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RESEARCH ARTICLE

Growth performance of selected bamboo species suitable for humid tropics of Kerala, India

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Abstract: A field study was carried out in two-year-old bambusetum established at main campus, Kerala Agricultural University, Thrissur, Kerala to evaluate the growth performance of selected six bamboo species of potential relevance to the humid tracts of Kerala, India. The selected bamboos included are *Dendrocalamus longispathus* Kurz; *D. brandisii* (Munro) Kurz; *D. asper* (Schult.f.) *Back.ex Heyne*; *Bambusa balcooa* Roxb; *B. vulgaris* Schrad and *B. tulda* Roxb. Growth parameters such as clump height, clump circumference (at 1.37 m), culm girth (at 1.37 m), internodal length and number of culms were observed in the field at periodic intervals of four months. The field result showed considerable variation in growth and productivity among the six bamboo species under study. Overall growth performance was better for *B. vulgaris*, *D. brandisii* and *D. longispathus.* For instance, *B. vulgaris* and *D. brandisii* were the toppers in terms of clump height, clump circumference and culm girth while *B. tulda* showed relatively poor growth for these parameters. Among the species, the highest internodal length was observed for *D. brandisii* and *D. longispathus* while *B. tulda* recorded the shortest internodal length. Number of culms per clump was highest for *D. asper* while it was the lowest for *B. balcooa.* Faster growth rendered by all the species except for *B. tulda* suggest their vast potential for integration in the farm lands of Kerala for enhancing the economic and ecological benefits to the farmers.

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Introduction

Bamboos are the arborescent grasses belonging to family Poaceae. They are fascinating plants with a wide range of values and uses and often referred as Green gold. Bamboos are known for their fast growth and high biomass production, some species often reach 40 m in height and 30 cm in diameter (Rao *et al*., 1998). Many bamboos need 3 to 4 years to mature before they are ready for harvesting and utilization (Wahab *et al.,* 2010). India is the second richest country of bamboo genetic resources after China. About 25% of bamboo species of the world are found in India distributed widely in almost all states. In India bamboos exhibit considerable diversity and has been distributed in diverse ecosystems. High rainfall regions of the country such as N-E states and Kerala are rich in bamboo diversity. Sharma and Nirmala (2015) reported that a total of 148 species in 29 genera of bamboos are currently expected to occur in India (both wild and cultivated). *Bambusa, Dendrocalamus* and *Ochlandra* are the most widely distributed bamboo genera in India which represent about 45% of the total bamboo species found in the country.

Kerala is one among the major diversity centers of bamboo in the country and 34 species of bamboos under seven genera have been recorded from this region (Somen *et al*., 2011). The edaphic and climatic conditions of Kerala permit the cultivation of diverse

species of bamboos. However, *Bambusa bambos* is the dominant species in the state that account for 96 percent of total bamboo distribution. Major consuming sectors of bamboo in the state are pulp and paper industry, traditional sector, export and households of which the consumption of pulp and paper is the major one constituting 0.085 million tons. The total consumption of bamboo and reed in the state is estimated as 0.256 million tons (Muraleedharan *et al*., 2007). By virtue of their economic potential bamboos play significant role in the prosperity and livelihood security of farming community of Kerala. Apart from other uses, many bamboos are edible that fetch high market value. Besides the economic advantages, bamboos offer excellent resilience to climatic extremes especially recurring floods and droughts. However, despite the potential for the cultivation of bamboos in Kerala, our understanding on potential bamboo species suitable for Kerala for various end uses are very limited.

In this backdrop, a field study was carried out to evaluate the comparative growth performance of six bamboo species of high economic and ecological importance to Kerala *viz*. *Bambusa balcooa, B. tulda*, *B. vulgaris*, *Dendrocalamus asper, D. brandisii, D. longispathus.*

Materials and methods

All the above bamboo species were planted in the bambusetum established in the Kerala Agricultural University Campus, Thrissur, Kerala (GPS readings) during June 2018 each in randomly placed blocks of size 20 x 20 m. The spacing between the clumps in each block was 5 x 5 m and a total number of 20 clumps were allocated per block. Six-month-old seedlings of the above bamboo species were planted during June 2018. Prior to the bamboo planting, the site was occupied by ruderal vegetation which were cleared as part development of bambusetum. The present trial was carried out during 2020 when the bamboos attained two years of age.

