12.93[b]	56.24±11.05[a]	0.51±0.02[a]

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

Table 3. Dimensional shrinkage of selected *Dendrocalamus* species at different height positions

Species	Height position	Shrinkage (%)			
		Radial	Tangential	Longitudinal	Volumetric
		Mean±SD			
D. asper	Bottom	1.89±2.83[a]	6.66±4.10[a]	3.33±2.79[b]	11.88±9.00[b]
	Middle	1.51±2.38[a]	4.63±3.53[a]	3.07±2.23[a]	9.20±4.57[a]
	Top	1.45±3.22[a]	6.88±7.65[a]	2.56±2.26[a]	11.89±8.43[b]
	Average	1.65±2.83[a]	6.06±5.46[a]	2.98±4.35[a]	10.99±8.01[a]
D. latiflorus	Bottom	0.96±1.55[a]	14.69±5.35[c]	8.33±3.72[a]	23.89±7.34[b]
	Middle	0.63±0.34[a]	11.67±4.55[b]	7.19±3.45[a]	19.25±6.15[a]
	Top	0.61±1.05[a]	9.18±4.45[a]	7.15±4.61[a]	16.94±5.94[a]
	Average	0.86±1.11[a]	11.85±5.27[b]	7.53±3.96[a]	20.03±7.08[a]
D. sericeus	Bottom	1.25±1.43[a]	2.87±1.05[b]	1.27±0.91[a]	5.40±1.97[a]
	Middle	1.92±1.59[b]	1.84±1.19[a]	1.00±0.73[a]	4.75±2.71[a]
	Top	0.92±1.15[a]	2.28±1.47[ab]	2.57±1.62[b]	5.76±2.58[a]
	Average	1.36±1.45[a]	2.33±1.31[ab]	1.61±1.34[a]	5.30±2.45[a]

D. strictus	Bottom	0.76±0.51^{a}	5.08±4.19^{a}	1.10±0.66^{a}	6.95±4.06^{a}
	Middle	0.78±0.51^{a}	5.77±3.88^{a}	1.71±0.97^{b}	8.26±4.22^{a}
	Top	0.75±0.60^{a}	5.52±4.70^{a}	1.81±1.89^{b}	8.17±5.07^{a}
	Average	0.79±0.54^{a}	5.46±4.24^{a}	1.54±1.31^{ab}	7.79±4.53^{b}

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

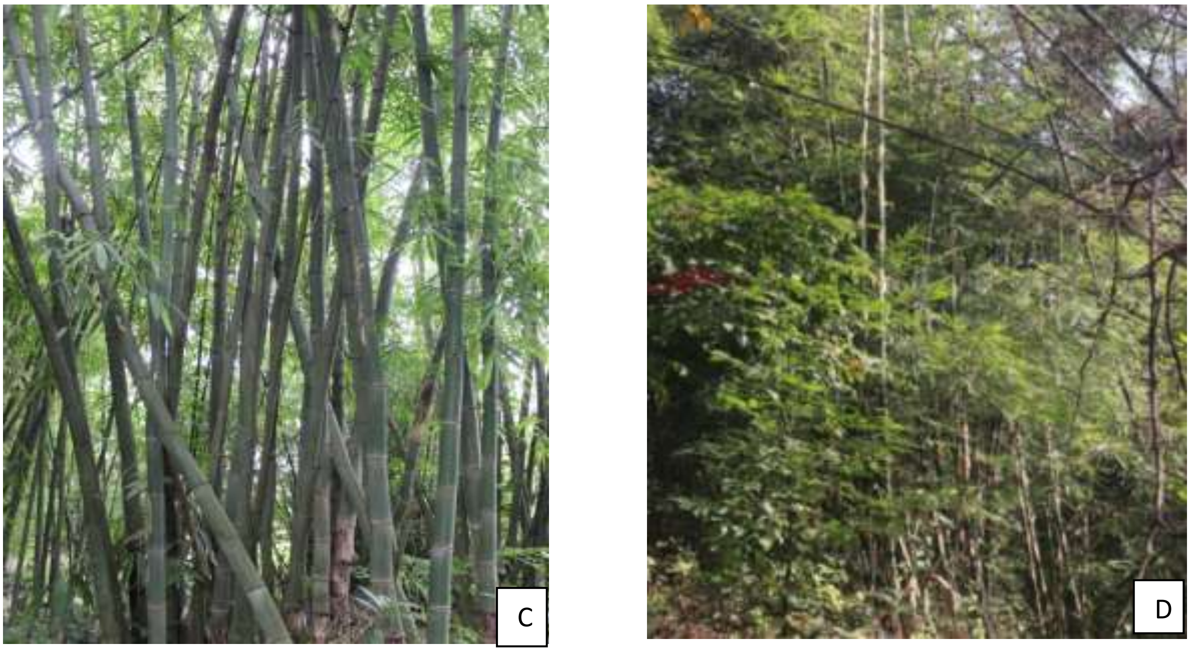
Table 4. Analysis of variance for physical properties among selected *Dendrocalamus* species

Height position	Moisture content (%)	Water Absorption (%)	Specific gravity	Shrinkage (%)			
				Radial	Longitudinal	Tangential	Volumetric
	(F value)						
Bottom	18.937**	49.320**	55.536**	82.929**	4.452**	43.869**	77.614**
Middle	11.757**	21.004**	24.159**	61.229**	4.919**	48.555**	72.099**
Top	1.274^{ns}	61.018**	217.529**	11.834**	8.590**	30.885**	27.235**

*The level of significance used are ns=non-significant, *= significant at P≤ 0.05 level, **=highly significant at P≤0.01 level.*

Dendrocalamus asper

Dendrocalamus latiflorus



Dendrocalamus sericeus *Dendrocalamus strictus*

Fig 1. Clumps of the selected four species of *Dendrocalamus.*