Bambusa balcooa Roxb. : A multi-utility bamboo for domestication

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1. *Bambusa balcooa* - multipurpose bamboo
i. Syam Viswanath
ii. Sreekumar V.B.
iii. Sruthi S.

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Front Cover: A 30 years old *Bambusa balcooa* clump growing inside FRC, Velupadam, KFRI brought from Arunachal Pradesh.
Back Cover: A 30 years old *Bambusa balcooa* clump growing inside KFRI Peechi Campus.
Photo Credits: E.M. Muralidharan, V.P. Raveendran and Siril George

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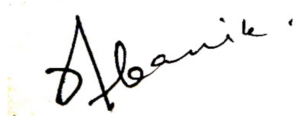
Foreword

In recent years, lots of interest have been generated for commercial bamboo cultivation in India and accordingly field activities started in most part of the country. Among different bamboos *Bambusa balcooa* is one of the most important and desired species to the farmer for raising plantation mainly due to its multipurpose utility mainly in housing and other major construction works including many number of 'pandals' or temporary structures for community gathering every year. No natural wild vegetation of *B. balcooa* has been reported.

It is only known in cultivation. Since unknown past, thus, the species has been extensively cultivated and become the most popular bamboo for to the farmers of Northeast, East Terai region, and upper central part of India including Bangladesh, Nepal and Bhutan.

Dr. Syam Viswanath and his colleagues have devoted considerable time and energy to study the ecology and cultivation needs of this important bamboo species and brought out, a very much useful and needed guide for the farmers and others. A few years earlier, Dr Syam along with some associated scientists have also contributed a few published documents on *Dendocalamus brandisii* and *D. stocksii*, the two most useful bamboos of south and south west India and provided know how to the planters and business entrepreneurs.

I appreciate the present good work of Dr. Syam Viswanath, Dr. V. B. Sreekumar, and Dr. S. Sruthi on *Bambusa balcooa* and believe that the booklet, like previous documents, will be of immense use not only for foresters and researchers, but all those concerned from planting to the utilization of this multipurpose bamboo species.



Dr. Ratan Lal Banik

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Preface

Bamboos with more than ten thousand uses in all the aspects of human life, is one of the most important plant groups useful to the world from time immemorial. Both herbaceous and arborescent types are included under bamboos and all are growing in the same geographical location. In India a reinvention of the potential of bamboo occurred during last two decades and several modern and traditional industries that depend on bamboo as raw material were established. Soon it was understood that available bamboo resources in the forests are limited and cannot cater to the requirement of upcoming industries. The reason being over extraction and lack of proper management. Integrated management of this sector was necessary and Two Bamboo Missions – National Mission on Bamboo Applications (NMBA) and National Bamboo Mission (NBM) was set up by Central Government.

One of the priority areas identified by these missions was enhancement of bamboo resources in non-forest areas by new plantations and increases in the productivity of existing areas by intensive scientific management. About fifteen sympodial and one monopodial species were identified to focus for this by NMBA in consultation with experts. While preparing the species specific package of practices for cultivation of these species many information gaps became evident. In fact, there was not much information on other species except two common ones like *Bambusa bambos* and *Dendrocalamus strictus*.

Bambusa balcooa Roxb. the densely tufted native bamboo of India was one of the important bamboo species identified for cultivation. It is popular in the homesteads of North eastern region and suitable for a wide variety of uses. In the absence of seed setting the species was easy to multiply with both micro and macro propagation methods. With the support of NBM it is widely cultivated all over the country and several doubts about suitable areas of cultivation, spacing, methods to increase productivity, and economic benefits are expressed by farmers.

In this context, the monograph on "*Bambusa balcooa* Roxb. A multi-utility bamboo for domestication" by the proficient team of researchers Drs. Syam Viswanath, V. B. Sreekumar and S. Sruthi is a valuable gift to the progressive farmers and also an asset to bamboo literature. It provides very authentic information with all aspects this species in one place. I really congratulate this team for this valuable contribution.

