Research Article

Variation of Bulk and Basic Density among Two Thornless Bamboos across Agroclimatic Regions in Tamil Nadu, India

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Abstract

Studies were undertaken to elicit information on variation in basic and bulk density of *Bambusa balcooa* and *Bambusa vulgaris* across five agro climatic regions as well as different age gradations. Among the species *Bambusa balcooa*, *Bambusa vulgaris* and *Bambusa bambos*, *Bambusa balcooa* registered significantly higher values for basic density over *Bambusa vulgaris* and *Bambusa bambos*. The performance of *Bambusa balcooa* across the agro climatic regions *viz.*, North Eastern Zone, Northern Zone, Western Zone, Cauvery Delta Zone and Southern Zone was consistent for the density parameters and was found to be higher than the *Bambusa vulgaris* and *Bambusa bambos*.

Keywords: Bulk density; Basic density; Thornless bamboos; Agroclimatic regions*; Bambusa bambos*

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Introduction

Bamboos form one of the very important natural resources playing a major role in the livelihood of the rural people and also act as a source of raw material for cottage industry and pulp and paper industry [1]. Bamboos have immense potential to transform the rural/tribal economy of India and contribute to the sustainable development efforts of the country and 12 % of the Indian forests are bamboo forest. The demands of raw material for wood based industries are due to consumption of papers at 5 kgs in 2005 and 11 kgs in 2017 [2]. Considering the widening gap between demand and supply, almost all industries in the country are in the process of establishment of industrial wood plantation [1]. Though several Bamboo species are considered pulpable feed stock but for many species the systematic studies towards physical properties suitable for pulp and paper production has not been done [3]. In India particularly in Tamil Nadu two thornless Bamboos *viz., Bambusa balcooa* and *Bambusa vulgaris* have been promoted through various schemes as a source of multifarious industrial wood raw material. The thorn less bamboo genetic resources has revolutionized the productivity and profitability of the plantations in many states of the country [4]. However, *Bambusa balcooa* and *Bambusa vulgaris* were developed taking only yield of the plantation into consideration and not the culm quality particularly in terms of density. Increase in one per cent density will have tremendous changes in end use of the products. However, studies pertaining to screening the density among the thorn less bamboo genetic resources across the age gradations as well as agro climatic regions are dismally modest and such investigations were very feeble with respect to thorn less bamboo genetic resources and hence warrant the current investigation.

Materials and Methods

The thorn less bamboos species *viz.*, *Bambusa balcooa* and *Bambusa vulgaris* grown in five agro climatic viz., Western Zone, Northern Zone, North Eastern Zone, Cauvery Delta Zone and Southern Zone were chosen as the experimental material for the present study. From the each agro climatic regions, one year, two year, three year, four year and five year old plantations were selected. From each plantation, 25 clumps in three replications were selected for recording the biometric observations *viz.*, height, diameter, number of culms, internodal length, leaf length and leaf breath. In order to carry out density analysis of *Bambusa balcooa* and *Bambusa vulgaris*, selected single culm were felled from a clump and billets of 1 m length were extracted and converted into dust for analysis. Similarly, *Bambusa bambos* was also deployed for recording the density across the age gradations as well as agro climatic regions. These observations were used to compare the performance of thorn less bamboos viz., *Bambusa balcooa* and *Bambusa vulgaris* and assess its superiority over thorn bamboo.

The thorn less bamboos plantations viz., *Bambusa vulgaris* and *Bambusa balcooa* established at various age gradations viz., first year, second year, third year, fourth year and fifth year as well as in five agro climatic regions viz., western zone, northern zone, north eastern zone, cauvery delta zone and southern zone were selected for this current investigation. The basic and bulk density was carried out in the NAIP – Pulpwood Lab established at Forest College and Research Institute, Mettupalayam.

Basic density

The basic density of each culm sample was found out by using the displacement method [5] and the density was calculated using the following formula.

$$\text{Basic Density} = \frac{E_2}{(F+G)}$$

Where, E_2- Green weight (after soaking in water for 48 hours), F – Oven dry weight, G – Deflection of the needle in cm due to water displacement

Bulk density

Sample of chips were collected and their volumes were determined by placing them in a suitably graduated container. The mass of these chips was determined. The oven dry weight at particular volume is calculated based on moisture content of the chips [6].

$$\text{Bulk density in kg m}^{-3} = \frac{m}{v}$$

m – Oven dry weight of chips, V – Volume

Statistical analysis

The data were subjected to statistical scrutiny through an analysis of variance and treatment differences were tested by 'F' test [7]. The data collected form the *Bambusa balcooa*, *Bambusa vulgaris* and *Bambusa bamboo* across the age gradations as well as agro climatic regions were analyzed separately in single factor analysis, using AGRES software.

