

Can *Dendrocalamus stocksii* (Munro.) be the ideal multipurpose bamboo species for domestication in Peninsular India?

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Abstract: *Dendrocalamus stocksii* is a thornless, mid-sized, erect, almost solid bamboo species endemic to the Central Western Ghats of India having considerable commercial importance. Its multifarious uses in agrarian sector is manifested in the way farmers maintain it in field bunds/farm boundaries and in homesteads. Due to the nearly solid nature of culms, it is replacing cane in the furniture industry. Evaluation of growth attributes of 100 clumps of *Dendrocalamus stocksii* randomly sampled along the Western Ghats showed considerable variation in culm and clump parameters. Analysis also revealed that certain parameters like culm wall thickness to diameter ratio and 5th internode length and diameter had better heritability estimates. The potential of *D. stocksii* for exploitation as edible shoots revealed that the macro nutritional composition was on par with three other local bamboo species. The cyanogenic glycosides responsible for the bitterness in shoots are found to be low in *D. stocksii*. Financial analysis reveal that from a plantation managed for culm and shoot production, a potential revenue of around Rs.4.5 lakhs (USD 6705)/year/ha from culms in the sixth year onwards and Rs. 1.6 lakhs (USD 2384)/year from juvenile shoots can be reasonably expected thus indicating the overall usefulness of the species in Central Western Ghats.

Key words: *Dendrocalamus stocksii*, edible shoots, domestication, Peninsular India

INTRODUCTION

Bamboos have long been cultivated and used by farmers for shelter, tools and implements for agriculture and materials for handicrafts. Farmers generally prefer to cultivate bamboo species to fulfill their social, ecological and economical needs (Nath and Das, 2008). Utilization potential of a species may be influenced by its growth behavior under exposed environmental conditions. *Dendrocalamus stocksii* is an extremely manageable bamboo species producing 12-18 culms from the third year onwards when rhizome offsets are used as planting material as in normally done in its natural distribution range in Konkan belt of Maharashtra State in Western India.

Dendrocalamus stocksii has considerable economic and ecological importance (Singhal and Gangopadhyay, 1999) and is endemic to Central Western Ghats of India (12° to 17.5 ° North latitudes) and is a widely domesticated species, usually

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incorporated in field bunds/farm boundaries and in homesteads (Viswanath *et al.*, 2013). This species finds large scale utilization in scaffolding, paper and pulp, crafts, construction, furniture, umbrella handles and poles. Culms of this species are thornless with non prominent nodes and better culm wall thickness to culm diameter (cw/cd) ratio, making it the most suitable species for furniture and construction industry in the lower diameter (< 2 inch) category. Owing to its multifarious uses and perceived importance, the National Bamboo Mission (NBM) in India has prioritized this species for large scale cultivation in Peninsular India. Hence, an attempt was made to understand various attributes of growth, utilization and socio-economic characteristics that would distinguish *D. stocksii* as an ideal species for domestication in Peninsular India.

MATERIALS AND METHODS

Growth characteristics of *D. stocksii* accessions

The growth attributes were evaluated by randomly sampling 100 clumps of *D. stocksii* along the Western Ghats. The selected clumps were analyzed for the quantity of old and new growing stock. The clump parameters *viz.* clump diameter, clump height, total number of standing culms (old + new), total number of harvested culms and current year emergents were recorded. The total number of standing culms and leftover stumps (remains of the harvested culms) along with the current year emergent culms with distinguishable intact sheaths were recorded. Five random culms each from matured and new emergent categories were evaluated for culm basal diameter, diameter and length of 5th internode using a digital vernier caliper. One mature culm each from the identified clumps was sampled from the base to measure its total height, commercial height (height upto 20 mm culm diameters) and extent of solidness (height upto which solidness was present in individual culm). The culm diameter and culm wall thickness was measured by cross cutting the culm at various height intervals to estimate the culm diameter to culm wall thickness ratio of the culm. The data was analyzed to assess the extent of variation for various parameters. The heritability values were estimated for various parameters for the entire data of all the genotypes following standard methods. The data was subjected to univariate analysis with SAS 9.3 statistical software and subjected to ANOVA and means compared using Duncan Multi Range Test (DMRT)