Dr. K. K. Seethalakshmi

Acknowledgements

We express our sincere thanks to Dr. Ratan Lal Banik and Dr. K. K. Seethalakshmi for providing necessary inputs and suggestions for improving this technical bulletin. We also thank Mr. Raveendran V.P, Dr. E. M. Muralidharan and Siril George KFRI for providing photographs. National Bamboo Mission, Govt. of India is acknowledged for providing financial assistance. Support by Dr. N. Barathi, CEO Grow More Biotech, Hosur is also gratefully acknowledged.

Authors

Contents

1. Knowing the species

Bambusa balcooa Roxb., belongs to subfamily Bambusoideae, tribe Bambuseae and is an important multipurpose species in India and surrounding regions. Locally the species is referred to as 'Baruwa' in Manipur, 'Bhaluka' in Arunachal Pradesh and West Bengal, 'Beru' in Meghalaya, 'Bhalu bans' in Nagaland and 'Barak' in Tripura and in fact the species derives its name from the Barak valley of Assam. The species is also found in certain parts of Bihar, Jharkhand, Uttarakhand and West Bengal. *B. balcooa* typically occurs at altitudes of up to 600m, with a preference towards soil conditions having good drainage and heavy texture. *B. balcooa* has multiple uses and it is because of this multifaceted nature of the bamboo, that this species of bamboo has been identified by the National Mission on Bamboo (NBM) India as one of the species for large scale cultivation. It is an extremely sturdy bamboo and is a preferred bamboo species for scaffolding. It is also used as raw material for paper making by the paper and pulp industry and for making agarbathi sticks along with *Bambusa tulda* by the agarbathi industry.

2. Distribution & Habitat

Bambusa balcooa has its origin in north-eastern part of India from where it has spread to other locations due to its multiple uses (Banik, 2000). This species was supposed to be introduced in the villages of Terai region of Uttarakhand by fleeing refugees from southern Bengal during the time of partition. The displaced refugees, some of whom were later rehabilitated in villages like Kalinagar, Udaipur, etc. in and around Pantnagar of this region had carried at least one offset of this valuable species along with their belongings and went on conserving the bamboo through regular cultivation again (Banik 2016). This was evident in some of these villages where huge isolated clumps of this species could still be seen. Now this species can be seen right across India and even up to the southern tip of Kerala. One of the largest Biotech companies dealing in Bamboo in India is Growmore Biotech India Ltd., Hosur. This company has produced 6 million plantlets of *B. balcooa* annually through tissue and branded it as 'Bheema' bamboo, in a reference to its extraordinary strength properties after the mythical character. Bheema depicted in the Hindu epic 'Mahabharata'. The company website (www.growmorebiotech.com) states that more than 6.4 million tissue cultured plantlets have been produced and marketed across the world since 2007 including India. The annual sale which was approximately 0.2 million in 2007-08 has now escalated to almost 1.5 million in 2016 which has also led to an increased spurt in commercial bamboo cultivation of this species in India. Today, it has spread to almost all parts of India with the exception of

Jammu and Kashmir, Himachal Pradesh and Haryana for use in construction and energy sector.

The species distribution map prepared using secondary data from different sources including GBIF data (Global Biodiversity Information Facility) shows that in addition to north-eastern India, occurrences have also been observed in Bangladesh and Nepal (Figure 1). The distribution map also reinforces what published literature (Rao et al., 1998 and Banik, 2000) also suggests that this bamboo species may have its origin in north-eastern part of India from where it spread to other locations. Some parts of Eastern India like West Bengal also showed the presence of the species. It also highlights the fact that Indian subcontinent has maximum occurrences of *B. balcooa*. In India, this species is cultivated in Khasi and Jaintia Hills, Garo hills of Assam, Arunachal Pradesh, Assam, Bihar, Mizoram, Nagaland, Tripura, Eastern Uttar Pradesh, and West Bengal (Ohrberger, 1999), apart from neighboring countries like Bangladesh (Banik, 1998) and Nepal (Shrestha, 1998). This species was reported from other South Asian countries like Indonesia (Widjaja, 1998), Vietnam (Ngo Thi Minh Duyen, 1998), Myanmar, besides Australia and South Africa (Ohrnberger, 1999) as either naturalized or in cultivation. This species has become naturalized in South Africa, where it is known as 'common bamboo' thrives under typical monsoonal climates with ample rain in the growing season (2500-3000 mm) and long dry seasons.