The field observations involved detailed assessment of growth and biometric attributes of the selected six bamboo species. The present experiment has been superimposed on the existing bamboo blocks in Completely Randomized Design with six bamboo species as treatments with six replications. Among the 20 clumps of each bamboo species within each block, six clumps were randomly selected for the study which were treated as the replicates. Growth parameters such as clump height, clump circumference, culm girth, internodal length, and number of culms per clump were observed at four monthly intervals. The growth performance of the selected six bamboo species was assessed over a period of 10 months from end of October 2020 to August 2021. The first observation was taken during October 2020 and second observation four months after (February 2021) while the third observation delayed to six months (August 2021) due to COVID 19 related restrictions. Ten culms from each clump were used for measuring the parameters like culm girth and internodal length. Culm girth was measured at breast height using a tailor tape and recorded in cm. The internodal length involved the measurement of length of the fifth internode from each culm which was measured with the help of tailor tape and recorded in cm. Also, the height of clumps in all the plots was measured from ground level to the tip with the help of Haga altimeter and recorded in meter. The circumference of clumps in all the plots was measured with the help of tape measured at the point corresponding to breast height (1.37 m). Also, the total number of culms for all the selected clumps was counted and recorded .

Statistical analysis

The data on growth biometric parameters were analyzed for treatment comparisons using statistical software R 3.6.1 version.

Result and discussion

All the six bamboo species under study showed good performance at two years after planting indicating their potential suitability for various end uses. Species variation in growth and their suitability for promotion in the agro-ecological conditions of Kerala are discussed here.

Clump height

Clump height in general varies from 10 to 14 m among the six bamboos under study at two years of age (Table 1). Among the species *B. vulgaris*, *D. brandisii*, and *D. longispathus* showed higher clump height during all the observational periods. At the final sampling period the corresponding clump heights were 14 m for *B. vulgaris,* 10 m each for other two species respectively. Over all, the height growth trends suggest considerable variation between species especially during the early growth phase. All the six bamboo species have great

Table 1. Clump height variation among the selected six bamboos species of two years age at Vellanikkara, Thrissur, Kerala.

Species	Average clump height (m)		
	October 2020	February 2021	August 2021
Bambusa vulgaris	10.00[a] ±1.73	11.42[a] ± 1.66	14 [a]±1.3
Dendrocalamus brandisii	10.00[a] ±1.22	10.82[ab]±1.91	12.92 [ab]±2.13
Dendrocalamus longispathus	9.83[a] ± 1.69	10.00[ab] ±1.82	12.25 [ab]±1.94
Bambusa balcooa	8.83[ab] ± 0.75	7.42[c] ± 0.74	10 [c]±1.14
Dendrocalamus asper	8.25[b] ± 1.57	9.25[b] ± 1.33	11.83 [c]±1.44
Bambusa tulda	4.33[c] ± 0.61	7.08[c] ± 1.32	10.08 [c] ±1.43
CD value (0.05)	1.58	1.79	1.89

potential for integration in the agriculture sector of Kerala. Interestingly, the clump height growth rates put by *B. vulgaris* and *B. balcooa* in the humid conditions of Kerala was considerably higher than elsewhere in India. For instance, reports from N-E zone of India suggest that clump height for *B. vulgaris*, *B. balcooa*, and *B. bamboos* respectively as 5.47 m, 7.52m and 3.95 m at three years of age which were far lower than our values (Krishnakumar *et al.,* 2017). Also reports from N-E states suggest that *B. balcooa* out performed *B. vulgaris* in general. However, the trend was reverse in the agro climatic conditions of Kerala where the *B. vulgaris* outperformed *B. balccoa.*