Results and Discussions

The present investigation was carried out in five agro climatic regions of Tamil Nadu with two thorn less bamboo species *viz,. Bambusa balcooa* and *Bambusa vulgaris* across different age gradations in order to elucidate the suitability of thorn less bamboos based on their density. The *Bambusa bambos* was used for comparison. The results of statistically analyzed data are presented here under.

A significant variation in basic density was observed at five per cent level as well as one per cent level among the thorn less bamboo species. The highest grand general mean of 460.38 Kg m^{-3} was registered by *Bambusa balcooa* followed by *Bambusa vulgaris* (448.72 Kg m^{-3}). The *Bambusa bambos* recorded only 449.70 Kg m^{-3} as its grand general mean. The *Bambusa balcooa* exhibited 2.13 percentage increases in basic density over *Bambusa vulgaris* across the age gradations as well as agro climatic regions. But the observed per cent increase in basic density over *Bambusa bambos* was 2.33 percentage. With regard to performance in various agro climatic regions in terms of basic density, *Bambusa balcooa* proved its superiority over *Bambusa vulgaris.* The maximum basic density was recorded by *Bambusa balcooa* in Western Zone (461.9 Kg m^{-3}). Whereas, *Bambusa vulgaris* registered only 449.5 Kg m^{-3}. This is 2.48 per cent increase of *Bambusa balcooa* over *Bambusa vulgaris*. *Bambusa balcooa* presented its superiority over *Bambusa vulgaris* by producing maximum basic density in first year (425.08 Kg m^{-3}), second year (442.03 Kg m^{-3}), third year (461.29 Kg m^{-3}), fourth year (485.59 Kg m^{-3}) and fifth year (487.94 Kg m^{-3}). However, in all these age gradations *Bambusa bambos* registered only minimum basic density in the order of 421.56 Kg m^{-3}, 439.84 Kg m^{-3}, 451.43 Kg m^{-3}, 461.46 Kg $m^{-3}$and 474.22 Kg m^{-3} in first year, second year, third year, fourth year and fifth year respectively (**Tables 1-5**).

Table 1 Variations in density among 1 year old thornless bamboos across the agro climatic regions of Tamil Nadu

S. No	Agroclimatic regions	Basic Density			Bulk Density		
		Bambusa balcooa	***Bambusa vulgaris***	***Bambusa bambos***	***Bambusa balcooa***	***Bambusa vulgaris***	***Bambusa bambos***
1.	Western zone	428.3**	405.3	422.3**	172.00	163.00	171.00
2.	Northern Zone	421.3	402.4	424.5**	171.00	164.00	173.00
3.	Northern eastern zone	423.7	405.7	421.4	175.00**	163.00	170.00
4.	Southern zone	426.6	406.7*	420.6	173.00	162.00	174.00*
5.	Cauvery delta zone	425.5	404.4	419.0	175.00**	166.00*	172.00
Mean		425.08	404.93	421.56	173.20	163.60	172.00
SEd		0.99	0.91	0.26	0.57	0.91	0.77
CD (0.05)		2.10	1.93	0.54	1.22	1.92	1.64
CD (0.01)		2.89	2.66	0.75	1.68	2.65	2.26

Table 2 Variations in density among 2 year old thornless bamboos across the agro climatic regions of Tamil Nadu

S. No	Agroclimatic regions	Basic Density			Bulk Density		
		Bambusa balcooa	***Bambusa vulgaris***	***Bambusa bambos***	***Bambusa balcooa***	***Bambusa vulgaris***	***Bambusa bambos***
1.	Western zone	444.0**	427.0	438.7	188.00	175.00	185.00*
2.	Northern Zone	439.4	421.5	437.4	187.00	174.00	182.00
3.	Northern eastern zone	442.6	429.6**	442.5**	188.00	178.00*	180.00
4.	Southern zone	443.5**	424.5	439.2	186.00	176.00	176.00
5.	Cauvery delta zone	440.7	426.0	441.4**	185.00	179.00**	181.00
Mean		442.03	425.76	439.84	186.80	176.40	180.80
SEd		0.48	1.30	0.24	0.75	0.75	1.64
CD (0.05)		1.01	2.76	0.51	1.59	1.59	3.48
CD (0.01)		1.39	3.80	0.70	2.19	2.19	4.80

Table 3 Variations in density among 3 year old thornless bamboos across the agro climatic regions of Tamil Nadu