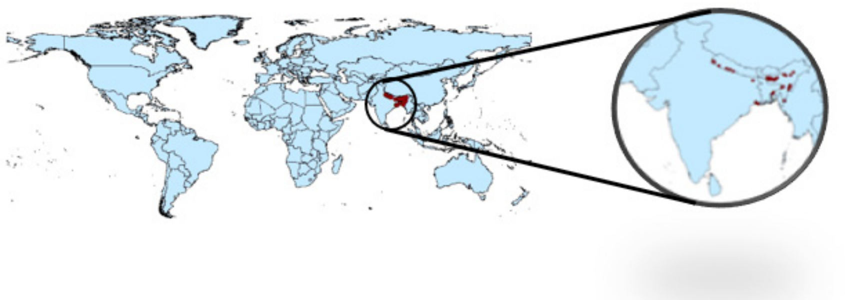


Figure 1: Natural distribution map of *B. balcooa*

3. Ecological niche modeling (ENM) in *Bambusa balcooa*

The ecological niche modeling prediction map of B.balcooa shows that natural distribution zones predicted high potential as compared to newly introduced other cultivated areas (Figure 2). The coastal areas were found more favorable to the species as compared to inland areas. Apart from the Indian subcontinent (Figure 3), South America and Africa also showed high potential for growing this bamboo species. In South America, Brazil was found to show favorable climatic conditions for growth of the species whereas in African continent the south west and south east coastal regions were found to be favorable and adjoining Madagascar was also found favorable. Overall, the southern hemisphere was slightly more favorable for the species as compared to the northern hemisphere. In India and the Indian subcontinent, it is observed that the species has a more favorable disposition towards the North-Eastern region and the Western Ghats. Additionally, a large part of central India also showed potential for growing *B. balcooa*. Nepal, Bangladesh and some provinces of China also showed considerable growth potential for the bamboo species.

