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RESEARCH ARTICLE :

Physical properties of thorn less bamboos (*Bambusa balcooa* and *Bambusa vulgaris*)

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SUMMARY : Studies were undertaken to elicit information on physical properties of *Bambusa balcooa* and *Bambusa vulgaris* across five agro climatic regions as well as different age gradations.Among the physical properties, *Bambusa balcooa* performed consistently better over *Bambusa vulgaris* and *Bambusa bambos* and registered significantly higher values for moisture content, basic density.

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KEY WORDS :
Physical properties, Moisture content, Basic density, Bulk density, Thorn less bamboos

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BACKGROUND AND OBJECTIVES

The growth of paper industry in India has been constrained due to high cost of production caused by inadequate raw material availability coupled with high cost of the available raw material. Hence, the paper industries in the country are looking for fast growing material to remain competitive and productive (Troy *et al.*, 2013). Under such circumstances Bamboos are considered one of the world's fastest growing tree suitable for pulp and paper industries (Tewari, 1996). The high growth rate of Bamboos are already witnessed in India and hence, exploited by several paper industries. In China the fibre shortage is met with production of one million tonnes of Bamboo pulp with mixed species (Zhao *et al.*, 2010). As far as India is concerned the bamboo available in the forest have been deployed for paper production till the recent past and the organized plantation development for pulp and paper production is only of recent origin (Tamang *et al.*, 2013). 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. 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 thornless bamboo genetic resources have revolutionized the productivity and profitability of plantations in many parts of the country (Kulkarni, 2013). However, these two species were promoted based on its rapid growth and yield potential and not on the quality perspectives. Under such circumstances,

studies have been carried out to assess the physical properties of two thornless bamboo along with one thorned bamboo (*Bambusa bambos*).

RESOURCES 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 in Tamil Nadu, India 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 of *Bambusa balcooa* and *Bambusa vulgaris* were selected. From each plantation, 25 clumps in three replications were selected. In order to carry out Physical properties of *Bambusa balcooa* and *Bambusa vulgaris*, selected single culm were felled from a clump and billets of 1 m length were extracted and chipped for analysis.Analysis was also carried out for the culms felled from all five agro climatic regions as well as across the age gradations in three replications. Similarly, *Bambusa bambos* was also deployed for physical properties 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 culm samples were subjected to analysis of physical properties which are essential to find out the suitability of the *Bambusa balcooa* and *Bambusa vulgaris* for pulping and paper manufacturing. The collected samples was subjected to analysis for Moisture content, Bulk density and Basic density as per Tappi methods (Tappi, 2001).

Moisture content :

100 g of culm chips were weighed and dried in an oven at 105°C for 8 hrs. From the loss in weight, the moisture content was calculated using the following formula:

$$\text{Moisture (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

Basic density:

The basic density of each culm sample was found out by using the displacement method (Haygreen and Bowger, 1982) 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.

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

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 (Panse and Sukhatme, 1978). The data collected from 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.

OBSERVATIONS AND ANALYSIS

The results obtained from the present study as well as discussions have been summarized under following heads:

Moisture content :

Significant difference in moisture content at one per cent level was observed among *Bambusa balcooa* and *Bambusa vulgaris* across the age gradation as well as agro climatic regions.The highest grand general mean over five years was registered by *Bambusa balcooa* (46.09%). The per cent increase in moisture content of *Bambusa balcooa* over *Bambusa vulgaris* was (7.82%). Whereas the per cent increase of moisture content over *Bambusa bambos* was 2.96 percentage (Table 1).