Clump circumference

Only marginal variation could be observed in clump circumference among the six species during the observational periods despite the considerable variation recorded in individual culm growth (Fig. 1). For all the six species, the clump circumference remained within range of 5-7.5 m. This range for the different species under study was much lower than *Bambusa Bambos*, most widely distributed species in Kerala (Amlani *et al.,* 2017). Despite the poor statistical significance, *D. asper* and *D. longispathus* showed higher clump circumference among all the species during the early period of observation. At the final sampling stage, again *D. asper* and *D. longispathus* recorded the highest clump circumference followed by *B. tulda* and *B. balcooa* while the lowest value was observed in *B. vulgaris*. It has been observed that there is increase in clump circumference of the individuals over time and this is consistent with reported gradual expansion of clump circumference of many bamboo species such as *B. balcooa*, *B. tulda*, and *B. vulgaris* at age of 2 and 3 years (Banik, 1988).

Clump spread is an important growth attribute for bamboos which has direct implications on the suitability for agro-forestry integration. Bamboos with lower clump circumference and compact growth are always preferred for agroforestry. May be, the species under study are comparatively compact and less spreading clumps as compared with the *B. bambos*, the predominant bamboo of Kerala which is reported to have higher clump circumference to the tune of 10.76 m (Kumar *et al*., 2005). Among the bamboos under study, *B. vulgris* showed better growth performance while the corresponding clump circumference was the minimum suggesting its better suitability for integration in multitier agroforestry systems such as home gardens of Kerala.

Culm girth

Among the six bamboo species considerable variation in culm girth was observed during the first two sampling periods (Fig. 2). However, there was some levelling in culm girth during the final sampling (2021). At the final sampling *D. brandisii* recorded highest culm girth

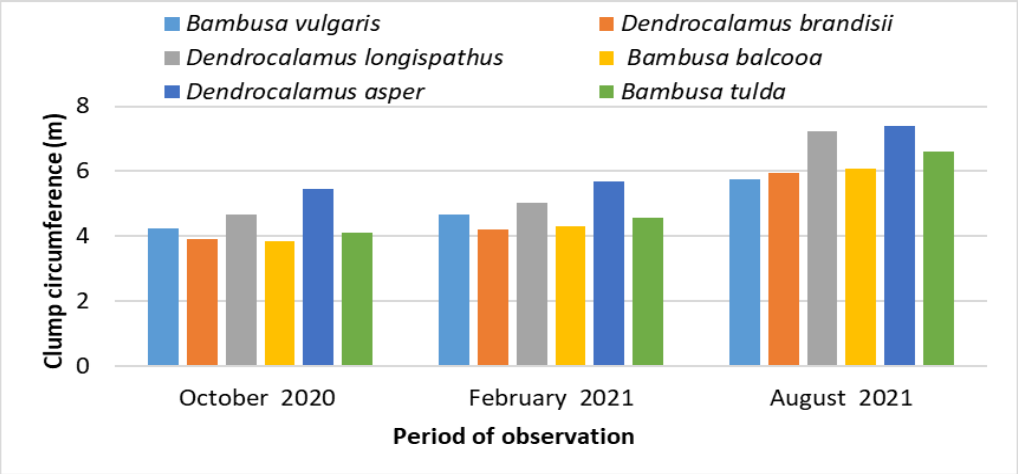

Fig. 1. Changes in clump circumference among the selected six bamboos species of two years age at Vellanikkara, Thrissur, Kerala.

followed by *B. vulgaris*. Culm growth, size, shape, etc. are very strongly related to the individual species character. Amlani *et al.,* (2017) on their study at Tapi, Gujarat reported culm diameter at breast height for bamboo species *viz*., *D. asper* (5.64 cm), *B. balcooa* (4.14 cm), *B. tulda (*3.97 cm), *B. vulgaris* (Green) (7.54 cm) and *B. vulgaris* (Yellow) (6.95 cm). Krishnakumar *et al.,* (2017) reported diameter of 3.37 cm, 3.19 cm and 4.40 m for *B. balcooa, B. vulgaris*, and *B. bambos* respectively at the end of three years age in north eastern zone of India. This clearly indicates the better performance of *B. vulgaris* and *B. balcooa* in the agro-climatic conditions of Kerala. Interestingly, the culm girth of *B. vulgaris* was considerably higher than *B. balcooa.* However, the trend was reverse in north eastern India where *B. balcooa* showed better culm girth than *B. vulgaris*. Among the species *B. tulda* showed the lowest culm girth among all the six bamboo species.