Nutritional composition of *D. stocksii* shoots

New culms or juvenile shoots in bamboos usually develop and emerge with the beginning of the rainy season in June/July, during which the young edible shoots are harvested. The shoot is actually a culm that emerges from the ground in full diameter and contains nodes and inter nodes in a vertically miniaturized form and the young shoots are tightly clasped with overlapping sheaths that have to be removed to extract the edible part. Shoots are normally harvested 7-14 days after the emergence from the ground and when the shoot height is about 15-30 cm. The outer sheath was removed and the inner creamy white portion was used for the analysis. The nutritional analysis was done for shoots collected from both the locations using different standard

methods. The moisture content was estimated by drying the sample at 100°C for 6-8 hours in hot air oven (AOAC, 2005), total protein was calculated by estimating the nitrogen present in the sample (AOAC, 1998), fat content was estimated by Soxhlet extraction with petroleum ether (AOAC, 2005), carbohydrate content was estimated by spectrophotometric method (AOAC, 2005), crude fibre content was estimated by alternate acid and alkali treatment of fat free samples (AOAC, 2005) and total ash content was estimated by charring the sample at 600°C for 5 hours in a muffle furnace (AOAC, 2005). The data obtained were subjected to statistical analysis.

Economics of *D. stocksii* cultivation

The profitability of *D. stocksii* cultivation was assessed through a Benefit – Cost Analysis (BCA) following Friday *et al.* (2000) and Purushothaman (2005). The financial returns from plantations raised for commercial exploitation were estimated four years after planting at a spacing of 4x4m on a per hectare basis. It becomes imperative to judge the viability of bamboo plantations through appropriate financial analysis, taking the time value of money into account. *D. stocksii* has a life span of around 40 years and is expected to keep producing shoots at least for 40 years, hence the time period taken for analysis was kept at 40 years. The number of harvestable culms per clump is calculated based on observation considering minimum retention of culms for clump sustenance. The indicators used for financial analysis include Net Present Value (NPV), Benefit Cost (B/C) ratio, Internal rate of return (IRR) and Equivalent Annual Income (EAI) at three different discount rates. BCA takes into account all the major costs incurred including labour, site preparation, pitting, soil working, fertilization, cost of planting material, transport, irrigation, fencing, watch and ward, protection etc. Costs and benefits were valued at farm gate or nearest market prices and discounted at 10 per cent, 12 per cent and 15 per cent based on prevailing interest rates. Discounted net benefits were added up to calculate NPV using the formula,

$$NPV = \sum_{t=0}^T (B_t - C_t) / (1 + r)^t$$

Where B_t is the benefits in year t , C_t is the costs in year t and r is the selected discount rate and t is the time period (Nair, 1993). IRR is calculated by finding the discount rate that makes NPV equal to zero and was calculated by using following equation,

$$IRR \% = L + \frac{NPV_L}{NPV_L - NPV_H} \times (H - L)$$

Where L is the lower discount rate, H is highest discount rate, NPV_L is the net present value results for the lower discount rate and NPV_H is the net present value results for the higher discount rate.