Table 1: Variations in moisture content (%) among the bamboos genetic resources across the age gradations and agro climatic regions

Location / Age	I Year			II Year			III Year			IV Year			V Year		
	B.balcooa	*B.vulgaris*	*B.bambos*	*B.balcooa*	*B.vulgaris*	*B.bambos*	*B.balcooa*	*B.vulgaris*	*B.bambos*	*B.balcooa*	*B.vulgaris*	*B.bambos*	*B.balcooa*	*B.vulgaris*	*B.bambos*
Western zone	52.68**	45.87**	56.87	49.84	40.21	49.35	47.86	38.48	41.18	42.57**	36.57**	36.78**	38.66	31.38**	32.48
Northern zone	51.33	44.78	56.38	50.16*	39.57	49.76**	47.69	38.62	41.57*	41.35	35.93	36.96**	39.77**	30.18	32.82**
Northern eastern zone	51.26	44.59	56.16	49.90	39.71	49.58**	46.40	39.02*	41.41	41.77	35.79	36.53	39.57*	30.54	32.69**
Southern zone	52.48**	46.21**	56.29	49.70	41.26**	48.14	46.67	39.46**	40.56	41.92	36.18	35.35	39.36	30.25	31.95
Cauvery delta zone	52.39**	45.57**	57.07	50.24**	40.24	48.85	47.37	38.83	41.29	42.35*	36.05	36.18	39.15	31.67**	32.18
Mean	52.03	45.40	56.55	49.97	40.20	49.14	47.20	38.88	41.20	41.99	36.11	36.36	39.30	30.80	32.42
S.E.±	0.1006	0.1058	0.1587	0.0911	0.0954	0.1119	0.1407	0.0545	0.1548	0.1317	0.0646	0.0858	0.1256	0.1108	0.0820
C.D. (P=0.05)	0.2132	0.2242	0.3364	0.1932	0.2023	0.2372	0.2982	0.1155	0.3281	0.2791	0.1371	0.1818	0.2662	0.2349	0.1739
C.D. (P=0.01)	0.2938	0.3089	0.4634	0.2662	0.2788	0.3269	0.4109	0.1591	0.4521	0.3846	0.1888	0.2505	0.3668	0.3236	0.2396

* and ** indicate significance of values at P=0.05 and 0.01, respectively

With respect agro climatic region wise performance, *Bambusa balcooa* exceled in moisture content significantly and reliably over all the agro climatic regions in the order of western zone (46.32%) followed by Cauvery Delta Zone (46.30 %) and north eastern zone (46.06%). However, *Bambusa vulgaris* registered only 38.50 percentage and 38.47 percentage and 37.81 percentage in Western Zone, Cauvery Delta Zone and North Eastern Zone, respectively (Table 1).

Regarding age gradation wise moisture content, *Bambusa balcooa* showed consistent and significant superiority over *Bambusa vulgaris* and *Bambusa bambos* at all the age gradations.

Basic density :

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 (Table 2). 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* (Table 2).

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 (Table 2).

Table 2 : Variations in basic density among the bamboos genetic resources across the age gradations and agro climatic regions

Location / Age	I Year			II Year			III Year			IV Year			V Year		
	B.balcooa	B.vulgaris	B.bambos	B.balcooa	B.vulgaris	B.bambos	B.balcooa	B.vulgaris	B.bambos	B.balcooa	B.vulgaris	B.bambos	B.balcooa	B.vulgaris	B.bambos
Western zone	428.3**	405.3	422.3**	444.0**	427.0	438.7	463.0**	445.3	449.0	485.7	467.0	459.7	488.5	502.7**	478.5**
Northern Zone	421.3	402.4	424.5**	439.4	421.5	437.4	457.6	442.4	452.2**	488.9**	463.5	460.2	493.1**	498.8	473.1
Northern eastern zone	423.7	405.7	421.4	442.6	429.6**	442.5**	464.2**	441.7	450.7	486.8*	469.6	462.6	485.3	500.3	475.3
Southern zone	426.6	406.7*	420.6	443.5**	424.5	439.2	460.3	448.1	453.5**	487.1*	464.7	463.5	482.2	504.5**	472.3
Cauvery delta zone	425.5	404.4	419.0	440.7	426.0	441.4**	461.4	452.4*	451.8	479.5	466.0	461.4	490.4**	497.3	471.9
Mean	425.08	404.93	421.56	442.03	425.76	439.84	461.29	446.01	451.43	485.59	466.20	461.46	487.94	500.72	474.22
S.E.±	0.9886	0.9102	0.2555	0.4767	1.3022	0.2397	0.4410	2.9960	0.2446	0.5329	1.7877	0.2124	0.5256	0.6245	1.0592
C.D. (P=0.05)	2.0957	1.9295	0.5417	1.0106	2.7606	0.5082	0.9348	6.3514	0.5185	1.1298	3.7899	0.4502	1.1142	1.3240	2.2454
C.D. (P=0.01)	2.8875	2.6585	0.7464	1.3924	3.8037	0.7002	1.2880	8.7511	0.7145	1.5566	5.2218	0.6203	1.5351	1.8242	3.0937

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Bulk density :

This trait 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 (Table 3).