S. No	Agroclimatic regions	Basic Density			Bulk Density		
		Bambusa balcooa	***Bambusa vulgaris***	***Bambusa bambos***	***Bambusa balcooa***	***Bambusa vulgaris***	***Bambusa bambos***
1.	Western zone	463.0**	445.3	449.0	195.00	181.00	191.00
2.	Northern Zone	457.6	442.4	452.2**	195.00	183.00	195.00*
3.	Northern eastern zone	464.2**	441.7	450.7	194.00	184.00	192.00
4.	Southern zone	460.3	448.1	453.5**	198.00**	181.00	189.00
5.	Cauvery delta zone	461.4	452.4*	451.8	193.00	184.00	190.00
Mean		461.29	446.01	451.43	195.00	182.60	191.40
SEd		0.44	3.00	0.24	0.89	0.99	1.68
CD (0.05)		0.93	6.35	0.52	1.88	2.10	3.57
CD (0.01)		1.29	8.75	0.71	2.60	2.89	4.91

Table 4 Variations in density among 4 year old thornless bamboos across the agro climatic regions of Tamil Nadu

S. No	Agroclimatic regions	Basic Density			Bulk Density		
		Bambusa balcooa	***Bambusa vulgaris***	***Bambusa bambos***	***Bambusa balcooa***	***Bambusa vulgaris***	***Bambusa bambos***
1.	Western zone	485.7	467.0	459.7	202.00	189.00	202.00
2.	Northern Zone	488.9**	463.5	460.2	204.00	192.00*	203.00
3.	Northern eastern zone	486.8*	469.6	462.6	203.00	191.00	201.00
4.	Southern zone	487.1*	464.7	463.5	206.00	190.00	204.00
5.	Cauvery delta zone	479.5	466.0	461.4	205.00	189.00	205.00*
Mean		485.59	466.20	461.46	204.00	190.20	203.00
SEd		0.53	1.79	0.21	1.08	0.67	1.22
CD (0.05)		1.13	3.79	0.45	2.29	1.42	2.58
CD (0.01)		1.56	5.22	0.62	3.16	1.96	3.55

Table 5 Variations in density among 5 year old thornless bamboos across the agro climatic regions of Tamil Nadu

S. No	Agroclimatic regions	Basic Density			Bulk Density		
		Bambusa balcooa	***Bambusa vulgaris***	***Bambusa bambos***	***Bambusa balcooa***	***Bambusa vulgaris***	***Bambusa bambos***
1.	Western zone	488.5	502.7**	478.5**	217.00*	200.00*	218.00**
2.	Northern Zone	493.1**	498.8	473.1	216.00	198.00	212.00
3.	Northern eastern zone	485.3	500.3	475.3	218.00**	199.00	214.00
4.	Southern zone	482.2	504.5**	472.3	209.00	197.00	211.00
5.	Cauvery delta zone	490.4**	497.3	471.9	211.00	196.00	216.00
Mean		487.94	500.72	474.22	214.20	198.00	214.20
SEd		0.53	0.62	1.06	1.24	0.76	1.06
CD (0.05)		1.11	1.32	2.26	2.63	1.60	2.25
CD (0.01)		1.54	1.82	3.09	3.62	2.21	3.11

The bulk density recorded significant highest grand general mean of 194.64 Kg m^{-3} in *Bambusa balcooa* over five years of growth period as well as agro climatic regions. However, *Bambusa vulgaris* registered only 182.16 Kg m^{-3} as grand general mean. The percentage increase of bulk density over *Bambusa bambos* was 1.18 percentage and over *Bambusa vulgaris* was 6.24 percentage. The *Bambusa balcooa* registered significant and constant higher bulk density over *Bambusa vulgaris* in all the agro climatic regions. Among the five agro climatic regions, the significant maximum bulk density was recorded in Northern Zone (195.6 Kg m^{-3}) followed by Western Zone (194.8 Kg m^{-3}) and North Eastern Zone (194.6 Kg m^{-3}). The minimum bulk density growth was observed in Cauvery delta zone (193.8 Kg m^{-3}). Bulk density across the age gradations as well as among the thorn less bamboo species was significant at one per cent level. Across the age gradations, *Bambusa balcooa* registered its consistent superiority over *Bambusa vulgaris* as well as *Bambusa bambos* (Tables 1-5).

The physical properties of culm material particularly basic density, bulk density are highly essential. The role of density on dimensional stability is studied as a basic concern while using any wood products. It is not usually desirable to use the material that experiences rapid moisture changes because moisture affects the physical and mechanical properties of wood materials [8][9]. In the current study, the physical properties *viz.*, basic density and bulk density studied had exhibited significant variation among *Bambusa balcooa* and *Bambusa vulgaris* as well as *Bambusa bambos*. The overall superiority was recorded by *Bambusa balcooa* across the age gradations as well as agro climatic regions. The variation due to bulk density was ranged between 193.80 kg m^{-3} and 195.60 kg m^{-3} in *Bambusa balcooa* and the difference in density may be due to the variation among the culms and within the culms [10]. The variation in bulk density was also reported between nodes and internode samples [8]. Similar difference was observed between *Bambusa balcooa* and *Bambusa vulgaris*. The variation in basic density among different species as well as across different agro climatic regions of bamboo may be due to the environmental influence on the culm anatomy. Similar results were also observed in *Eucalyptus globulus* [11]; Eucalyptus clones [12][13]; Eucalyptus species [14][15]; *Melia dubia* [16] and Bamboo species [17]. The wood density properties are of major importance for the production of quality pulp and paper. The amount of wood needed to produce one ton of air dried pulp is calculated from the density and pulp yield [18]. Similarly, the variability exhibited in most physical properties *viz.*, basic density and bulk density studied among different bamboo species in the current study also supports the results of earlier findings.

