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Morphological and Physical Properties of Bamboo Species in South Gujarat, India

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Abstract: Bamboo, a versatile, fast-growing woody perennial grass is considered as one of the important non-timber forest products. The morphology and physical characteristics of bamboo vary between species and among the culms which influence its utilization pattern for various industrial applications. Total five (4-year-old) culms per clump of six bamboo species *i.e*. *Dendrocalamus strictus*, *D. stocksii*, *D. hamiltonii*, *Bambusa vulgaris* (Green), *Bambusa balcooa* and *B.bambos* were selected and harvested to study the morphological and physical properties. The highest clump height and internodal length were in *B. vulgaris*, while the maximum clump girth was in *B. balcooa*. Culm mid-diameter and internodal mid-diameter were highest in *B. bambos*. However, the maximum yield per clump recorded in *D*. *strictus* followed by *B. bambos* and *B. balcooa*. The moisture content in each bamboo species varied inversely with basic density. The highest basic density and the lowest moisture content were in *B. balcooa* followed by *B. vulgaris*. The minimum and maximum hollowness proportion was in *D. stocksii* and *B. bambos*, respectively. Based on the morphological and physical properties, *D. strictus* and *B. bambos* performed better for biomass, while *B. vulgaris* and *B. balcooa* showed high basic density. Hence, bamboo culms and their clumps could be characterized by individual growth, biomass and physical variables for further utilization.

Keywords: Clump, Culm, Yield, Moisture content, Basic density

Bamboo, popularly known as 'green gold' is a fast-growing woody perennial grass and an important component of non-timber forest products that plays a key role in many stages of life and culture of people (Pathak et al 2017). The bamboo culms have been extensively used in building constructions, such as scaffoldings, housing roofs, trusses, ceiling, flooring, wall panelling, windows and doors; it is also used as structural materials for making fences, bridges and water-transportation facilities. Furthermore, it has been also processed into innumerable domestic value-added products such as, food containers, skewers, papers, hopsticks, handicrafts, furniture, flooring, boats, weapons, charcoal and musical instruments (Chaowana 2013). Hence, bamboo is called the poor man's timber in rural areas, because of its multipurpose utility in the human life. The individual upper ground part of bamboo is known as culm that comprises most of the woody fibrous material (Jiang and Peng 2007). Culm is the most utilized part of bamboo plant, its diameter tapers from the bottom to the top with the reduction in culm wall thickness (Biswas et al 2011). Bamboo culms have nodes between two internodes, its length, number and form depend on the bamboo species. Internodal length of culm is much shorter towards the base in comparison to internodal length towards the tip of the culm. Internodes of bamboo are generally hollow inside and form bamboo cavities. The culm wall thickness can vary significantly from thin walled to even solid depending on the bamboo species (Anonymous 2023). Bamboo has usually low density and high strength and stiffness compared to other plants (Osorio et al 2011). The properties of bamboo vary between species and along the culm. It is therefore, essential to study the different properties of every bamboo species for the proper end use.

The morphological characteristics such as the culms height, number of internodes per culm, internodal length, internode diameter, culm wall thickness and physical properties *viz*., moisture content, basic density and hollowness are considered as important factors in determining the strength and suitability of bamboo for various applications (Selvan et al 2017). Basic density, moisture content and hollowness proportion of bamboo are important because they reflect the amount of cell-wall materials per unit volume of culms and relate directly to strength properties. (Razak et al 2005). Hence, keeping in view of this, the present investigation was carried out on six important bamboo species such as *Dendrocalamus strictus* (Roxb.) Nees (Manvel or Bharat baans), *Dendrocalamus stocksii* (Munro.) (Goagiri baans), *Dendrocalamus hamiltonii* Gamble (Tama baans), *Bambusa vulgaris* Schrad. ex J.C. Wendl. (Green baans), *Bambusa balcooa* (Roxb.) (Beema baans) and *Bambusa bambos* (L.) Voss (Kantas baans) to evaluate the morphological and physical properties.

MATERIAL AND METHODS

Total 24 clumps of six different bamboo species *viz*., *D. strictus*, *D. stocksii*, *D. hamiltonii*, *B. vulgaris*, *B. balcooa* and *B. bambos* were selected randomly from 7 years old plantations (spacing 3.5m x 3.5m) established at the bambusetum, College of Forestry, Navsari Agricultural University, Navsari for the present study. The area is located at coastal region of South Gujarat at 20°95' N latitude, 75°90' E longitude and at an altitude of 12 m above the mean sea level. The climate of Navsari is tropical warm with fairly hot summer, moderately cold winter and warm humid monsoon with average annual rainfall of about 1600 mm. In the current study, five 4-year-old culms per clump were randomly harvested to evaluate the morphological characteristics such as clump height, clump girth, culm length, culm mid-diameter, internodal length and internodal mid-diameter of entire culm, culm weight and number of culms per clump and the yield per clump and physical characteristics such as moisture content, basic density and hollowness proportion.

