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Morphological Variations in Bamboos: A Review

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Introduction

Bamboos are woody stemmed grass belonging to family Poaceae subfamily Bambusoideae (Sanchez *et al*., 2019; Wu *et al*., 2009). It is categorized under non-timber forest product plant (NTFP) (Lugt *et al*., 2009). It is known by different local names in Asia and as called "friend of people, wood of the poor and "the brother" in China, India, and Vietnam, respectively (Waite, 2009; Farrelly, 1984). It contributes in achieving a number of United Nations 2030 Agenda Sustainable Development Goals - mainly, SDG1, SDG7, SDG 11, SDG 12, SDG 13, SDG 15 and SDG 17 (https://www.inbar.int/global-programmes/).

India is one of the richest countries of the world in terms of bamboo genetic resources with 136 species (125 indigenous and 11 exotic) belonging to 23 genera (ISFR, 2023). Major genera of bamboo found in india are *Arundinaria*, *Bambusa*, *Chimonobambusa*, *Dendrocalamus*, *Dinochola* and *Gigantochloa*. *Bambusa* and *Dendrocalamus* genus species found in tropical conditions, *Arundinaria* and its associates in the temperate region, *Dendrocalamus strictus* in the dry deciduous forests, *Bambusa bamboos* in the moist deciduous forests, *Gigantochloa rostrata* in the semi evergreen forests of Andaman Islands, *Bambusa tulda*, *Dendrocalamus hamiltonii* and *Melocanna bacciferra* commercially important bamboo species of the Eastern and the north-eastern India. The total bamboo bearing area in country is 15.46 million hectare (ISFR, 2023). Bamboos raw material is used for making about 1,500 known commercial products (Scurlock *et al*., 2000). Bamboo is used for variety of purposes such as fodder, pulp, timber, construction works, charcoal, edible shoots, cottage industries etc. Bamboo is a substitute for wood can be used for decorative and shuttering plywood, various board products such as block board, wafer board, strip board, laminated boards, roofing sheets; earthquake-resistant and long-lasting conventional housing and buildings, furniture, fuel-wood, charcoal and briquettes, active carbon, matchsticks, agarbattis, toothpicks, skewer sticks, etc.

With the emergence of novel and sophisticated techniques taking the lead in understanding the evolutionary process, morphological data sources, while informative and natural, must be combined with morphological studies to gain a much deeper understanding of variability.

Variation in quantitative morphological parameters

Bedell, (1997) conducted a thorough investigation into the morphological characteristics of taxonomic significance in bamboo. The morphological features studied were anatomy of culms, morphology of culms, anatomy of leaf and morphology of culm sheath. The findings were consistent with the previous bamboo identification tools (Ohrnberger and Goerrings, 1986). Stapleton investigated the variation in morphological features such as rhizomes, branch components, and inflorescence structure in depth. Biswas, (1999) presented a comprehensive note on morphometric traits on the taxonomic variability of *D. strictus* on bio climatically defined forest types (12 types and 5 subtypes) of India, whereas Das *et al*., (2006a) elaborated on *Bambusa tulda* to describe the species for morphological characters in order to enable the species identification at various stages of life cycle. He investigated 32 morphological characters (15 culm and 17 culm sheath) as well as detailed inflorescence and floral characteristics. The culm, culm sheath, inflorescence, and floral morphology were all described in accordance with the previous taxonomic description. Adhikari and Shrestha, (2008) conducted extensive research on the infra variation of *Bambusa nutans* and reported the culm height, culm diameter at breast height, culm wall thickness, internode length, culm sheath, culm sheath length and culm sheath breadth. Bakshi and Rasool, (2015) found significant differences among the quantitative characteristics *D. strictus* accessions. Several authors including Singh *et al*., (2006) studied three-year-old *D. strictus* plantations and recorded significant variations in morphometric parameters such as culm diameter, culm height, internodal length and leaf area. Singh *et al*., (2018) estimated growing biomass by measuring clump diameter, culm diameter and internodal length, clump height, and the number of culms per clump in six bamboo species viz. *Bambusa balcooa*, *Bambusa bambos*, *Bambusa nutans*, *Bambusa tulda*, *Bambusa vulgaris* and *Dendrocalamus strictus*. Rasool (2011) found significant differences between genotypes of *Dendrocalamus strictus* at both the morphological and biochemical levels. Nirala *et al*. (2016) also investigated variation in morphological features of *Bambusa tulda* such as height, diameter, internode length, colour, wall thickness, length-breadth of culm sheath, blade, and leaves. Tewari (2013) investigated low variability in four hill bamboo species using morphological tools in *Arundinaria falcata*, *Thamnocalamus falconeri*, *Sinarundinaria anceps*, and *Thamnocalamus spathiflorus*. Keshavarzi and Seifali (2007) morphological variation in Polypogon (Poaceae), a genus with approximately eighteen species was investigated worldwide. Rani (2020) found significant differences in morphological parameters such as clump circumference, culm number, young shoots, culm height, intermodal length, intermodal diameter, leaf length, ligule length, and culm sheath area among five *D. strictus* genotypes. Numerous studies have found significant correlations between morphological parameters (Janssen, 1981; Liese, 1987; Kitamura *et al*., 1975 and Latif *et al*., 1990). Bakshi and Rasool (2015) investigated a trend in the linear relationship between and within various morphological parameters, such as culm sheath area, which was significantly positively correlated with culm length, internodal length, internodal diameter, and leaf length. Culm length had a significant positive correlation with internodal length.

Variation in qualitative morphological parameters

The qualitative morphological characteristics like clump habit and culm nature, branches, leaves and rhizomes including sheathing organs the nature of clump and culm wall thickness and other characters viz. the increment in culm height and diameter at breast height, increments in clump girth, the presence or absence of culm sheath, culm texture and colour, node nature, branching habits etc., are found important to characterize and diagnose the age of a culm in the field (Banik, 2015). Various qualitative parameters such as culm straightness, culm small branching, clump density, culm colour, culm surface, hair on culm sheath, colour of culm sheath, culm sheath texture, ligule margin, hairs on ligule, pointed/tilt blade, leaf colour and leaf texture were studied to estimate morphological divergence. Morphological characteristics such as culm sheath presence or absence, culm texture and colour, node nature, branching habits, and soon have been found to be important in determining the age of a culm in the field (Banik, 2015). The colour, shape, and size of sheath characteristics of emerging shoots of various bamboo species vary greatly (Banik 1997a, 2000). The morphology of the culm sheaths is species specific and is thus used in the identification of bamboos at the species level (Chatterjee and Raizada, 1963). Culm sheaths can be persistent or quickly shed from culm internodes, depending on the species (Banik, 2015). Sarma and Pathak (2004) used leaf and culm sheath morphology to identify bamboos in *Bambusa nutans*, *Bambusa tulda*, *Bambusa balcooa*, *Bambusa bambos*, *Bambusa pallida*, *Melocanna baccifera*, *Dendrocalamus hamiltonii*, and *D. giganteus*. Triplett and Clark (2009) described the diagnostic morphological features of three *Arundinaria* species and commented on their phylogenetic relationship based on molecular and morphological data. Bakshi and Rasool (2015) assessed genetic variability in *Dendrocalamus strictus* (Roxb.) Nees accessions based on culm characteristics, culm sheath morphology, and ligule shapes.

Conclusion

Due to the unusually long gestation period and the lack of any other diagnostic tool, vegetative descriptors such as culm morphology and culm-sheath morphology including ligule and auricle are useful tools for bamboo identification.

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