Conclusion

Based on the observations made on density among the species *Bambusa balcooa*, *Bambusa vulgaris* and *Bambusa bambos*, *Bambusa balcooa* performed consistently better over *Bambusa vulgaris* and *Bambusa bambos* and registered significantly higher values for basic density. The performance of *Bambusa balcooa* across the agro climatic regions *viz.*, North Eastern Zone, Northern Zone, Western Zone, Cauvery Delta Zone and Southern Zone was consistent for the density parameters and was found to be higher than the *Bambusa vulgaris* and *Bambusa bambos.*

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References

[1] S.S. Negi, 1996. Bamboos and Canes. Bishen Singh and Mahendra Pal Singh, Dehradun, India.
[2] R.T. Selvan, K.T. Parthiban and S.U.Khanna, 2017. Physio-Chemical Properties of Bamboo Genetic Resources at Various Age Gradations. Int. J. Curr. Microbiol. App. Sci, 6(9), pp.1671-1681.
[3] N. Krishnakumar, S. Umesh Kanna, K.T. Parthiban, and P. Rajendran, 2017. Physical properties of thorn less bamboos (Bambusa balcooa and Bambusa vulgaris). Agriculture Update. 12 (TECHSEAR-4): 946-951.
[4] H.D. Kulkarni, 2013. Pulp and paper industry raw material scenario – ITC plantation a case study. IPPTA, vol-25. No, 1 pp-79-88.
[5] G.J. Haygreen, and J.L. Bowyer. 1996. Forest products and wood science: An introduction. 3rd ed. Ames: Lowa State University Press. 558 p.
[6] Tappi. 2001. Laboratory manual on testing procedures. Published by the Director, Central Pulp and Paper Research Institute, Saharanpur (U.P.). TM 1-A9.
[7] V.G. Panse and P.V.Sukhatme, 1978. Statistical methods for agricultural workers. ICAR Publication, New Delhi, India.
[8] M. Ahmad and F.A. Kamke., 2005. Analysis of Calcutta bamboo for structural composite materials: Physical and mechanical properties. Wood Science and Technology, 39(4): 448-459.
[9] Anonymous. 1992. Advances in pulp and paper research. Indian Council of Forestry Research and Education, Dehra Dun.
[10] F.S. Malan and A.L. Arbuthnot. 1995. The Inter-relationships between density and fiber properties of South Africa grown Eucalyptus grandis.
[11] A.Santos, A. Ofelia and R.Simoes. 2004. Wood and pulp properties of two Eucalyptus globulus wood samples. In: N. Borralho et al. Eucalyptus in a Changing World Proceeding of IUFRO Conference, Aveiro. 11-15th October.
[12] S. Vennila, 2009. Pulpwood traits, genetic and molecular characterization of Eucalyptus genetic resources. Ph.D thesis. Tamil Nadu Agricultural University, Coimbatore.
[13] C. Yu Chen. 2006. Variation of wood density, pulp yield other wood properties for four Eucalyptus clones in Stora Enso Guangxi (China) plantation. M.Sc. Thesis, Lulea University of Technology. Sweden.
[14] K.F.S. Hamza, 1999. Basic density and some anatomical properties of Eucalyptus camaldulensis Dehn., C. citriodora Hook and E. paniculata Sm. grown as Ruvu, Tanzania. Ann. For., 7(2): 221-226.
[15] L.Rockwood, A. W. Ruide, A. Sally, J.Y. Zhu and J.E. Wiandy. 2008. Energy product options for Eucalyptus species grown as short rotation woody crops. Intl. J. Mol. Sci., 9: 1361-1378.
[16] V, Saravanan, 2012. Genetic evaluation and wood characterization of Melia dubia for pulp, anatomical, mechanical and energy properties, Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore.
[17] R. Thiruniraiselvan, 2012 genetic analysis, biometric attributes and pulping characterization of bamboos. M.Sc, Thesis, Tamil Nadu Agricultural University, Coimbatore.
[18] S. Storebraten, 1990. Sulfa tfabrikken – virkesforsyningens soppelplass Foredrag i PTF, Masseteknisk gruppe, 9 Oktober, Oslo, Norway. p. 25.

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