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})(Table 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*.

The physical properties of culm material particularly basic density, bulk density, culm moisture are highly essential. The role of moisture content on dimensional stability is studied as a basic concern while using any forest 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 (Anonymous, 1992 and Ahmad and Kamke, 2005).

In the current study, the physical properties 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 moisture content ranged between 45.78 and 46.32 per cent. Particularly in western zone (46.32) maximum significant moisture content was evidenced. Similarly, the 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 (Malan and Arbuthnot, 1995). The variation in bulk density was also reported between nodes and internode samples (Ahmad and Kamke, 2005). Similar difference was observed between *Bambusa balcooa* and *Bambusa vulgaris*. The variation in basic density

Table 3. Variations in bulk density among the bamboos genetic resources across the age gradations and agro climatic regions

Location / Age	I Year			II Year			III Year			IV Year			V Year		
	B.balcooa	*B.vulgaris*	*B.bambos*	*B.balcooa*	*B.vulgaris*	*B.bambos*	*B.balcooa*	*B.vulgaris*	*B.bambos*	*B.balcooa*	*B.vulgaris*	*B.bambos*	*B.balcooa*	*B.vulgaris*	*B.bambos*
Western zone	172.00	163.00	171.00	188.00	175.00	185.00*	195.00	181.00	191.00	202.00	189.00	202.00	217.00*	200.00*	218.00**
Northern zone	171.00	164.00	173.00	187.00	174.00	182.00	195.00	183.00	195.00*	204.00	192.00*	203.00	216.00	198.00	212.00
Northern eastern zone	175.00**	163.00	170.00	188.00	178.00*	180.00	194.00	184.00	192.00	203.00	191.00	201.00	218.00**	199.00	214.00
Southern zone	173.00	162.00	171.00*	186.00	176.00	176.00	198.00**	181.00	189.00	206.00	190.00	204.00	209.00	197.00	211.00
Cauvery delta zone	175.00**	166.00*	172.00	185.00	179.00**	181.00	193.00	184.00	190.00	205.00	189.00	205.00*	211.00	196.00	216.00
Mean	173.20	163.60	172.00	186.80	176.40	180.80	195.00	182.60	191.40	204.00	190.20	203.00	214.20	198.00	214.20
S.E.±	0.5745	0.9055	0.7746	0.7483	0.7483	1.6432	0.8888	0.9899	1.6823	1.0817	0.6708	1.2166	1.2410	0.7550	1.0630
C.D. (P=0.05)	1.2178	1.9197	1.6421	1.5864	1.5864	3.4834	1.8842	2.0986	3.5663	2.2931	1.4221	2.5790	2.6308	1.6005	2.2535
C.D. (P=0.01)	1.6779	2.6450	2.2625	2.1858	2.1858	4.7995	2.5962	2.8915	4.9137	3.1594	1.9594	3.5534	3.6247	2.2052	3.1050

* and ** indicate significant of values at P=0.05 and 0.01, respectively

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* (Santos *et al.*, 2004); Eucalyptus clones (Yu Chen, 2006 and Vennila, 2009) Eucalyptus species (Hamza, 1999; Rock Wood *et al.*, 2008) *Melia dubia* (Saravanan, 2012) and Bamboo species (Thiruniraiselvan, 2012). 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 (Storebraten, 1990). Similarly, the variability exhibited in most physical properties studied among different bamboo species in the current study also supports the results of earlier findings.

Conclusion :

Based on the observations made on physical properties 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 moisture content, basic density.

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