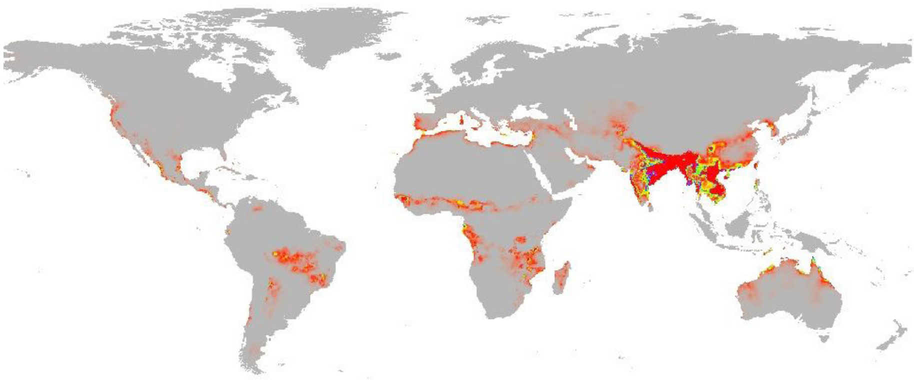


Figure 2: World map depicting habitat suitability prediction for *B. balcooa*

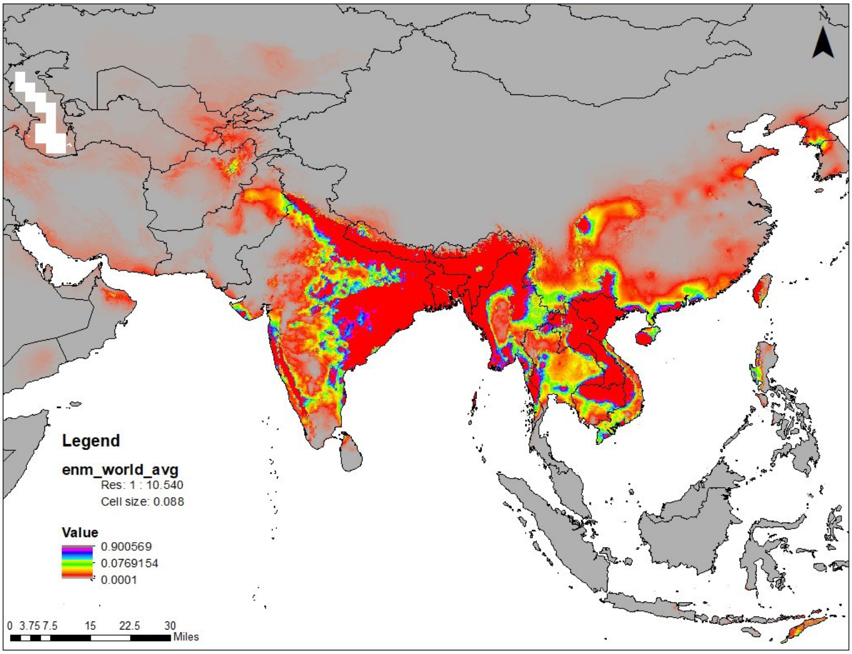
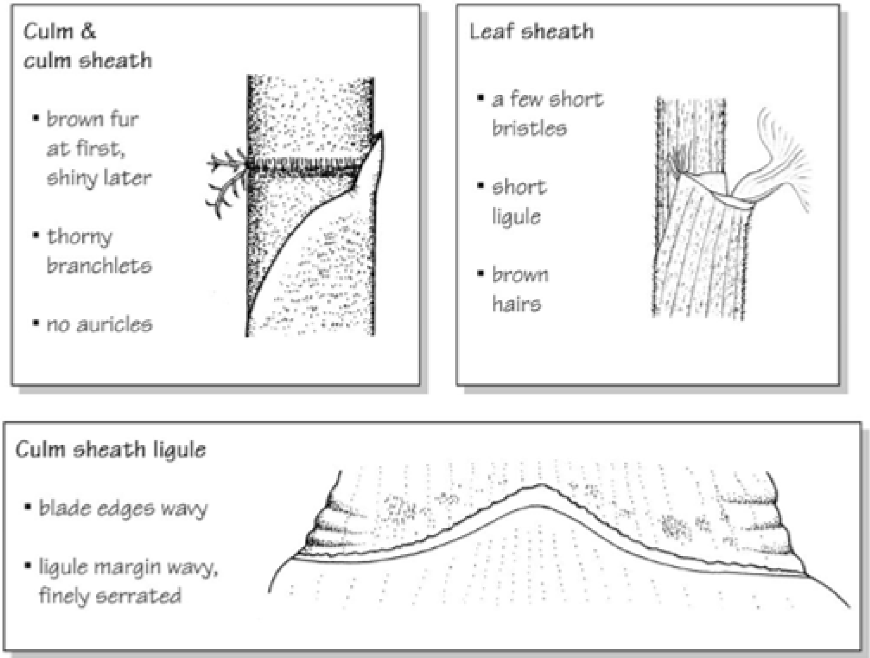


Figure 3: Ecological Niche Model predictions for *B. balcooa* in India and surrounding regions

4. Morphology

Taxonomically *B. balcooa* is a large thick-walled, densely tufted, sympodial bamboo species with strong branching and thorn-like branchlets lower down the culm. This species is easy to identify because of the brown hairs on the leaf sheaths and the small curving thorn like branchlets. Another important feature is the complete absence of auricles on the culm sheaths. The important morphological characteristics of *B. balcooa* have been provided in Table 1 and Figure 4. The species has chromosome number 2n = 72 with karyotype formula 2Asm + 42Bnm + 28Csm (Chakraborty and Sinha, 2010).