Equated annual income (EAI) gives NPV converted into the annual amount for 40 years rotation period which was calculated using the formula

$$EAI = NPV \frac{i(1+i)^n}{(1+i)^n - 1}$$

Where 'n' is the number of years in rotation

$$\text{Benefit-Cost Ratio} = \frac{\text{Total discounted benefits}}{\text{Total discounted costs}}$$

RESULTS AND DISCUSSION

Diversity and growth characteristics

D. stocksii species was widely domesticated along its geographical region of Western Ghats and maintained as isolated clumps on farm bunds, homesteads, boundaries and block plantations. As this species does not produce viable seeds, the species was extensively propagated through the vegetative rhizome offset method (a portion of rhizome from part of bottom culm) and conserved by the local inhabitants of this region. Clump parameters namely growing stock and diameter varied among the selected *D. stocksii* accessions along the Central Western Ghats. The number of old culms clump⁻¹ varied between 0 to 115 with an average of 62 culms clump⁻¹ (Table 1). All the clumps surveyed contained new culms and ranged between 3 to 38, with an average of (16 culms clump⁻¹) for the Central Western Ghats. It was observed that 35 percent of the culms in a clump were new and invariably contributed to the clump growing stock density. The clump diameter of the selected phenotypes ranged between 6.75 m to 0.23 m. Average culms basal diameter of old culms ranged between 9.0 mm to 70.06 mm with an average of 44.85. Culm diameter at fifth internode averaged at 37.39 mm with a low of 6.25 m and high of 57.32 mm. Interestingly, the culms at fifth internode length ranged between 52 cm to 11 cm among the selected *D. stocksii* accessions.

Table 1: Mean and Standard Deviation for culm and clump parameters of *D. stocksii*

Parameter	Mean	Maximum	Minimum
Number of New culms per clump	16 ± 9	38	3
Number of old culms per clump	40 ± 25	115	0
Total number of culms per clump	80 ± 40	233	10
Clump diameter (cm)	2.59 ± 1.14	6.75	0.23
Culm Basal diameter of old culm (mm)	44.85 ± 8.13	70.06	9.00
Culm fifth internode diameter of old culms (mm)	37.39 ± 7.21	57.32	6.75
Culm fifth internode length of old culms (cm)	33.62 ± 6.41	52.00	11.00
Culm height	10.70 ± 2.67	16.20	5.40
Commercial culm height (m)	3.03 ± 3.35	12.5	2.90
Height of culm solidness (m)	7.76 ± 2.05	13.00	2.90
Culm wall thickness to diameter ratio	0.33 ± 0.15	1.00	0.09

Values preceding ± are standard deviations

Culm height of the selected phenotypes which governs the enduse potential of a stick varied between 16.2 m and 5.4 m with an average of 10.70 m. The commercial height (culms height upto 20 mm diameter) ranged between 0.10 m to 12.5 m, but had a very wide standard deviation. So was the case with height of culm solidness from the base which ranged between 2.90 m to complete culm solidness (13.00 m). The maximum culm wall thickness to diameter ratio of the solid culm was 0.50, while the accession with thinnest culm wall had culm wall thickness to diameter ratio of 0.09. Heritability estimates of various parameters revealed that most of them had moderate values (Table 2). Comparatively, parameters like culm wall thickness to diameter ratio and 5th internode length contained better heritability estimates. These values provide information that most of the parameters of economic importance have moderate genetic control. Most tree species exercise similar genetic control over most parameters.

Table 2: Coefficient of Variation and Heritability values of different parameters of *D. stocksii*

	Genotypic Coefficient Variance	Phenotypic Coefficient of Variance	Heritability	Genetic Advance
Basal Diameter	15.85	23.17	46.74	9.89
5 th internode diameter	11.89	18.40	41.78	5.93
5 th internode length	21.09	26.04	65.57	11.86
Culm wall thickness	51.34	78.74	42.52	8.26
Culm diameter to wall thickness ratio	64.89	84.88	58.44	0.33
Culm height	12.05	25.61	22.16	1.10
Commercial height	8.55	25.35	11.37	0.44
Height of culm solidness	60.58	153.55	15.57	1.93