Internodal length

Internodal length is one of the most important growth character of commercial important among the bamboos. The average internodal length (fifth internode from the base) varied considerably among the species (Table 2). Obviously, *D. brandisii* recorded highest internodal length of 44.64 cm whereas, *B. tulda* had only half of the intermodal length of *D. brandisii* (22.16 cm). Similar to culm size, the internodal length is very strongly influenced by species character. However, for the same bamboo species, the internodal length may vary with soil and climatic variables. For instance, reports from Tapi, Gujarat suggest internodal length for *B. tulda* as 45.19 cm while in the present study the corresponding value for *B. tulda* was 22.16 cm (Amlani *et al.,* 2017). However, species such as *D. asper* showed uniformity in internodal length (35.64 cm) compared to the value reported from Gujarat, India (34.46 cm) suggesting strong species influence on internodal (35.64 cm) compared to the value reported from Gujarat, India (34.46 cm) suggesting strong species influence on internodal length. *B. vulgaris* also showed similar stronger species linearity in terms of internodal length.

The striking characteristic of all bamboo is that most bamboos have a hollow culm with many nodes and these nodes are non-uniformly distributed along the culm (Liese and Tang, 2015; Singnar *et al.,* 2015). The nodes have important role in reinforcing the mechanical functions for the culms and can prevent bending, buckling, and axial cracking (Wang *et al.,* 2014; Taylor *et al.,* 2015; Shima *et al.*, 2016). The distance between adjacent nodes is considered to be optimally configured to enhance the mechanical stability of each culm according to the design concept of light-weight and high-strength (Shima *et al.,* 2016). Most of the bamboos studied here have excellent strength properties and hence clearly demonstrate the optimal average internodal length for different bamboo species under study. Bamboo growth reports from N-E states suggest comparable results for 3-year-old bamboos. For instance, Krishnakumar *et al., (*2017) reported internodal length 28.00 cm, 24.44 cm and 19.60 cm for *B. balcooa, B. vulgaris*, and *B. bambos* respectively at the end of three years age in north eastern zone of India. The values for *B. balcooa* and *B. vulgaris* are comparable with our values.

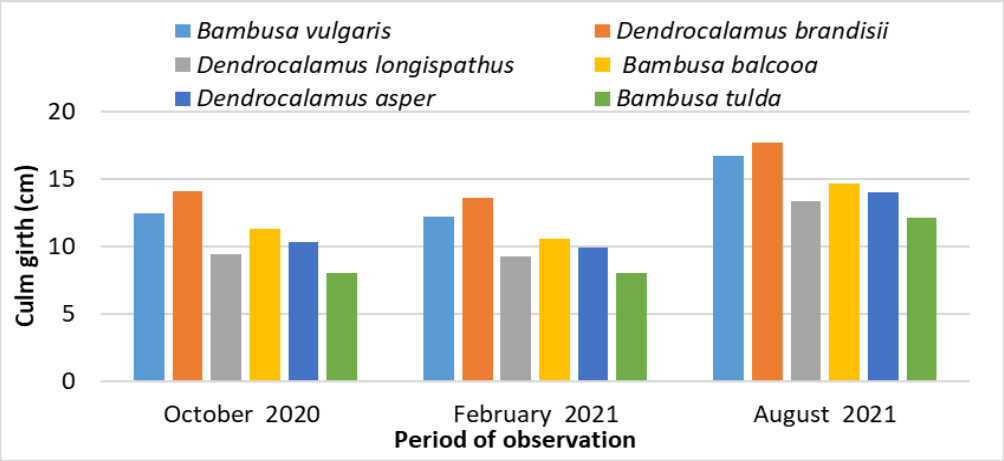

Fig. 2. Changes in culm girth among the selected six bamboos species of two years age at Vellanikkara, Thrissur, Kerala.