In Tripura, southern Assam and Sylhet, indigenous people have identified two distinct forms of culms known as ‘Sil’ and ‘Nali’ types (Banik 2000, 2016; Karmakar et al., 2013) in which the former is much stronger and harder than the later. The ‘Sil’ culm type is mostly preferred for heavy construction and furniture purposes because relatively short internodal length and distinct swollen supranodal rings up to 14-16 is found in nodal zone than the Nali type.



(Source: Stapleton, 1994)

Figure 4. Key identification features of *B. balcooa*

5. Propagation of *B. balcooa*

In bamboo, propagation is usually done by two main methods (a). macro-propagation ie. propagation of bamboos by use of offsets, culm or side branch cuttings and (b). micropropagation or clonal propagation which is the best achieved through Tissue Culture techniques.

B. balcooa has long flowering cycle of only once during its life time around 55-60 years or even >90 years (Banik, 1985) and the clump dies without seed production (Banik and Alam 1987; Tewari, 1992). The only way to raise bulk planting materials is by means of vegetative propagation or through tissue culture. Vegetative propagation through culm cuttings, branch cuttings, or rhizomes is difficult on account of few and bulky propagules, season specificity, and low rooting ability of the culm. Propagation through branch cuttings reported low success rates of 18.5% (Hasan, 1977), 40% (Seethalakshmi et al., 1983) and only 66.7% cuttings were found forming roots and baby rhizomes; while 60% rooting was obtained in pre-rooted and pre-rhizomed branch cuttings with 100 % rhizome formation (Banik, 1985).

Table 1. Morphological characteristics of *B. balcooa*

Morphology	**Typical Characteristic**	**Image of part**
Rhizome	Pachymorph, short necked	
Culm	Erect, dark green, becoming dull greyish with age, 15-30m high, 1-1.3 cm diameter nodes raised, hairy below with the nodal line, without nodal roots. Culm nodes swollen, pubescent	
Culm wall	Culms wall thickness varies from 2.5-3.0cm	
Culm Sheath	Deciduous, lower ones broadly and upper ones elongately triangular, longer than internodes, 25–35 cm long, 20-18 cm broad, dark brown hair on the upper surface, margins hairy, truncate at apex; auricles not prominent. Culm-sheath blade triangular; 15–20 cm long; pubescent culm-sheath orange or brown in color and covered sparsely with dark brown hairs, ligule 5-6mm, unevenly serrated, ciliate at mouth.	

Internode	Internodes of 20-25cm in long, thick walled, semi-solid, white pubescent in young culms, bud ovate.	 
Emerging young culms	Blackish and dark green young shoots with an acute tip.	

Inflorescence	Large panicle, clustered at the nodes; in globose clusters; dense; with glumaceous subtending bracts. Spikelets compressed, 1-1.5 cm long, 6-7 flowered with terminal imperfect flower, rachilla very short, 0–2 empty glumes; glabrous, faintly nerved, persistent; shorter than spikelet; palea nearly as long as lemma, stamens 6 (-7 or 8), ovary oblong, hairy, style hairy dividing into 3, plumose stigmas.	