Commercial exploitation of *D. stocksii* culms

This species has a high commercial value and hence it was observed that the farmers retain the entire bulk of culms in their clumps and harvest once in two to three years. This may benefit in providing enough space to the new emerging culms in the following growing season so that they grow straight, efficient allocation of biomass stored in the rhizomes for new emerging culms and the size of the emerging culms is even. Besides its use in furniture making and in handicrafts, it is a component of various agricultural implements, as stakes in agriculture commodities like tomato, support-/prop for banana and grape cultivation, farm structures and as a live fence. It is also used for scaffolding, pulp and paper, crafts, construction, making baskets, umbrella handles, walking sticks etc. Larger culms (>4 cm diameter) has demand in furniture and construction sectors while smaller culms (<4 cm diameter) find use in agricultural implements, handicrafts, fencing material, etc. In riverine areas of coastal areas where country boats have an important role in transportation of goods, this is the most preferred species by boatmen. In recent times the culms have a ready market in the bamboo and cane based furniture industry and is currently sold at Rs.80 (USD 1.19) per piece (20 feet long). Lot of innovative designs have developed in household

furniture like chairs, tables, sofa sets, cots, partitions, outdoor furniture, benches etc. by Konkan Bamboo and Cane Centre (KONBAC) based in Kudal, Sindhudurg Dist. Maharashtra. The National Institute of Design (NID), Bangalore has also come out with some innovative designs in household furniture using *D. stocksii*. The market potential of this species can be increased further for the furniture industry if *D. stocksii* clumps with average culm diameter in excess of 40mm and a culm wall thickness to culm diameter ratio of 1:3 can be identified and propagated. This dimension of culms may help in better joinery and minimize cracking during its treatment and utilization.

Edible shoots from *Dendrocalamus stocksii*

Bamboo shoots are used as vegetable in many south Asian nations. Shoots are reported to be high in proteins, fibre, essential amino acids, bioactive compounds and minerals, and low in fat, which makes it an excellent food for direct consumption and in nutraceuticals (Nirmala *et al.*, 2011). The macronutritional composition (ash, protein, carbohydrates, fat, crude fibre) (AOAC 1998, 2005) and total cyanogen content (Bradbury *et al.*, 1999) of the species was analyzed in comparison with other commonly consumed species in the region like *Bambusa bambos* and *Dendrocalamus strictus* and the well-known 'sweet bamboo' *Dendrocalamus asper* which is solely cultivated for edible shoots. Study revealed that the macronutritional composition of *D. stocksii* was on par with the other three species and also the cyanogenicglucosides responsible for the pungent taste and bitterness in the shoots are found to be low in *D. stocksii* (Fig. 1&2).

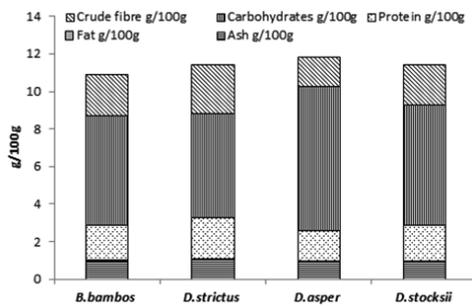


Figure 1: Macronutrient composition in g/100g of fresh bamboo shoots of *B. bambos*, *D. strictus*, *D. asper* and *D. stocksii*.

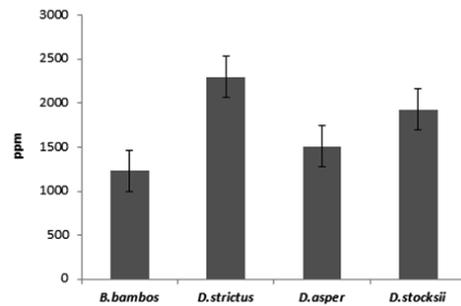


Figure 2: Total cyanogen content in ppm in fresh bamboo shoots of *B. bambos*, *D. strictus*, *D. asper* and *D. stocksii*.