Number of culms per clump

Yet another growth factor of higher importance among bamboos is the culm number per clump. As suggested before, culm number per clump vary primarily with species and clump circumstance. For instance, among the six bamboos studied here, *D. asper, D. longispathus* and *B. tulda* showed higher clump circumference (Fig. 3). Interestingly, all these three species showed corresponding higher number of culms per clump in the present study. Yet another factor that decide the culm number is the culm girth which usually maintain inverse relation with culm number per clump. That is, smaller the culm girth, more the number can be accommodated per clump. This was obvious in the present study as well. For instance, bamboos with higher number of culms per clump such as *D asper*, *D. longispathus* and *B. tulda* showed lower culm girth of 14.02, 13.38 and 12.17 cm. It is always desirable to have bamboos produce optimal number of culms per clump with desirable culm size.

It is also interesting to observe that species like *B. balcooa* showed very low number of culms per clump in the present study (9.33) which was in conformity with other studies reported from Tapi, Gujarat (9.67) by Amlani *et al.,* (2017). However, culm number for species such as *D. asper, B. vulgaris* and *B. tulda* were higher than the present study which were 26, 48, 54 number per clump respectively. In yet another study from North-eastern India it was reported that number of culms were 18.99, 19.37 and 15.58 for *B. balcooa, B. vulgaris* and *B. bambos* respectively at the end of three years age (Krishnakumar *et al.,* 2017) which was much lower than our observed values suggesting that agro-climatic condition have a major role in deciding growth and productivity of bamboo species.

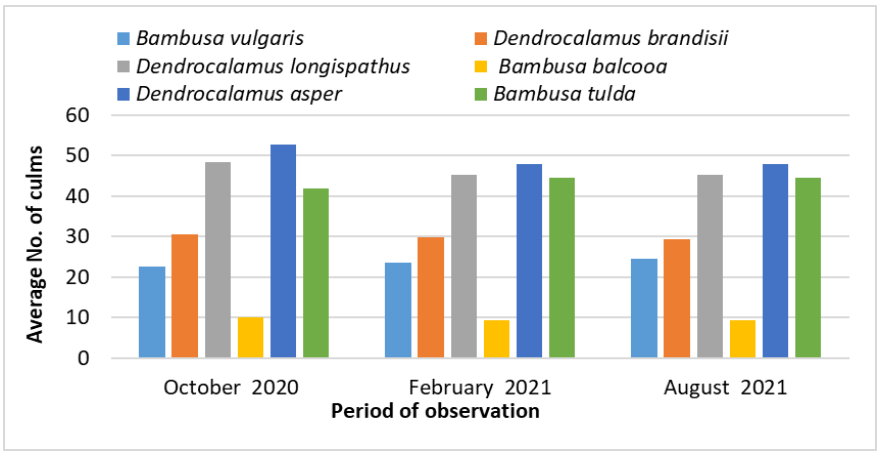

Fig. 3. Changes in number of culms among the selected six bamboos species of two years age at Vellanikkara, Thrissur, Kerala.

Table 2. Changes in internodal length among the selected six bamboos species of two years age at Vellanikkara, Thrissur, Kerala.

Species	Average internodal length(cm)		
	October 2020	February 2021	August 2021
Bambusa vulgaris	28.73[c] ± 2.01	28.93[b] ± 2.26	32.58 [b]±2.32
Dendrocalamus brandisii	41.72[a] ± 4.93	40.48[a] ± 4.81	44.64 [a] ±5.16
Dendrocalamus longispathus	34.20[b] ± 4.93	32.55[b] ± 5.11	36.23 [b]±5.38
Bambusa balcooa	23.51[d] ± 1.36	22.93[c] ± 1.67	26.99 [c]±1.72
Dendrocalamus asper	32.80[b] ± 2.55	31.80[b] ± 2.79	35.64 [b]±2.84
Bambusa tulda	18.64[e] ± 1.83	18.01[d] ± 0.94	22.16 [d]±1.45
CD value (0.05)	3.86	3.91	4.14

Conclusion

The present study attempted to explore the comparative growth performance of six bamboo species in the humid high rainfall conditions of Kerala revealed that *B. vulgaris* followed by *D. brandisii* and *D. longispathus* as most promising in terms of growth attributes. However, management objectives and market value are the primary consideration in deciding deciding the farmer's choice of bamboo species. Hence, depending on the management objective, any of these species can be suggested for farmer cultivation. For example, *D. asper* and *B. brandisii* are edible bamboos and fetch high price in the market while *B. balcooa*, *B. vulgaris, B. tulda* are structurally stronger bamboos which have unique market niche. Furthermore, the clump circumference of the bamboos under study showed compact spread as compared with *B. bambos*, the traditional bamboo of Kerala, suggesting their possible suitability for integration with the multitier agroforestry systems in Kerala.