5.1. Macropropagation in *B. balcooa*

Propagation through culm cuttings and macro-proliferation

Generally rooting of culm cuttings is affected by several factors like age, season, position, source of planting material, hormone levels, growing conditions etc., Culm cuttings can be collected from one-year-old culms of healthy growing clumps especially 50 cm above the ground and ideal season for collection is March. Then it can be cut into smaller sections leaving 2-4 nodes on each section (Figure 5). Leaves and side branches of each section can be pruned to a length of 15cm. Nursery beds could be of 1.20 × 5 m size made of bricks ideally filled with three layers of river sand. Culm cuttings may be treated with 200 ppm NAA by pouring 200ml of solution into the internodal cavity. The hole can be covered with tape to avoid spilling of solution from the internodal cavity (Figure 5a). Culm cuttings can be placed the nursery beds at spacing of 20 cm horizontally in such a manner that the obliquely cut surface faces upward (Figure 5a). The adjacent hollow sides can be filled with sand and cuttings can be planted 5-7 cm below surface on the bed covered with a thin layer of fine sand. One week prior to planting, the nursery beds may be drenched with insecticides and fungicides to prevent the attack of termites and fungi.

Sprouting from the nodes takes place within a week. Initially a cluster of sprouts develops and completes its height growth within one month. Natural thinning occurs retaining two to five dominant sprouts. Slender roots develop within one month and rhizome development takes place within three to six months. At this stage the rooted cuttings can be transferred to poly bags for macro-proliferation (Figure 5b.). If rooting occurs in two nodes, they can be separated into two plants by cutting in the middle.

5.2. Micro-propagation of *B. balcooa*

IWST, Bangalore has developed micropropagation technique for *B. balcooa* (Tresa et al., 2018). For micropropagation of *B. balcooa*, nodal shoot segments are surface sterilised and inoculated in MS liquid medium containing additives, 0.25 mg/l NAA and 0.1 – 0.25 mg/l TDZ for shoot induction. The shoots are multiplied in MS medium containing additives, 25 mg/l adenine sulphate, 1 – 2 mg/l BAP and 10% coconut water, and subcultured on to fresh medium till sufficient number of shoots are obtained. The *in vitro* grown shoots are rooted in half concentration MS medium containing additives, 2 – 4 mg/l NAA and 0.2 – 0.5mg/l BAP, followed by hardening (Tresa et al., 2018).

Similarly, for micropropagation of *B. balcooa*, the best sprouting of buds was obtained on MS + BAP (2mg/l) + Kin (1mg/l) + Sucrose (2%) (Muralidharan and Seethalakshmi, 2017). Even though the sprouting of axillary buds was 100% cultures damage due to bacterial and fungal contamination are high. Pretreatment with a combination of 1.5% Bavistin and a mixture of Cefotaxime and Tetracycline at 200 mg/l each for 45 min may be effective (Figure 6).

Muralidharan and Seethalakshmi (2017) has reported that multiple shoots of *B. balcooa* were induced and prolific multiplication of shoots took place when sprouted nodes along with the original explants are transferred to liquid MS basal media supplemented with Cytokinins. 2 mg/litre each of BAP and Kinetin and 3% sucrose are ideal. Subculturing may be carried out at 10-day intervals with splitting of the shoot growth clusters into 2-3 smaller clusters and inoculation into fresh media in separate bottles. Multiplying shoot cultures in glass bottles required subculture every 10 days to maintain them in healthy condition without browning. Larger rigid plastic containers are ideal and it is also possible to maintain the shoot cultures beyond 10 days. If media volume was increased to 200 ml and culture carried out in large containers the subculture period could be increased beyond 20 days. When shoot cultures can be transferred to polypropylene bags, shoot multiplication was found to be as good as in rigid plastic containers. Increased availability of light through the clear thin walls of the bags enabled several cultures to be stacked side to side