Consumption of tender shoots is confined mainly to the Northeastern states of India and few parts of Southern peninsula like Coorg, South Canara in Karnataka and in Wayanad, Kerala where they are part of the traditional cuisine during monsoon when the shoots emerge. In other parts, especially surrounding forest areas, shoots of species like *B. bambos* and *D. strictus* which generally occur in the wild are consumed. Another interesting point is that restrictions imposed by Forest Department on the harvest of bamboo from the forests of Western Ghats have not really discouraged the exploitation of bamboo shoots for edible purposes by local communities. Shoots of *B. bambos* are freely available in some selected outlets even in Bangalore city during July-Sept. Although multipurpose species like *D. stocksii*,

B. balcooa, *D. asper*, *D. brandisii* and *D. hamiltonii* are widely cultivated, its potential as food is poorly recognized and there is a lack of awareness on sustainable management. Observations on the average number of new shoots emerging *D. stocksii* clumps per year at IWST field stations in Hoskote, Bangalore indicate that around 18-20 new shoots emerge as compared to 10-15 shoots in *B. bambos* and *D. strictus* and 8-10 shoots in *D. asper* grown under same conditions which indicate that after scientifically harvesting 20-30% of the emerging shoots for edible purposes, the mature culms can still be exploited for other commercial uses (Viswanath *et al.*, 2013).

Cultivation prospects

D. stocksii is currently a homestead species often planted on farm boundaries by the farmers. Commercial cultivation as pure block plantations at 4x4 m is currently undertaken by a few farmers along the Konkan belt of Western Ghats. Attempts have been made to incorporate *D. stocksii* along with agricultural crops especially in the upland agricultural systems in humid tropics along Western Ghats. Preliminary observations reveal that there is a significant improvement in culm emergence, culm collar diameter and diameter at fifth internode of emerging culms under intercropping (Bhave *et al.*, 2011). Bamboo intercropped with *Eleusine coracana* (finger millet) annually produced as much as 18 culms per clump while sole bamboo produced around 8 culms per clump only. This indicates better performance of bamboo after intercropping with agricultural crops at least in the initial years as bamboo is able to effectively utilize management inputs given to agriculture crops. Spacing plays a vital role in determining the yield of the agriculture crop. Though, there is little variation initially in agricultural yield from the base of the clump, that trend is unlikely to continue with age as competition for resources may become more evident and may cause reduction in yield in later stages (Viswanath *et al.*, 2012).

Economics of cultivation of *D. stocksii*

D. stocksii is considered as a potential bamboo species which can be commercially cultivated by farmers and has a high demand in the furniture industry. A spacing of 4 x 4m (625 plants/ha) is considered appropriate for this mid-sized bamboo species since the culms grow straight, have a diameter of around 40mm and is very less branching. An initial expenditure of around Rs.1.0 lakhs (USD 1490) is incurred per hectare for site preparation, pitting, soil working, fertilization, cost of planting material, transport, irrigation, weeding. From first year to fifth year, cost may be incurred in soil working, irrigation, watch and ward. Further expenditure from fifth year onwards may include tending, cleaning and soil working in clumps and annually for harvesting and processing of mature culms. Recurring costs may be in the form of fertilization with both organic and inorganic fertilizers and for plant protection measures. Returns can be expected from the fifth year onwards through selective harvesting of mature culms by maturity marking.

Observations in on-station trials at Hoskote (semi-arid conditions) and in on-farm trials at Koppa, Chickmagalur and Virajpet, Coorg (Tropical humid conditions) have indicated that *D. stocksii* has the potential to produce around 10 culms in the fourth

year and around 15 culms from the fifth year onwards. Around of 5 culms/clump may be harvested in the fifth year and around 10 extractable culms/clump/year from the sixth year onwards, to maintain continuous sustained productivity of the clumps. Nearly 25-30 shoots may be produced annually from 5th year onwards. However, of the 25-30 shoots that emerge, not all the shoots develop into fully grown culms. Around 15-20 develop into fully grown culms. To facilitate removal of around 15 culms/clump/year from the fifth year onwards, inputs like fertilization and irrigation will have to be given every year in dosages indicated. The harvested culms may be trimmed to get poles of 20 feet length which are readily sold at the rate of Rs.80 (USD 1.19)/ culm to buyers like Konkan Bamboo and Cane Centre (KONBAC), Kudal, Maharashtra. KONBAC with annual turnover of two million Indian Rupees (INR) (USD 29800), requires around 3,00,00 culms of 20 feet height and 40mm diameter for furniture making annually.