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References

Amlani, M.H., Tandel, M.B., Prajapati, V.M., Pathak, J.G., and Behera, L.K. 2017. Assessment of growth variation among different species of Bamboo. *Int. J. Chem. Stud., 5* (6):1436-1439.

Banik, R.L. 1988. Investigation on the culm production and clump expansion behavior of five bamboo species of Bangladesh. *Indian Forester*, 114 (9):576-583.

Krishnakumar, N., Umesh Kanna, S., Parthiban, K.T., and Preethi Shree, M. 2017. Growth performance of Thorn less Bamboos (*Bambusa balcooa* Roxb. and *Bambusa vulgaris* Schrader ex J. C. Wendland). *Int.J.Curr.Microbiol.App.Sci.* 6 (4):32-39.

Kumar, B.M., Rajesh, G. and Sudheesh, K.G. 2005. Above-ground biomass production and nutrient uptake of thorny bamboo [*Bambusa bambos* (L.) Voss] in the homegardens of Thrissur, Kerala. *Journal of Tropical Agriculture* 43 (1-2): 51-56.

Liese, W. and Tang, T. K. H. 2015. Properties of the bamboo culm. *In*: W. Liese and M. Kohl (Eds.), *Tropical forestry, bamboo: the plant and its uses* Switzerland: Springer International Publishing. pp. 227–256.

Muraleedharan, P. K., Anitha, V., Krishnankutty, C. N., Gnanaharan, R., Vijayakumaran, N. P., Sanker, S., and Seethalakshmi, K. K. 2007. *Bamboo sector in Kerala: Base line data generation for developing an action plan,* KFRI Research Report No. 291, p. 105.

Rao, A. N., Ramanatha Rao, V., and Williams, J. T. 1998. *Priority species of bamboo and rattan*. IPGRI-APO, Serdang, Malaysia. 95 pp.

Sharma, M.L. and Nirmala, C. 2015. Bamboo diversity of India: an update. In: *Proceedings of the 10th World Bamboo Congress,* (17-22 September 2015), Damyang, Korea. World Bamboo organisation, Plymouth, MA, USA.

Shima, H., Sato, M., and Inoue, A. 2016. Self-adaptive formation of uneven node spacing in wild bamboo. *Physical review E*., 93 (2), p.022406.

Singnar, P., Nath, A.J., and Das, A.K. 2015. Culm characteristics and volume weight relationship of a forest bamboo (*Melocanna baccifera* (Roxb.) Kurz) from northeast India. *J For Res*., 26 (4): 841–849.

Somen, C.K., Seethalakshmi, K.K., Unni, K.K and V. P. Raveendran. 2011. Planting stock production of selected commercial species of bamboos. KFRI Research Report No. 391, ISSN. No.0970-8103. Pp- 5.

Taylor, D., Kinane, B., Sweeney, C., Sweetnam, D., O'Reilly, P. and Duan, K. 2015. The biomechanics of bamboo: investigating the role of the nodes. *Wood Sci. Technol.* 49 (2): 345-357. DOI10.1007/s00226-014-0694-4

Wahab, R., Mustapa, M.T., Sulaiman, O., Mohamed, A., Hassan, A. and Khalid, I. 2010. Anatomical and physical properties of cultivated two-and four-year-old *Bambusa vulgaris*. *Sains Malaysiana* 39 (4):571-579.

Wang, F., Shao, Z., Wu, Y. and Wu, D. 2014. The toughness contribution of bamboo node to the Mode inter-laminar fracture toughness of bamboo. *Wood Science and Technology 48* (6):1257-1268.