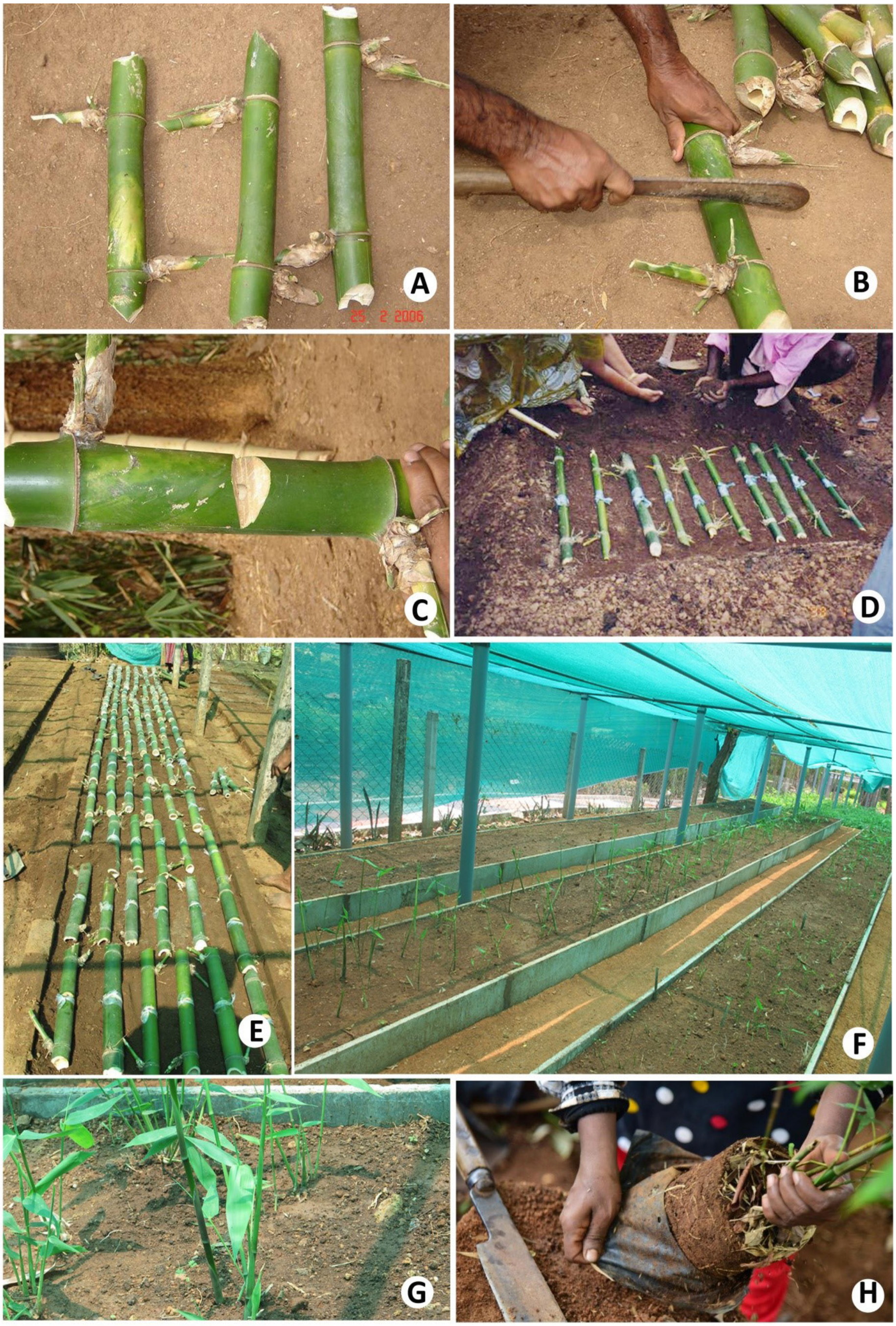


Figure 5a. Different stages in macro-propagation using culm cuttings of *B. balcooa* (A –H)