From a six year old clump around 10 culms of extractable size/ clump/ year can be obtained and 10 juvenile shoots/clump/year for edible purposes can be obtained which has been taken for financial analysis taking into account out retaining 30 % of the shoots for the future sustenance of the clump. The culms of 20 feet height can be sold at a rate of Rs.80/ culm. Around 300g of edible portion from shoots can be extracted if the shoots are harvested at the right size after removal of the sheath and nodal portions. This can be processed and sold at a minimum rate of Rs.80 (USD 1.19)/kg at farm gate prices. Potential revenue of Rs. 4.5 lakh (USD 6705)year⁻¹ can be expected from approximately 5630 fully grown culms of harvestable size and a revenue of around Rs. 1.6 lakh (USD 2384) year⁻¹ from approximately 5630 juvenile shoots from fifth year onwards after accounting 10 % mortality of clumps (Table 3).

Table 3: Financial analysis of *D. stocksii* plantations at different discount rates (in INR.)

Discount rates	Net Present Worth (NPV)	Benefit cost Ratio (B/C)	Internal rate of Returns (IRR)	Equated annual Income (EAI)
10%	26,73335.21	6.85	34.00%	2,73373.69
12%	20,56859.56	5.80	31.00%	2,49504.52
15%	14,43903.30	4.71	28.00%	2,17397.09

(USD = Rs.67.11 as on 30th August 2016)

CONCLUSION

Though the natural distribution of this species is in humid tropics with lateritic soil type, this species has a wide adaptability and comes up well in sub humid and semi-arid conditions under black and red soils as well (Viswanath *et al.*, 2013). It is the most preferred species after *B. bambos* and *D. strictus* by the farmers in Konkan belt of Maharashtra (Rane, 2015). Its non-thorny nature, loosely spaced culms facilitates easy management and is widely recommended for cultivation and research by various national agencies like National Bamboo Mission by Government of India (Haridasan and Tiwari, 2008). The main stakeholder of this species is the furniture industry which mainly uses this species as a substitute for cane for making high-end innovative furniture. The market potential of this species can be increased further for the furniture industry if *D. stocksii* clumps with average culm diameter in excess of 40mm and a

culm wall thickness to culm diameter ratio of 1:3 can be identified and propagated. This dimension of culms may help in better joinery and minimize cracking during its treatment and utilization. The emerging shoots could serve as additional source of nutrition during monsoon. Since the mature culms also have very high utility value, sustainable harvest of juvenile shoots could serve as an additional source of income for the farmers in Central Western Ghats and the species could truly be recommended as a multi-purpose bamboo species for large scale commercial cultivation. Presently, it remains confined to the coastal tracts where it is cultivated in homesteads, and in farm and community lands as live fences and/or block plantations. Multi-location trials have shown that this species performs well in humid, sub-humid and semi-arid zones, which expands the scope for its cultivation across peninsular India (Viswanath *et al.*, 2013). Commercial plantations of this multipurpose species may be highly viable in Peninsular India if it can be raised with appropriate scientific management practices. The overall results indicate that *D. stocksii* may have the potential to be designated as a truly multipurpose bamboo species catering to farm requirements, additional income generation and household food security thereby indicating the overall usefulness of the species in Central Western Ghats region.

ACKNOWLEDGEMENTS

The support extended by Karnataka State Forest Department, Dr. DBSKKV, Dapoli and IWST, Bangalore is acknowledged. The support and encouragement extended by National Bamboo Mission is also gratefully acknowledged.

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