The clump girth was measured at 1.5 m from the ground level. The yield per clump was calculated by multiplying average weight of randomly selected five bamboo culms per clump with number of culms in each clump. For measuring the physical properties of bamboo cross-sectional samples from each culm of bamboo species were collected from the internode of bottom (1.5 m from the ground), middle (mid of the entire culm) and top portion at the commercial height and the average value was used for further analysis. The moisture content of cross-sectional bamboo samples was calculated on the oven-dry basis, basic density was calculated by dividing oven-dry weight of the sample by green volume and hollowness was evaluated on the basis of surface area.

The data of all the parameters generated in the study were subjected to the statistical analysis using the statistical software package developed by Sheoran et al (1998).

RESULTS AND DISCUSSION

There was significant variation among the morphological properties of six bamboo species (Table 1). Among six species, the maximum culm weight (10.64 kg) was recorded in *B. bambos* followed by *B. vulgaris* while, the lowest culm weight (2.89 kg) was in *D. stocksii*. The maximum culms per clump (62.00) was in D. *strictus* followed by *D. stocksii* whereas, the minimum culms per clump (12.50) was in *B. vulgaris*. The highest biomass in terms of yield per clump was in *D. strictus* (299.9 kg) followed by *B. bambos* (Fig. 1). The highest clump height (11.25 m) and culm length (8.64 m)

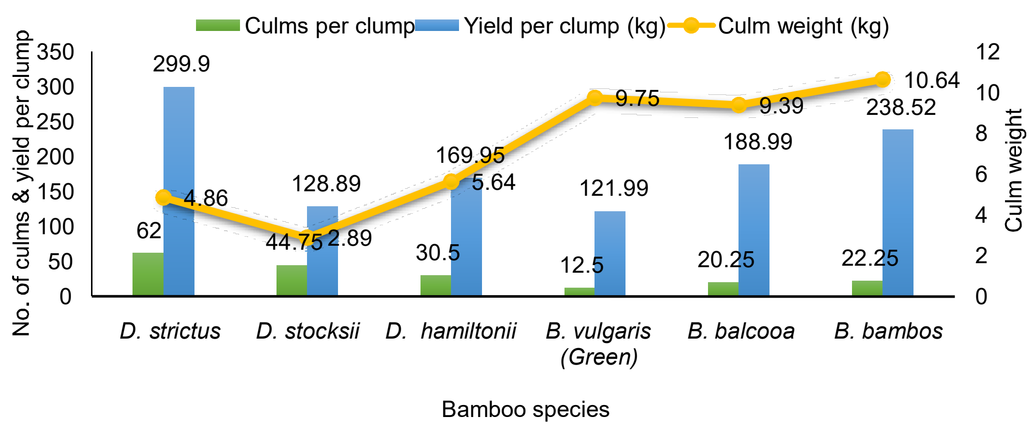

Fig. 1. Variation in culms per clump, culm weight and yield per clump of different bamboo species

Table 1. Variation in culm and clump dimensions of different bamboo species (Mean±SD)

Bamboo species	Clump height (m)	Clump girth (m)	Culm length (m)	Culm mid-diameter (cm)	Internodal length (cm)	Internodal mid-diameter (cm)
D. strictus	10.60±0.35	6.99±0.46	6.86±0.47	2.66±0.17	22.04±1.39	2.70±0.15
D. stocksii	8.99±1.39	5.06±0.34	6.59±0.40	2.03±0.14	27.16±4.51	2.20±0.16
D. hamiltonii	10.45±0.21	4.82±0.48	6.80±0.58	3.07±0.23	24.25±2.50	3.19±0.31
B. vulgaris (Green)	11.25±0.19	4.56±0.23	8.51±1.10	3.65±0.85	27.77±1.35	3.44±0.41
B. balcooa	11.23±0.50	7.38±0.72	8.64±0.89	3.17±0.17	25.82±0.43	3.37±0.23
B. bambos	11.13±0.49	4.71±0.35	6.95±0.74	3.87±0.69	23.48±1.82	4.02±0.73
CD (p≤0.05)	0.98	0.68	1.11	0.71	3.55	0.58

were in *B. vulgaris* and *B. balcooa*, respectively. However, the lowest clump height (8.99 m) and culm length (6.59 m) were in *D. stocksii*. The maximum (7.38 m) and minimum (4.56 m) clump girth was in *B. balcooa* and *B. vulgaris*, respectively. The average mid-diameter of entire culm (3.87 cm) and the average internodal mid-diameter of culm (4.02 cm) were largest in *B. bambos* and smallest in *D. stocksii*. The longest internodal length (27.77 cm) was in *B. vulgaris* and shortest internodal length (22.04 cm) was found in *D. strictus*.

Generally, the clump height, clump girth, culm length, culm diameter, internodal length, internodal mid-diameter, culms per clump, culm weight and yield per clump of bamboo vary from species to species (Kumar et al 2006, Nath et al 2007, Maya et al 2013, Amlani et al 2017, Singh et al 2018). In the present study, the clump height, culm length, culm weight, culm mid-diameter and internodal mid-diameter of *B. balcooa*, *B. vulgaris* and *B. bambos* were higher than other bamboo species. Pathak et al (2015) also reported maximum clump height, culm diameter and culm length in *B. balcooa, B. bambos* and *B. vulgaris* along with *B. tulda*. The maximum clump girth was recorded in *B. balcooa*, followed by *D. strictus* and the minimum clump girth was in *B. vulgaris*. However, Singh et al (2018) reported high clump girth in *B. vulgaris* (13.28 m). This may be due to the large spacing between two clumps and locality factors. Amlani et al (2017) observed long internodal length in *D. stocksii* and *B. vulgaris* and short internodal length in *B. bambos* and *D. strictus* which were similar to the results of present study. The highest biomass in terms of yield per clump was in *D. strictus* due to high number of culms per clump and average culm weight.

Considering the physical properties of bamboo, the moisture content, basic density and hollowness proportion of six bamboo species varied significantly (Table 2). The moisture content in each bamboo species varied inversely with basic density (Fig. 2). Usually, the moisture content of any lignocellulosic material decreases with increase in the basic density of that material or *vice-versa* (Kollmann and Côté 1968, Abd. Latif and Zin 1992). The highest basic density (0.693g/cm^3) and the lowest moisture content (64.58 %) was in *B. balcooa* followed by *B. vulgaris*, while the lowest basic density (0.505 g/cm^3) and high moisture content (121.66 %) was in *B. bambos* followed by *D. hamiltonii*. Similar results were also reported by Guleria et al (2020). Similarly, Singh et al (2018) reported highest basic density in *B. tulda* followed by *B. vulgaris*, *D. strictus* and *B. balcooa*. The minimum hollowness proportion (2.35%) was in *D. stocksii* followed by *D. strictus* (2.90%), whereas the maximum hollowness proportion (27.32%) was in *B. bambos* followed by *B. vulgaris* (24.85%). Singh et al (2018) also

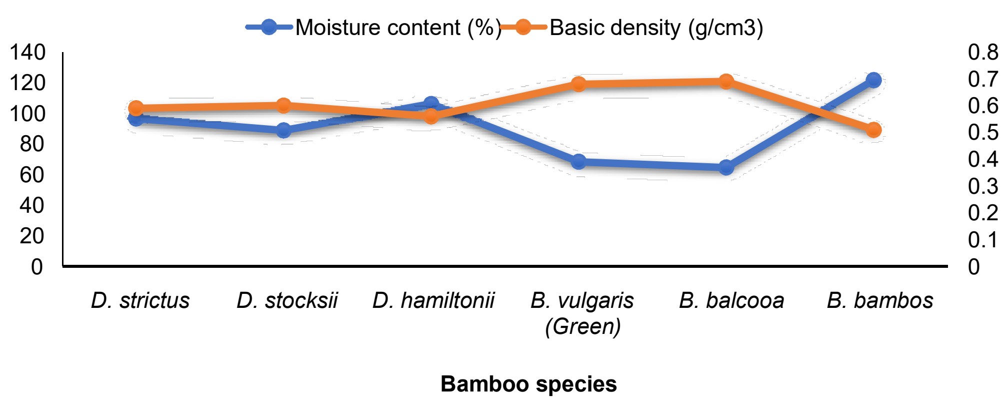

Fig. 2. Moisture content and basic density variation in different bamboo species

Table 2. Variation in physical properties of different bamboo species (Mean±SD)

Bamboo species	Moisture content (%)	Basic density (g/cm^3)	Hollowness (%)
D. strictus	96.63±5.60	0.588±0.03	2.9±3.21
D. stocksii	88.88±4.07	0.599±0.03	2.35±2.09
D. hamiltonii	106.04±3.47	0.559±0.03	11.2±2.17
B. vulgaris (Green)	68.31±3.72	0.679±0.03	24.85±3.10
B. balcooa	64.58±2.62	0.693±0.04	9.05±0.93
B. bambos	121.66±6.87	0.505±0.01	27.32±2.37
CD (p≤0.05)	6.91	0.04	3.64

reported more hollowness in *B. vulgaris, B. tulda* and *B. bambos* and less hollowness in *D. strictus* and *B. balcooa*.

CONCLUSION

Among six selected bamboo species, *D. strictus* and *B. bambos* performed better for biomass in terms of yield per clump in south Gujarat. Considering the physical properties, *B. vulgaris* and *B. balcooa* showed higher basic density than rest of the bamboo species. Hence, bamboo culms and their clumps could be characterized by individual growth, biomass and physical attributes for further utilization.

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