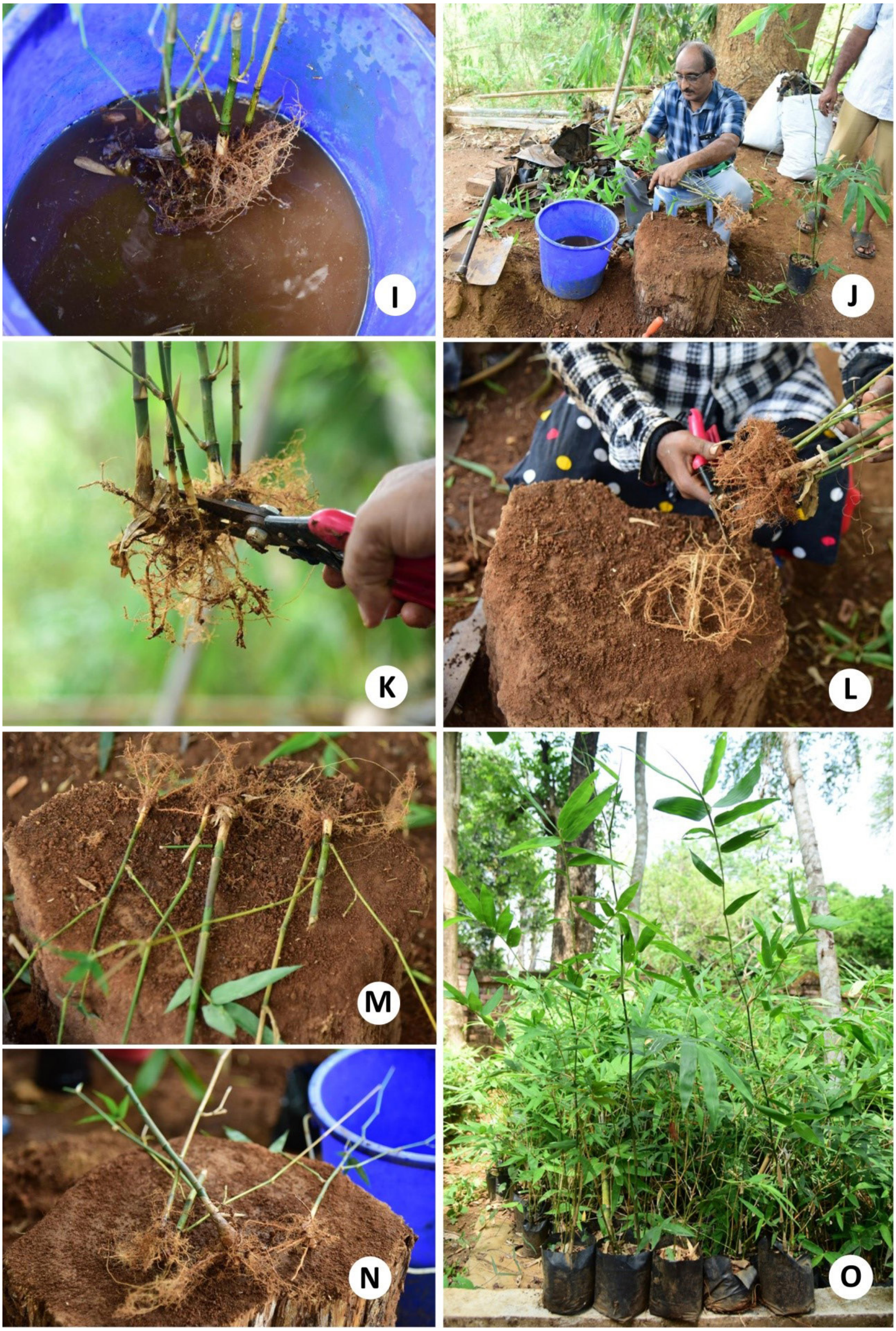


Figure 5b. Different stages of macro proliferation in *B. balcooa* (I –O)

without light availability getting reduced substantially. Since the bags are inexpensive when compared with rigid glass or plastic containers considerable savings in cost of production can be achieved. The comparison of *in vitro* rooting treatments of *B. balcooa* shows that highest percentage of rooting was obtained in liquid media (Table 2) and percentages of rooting was lower in solid root induction media in both the control (Figure 7 & 8)

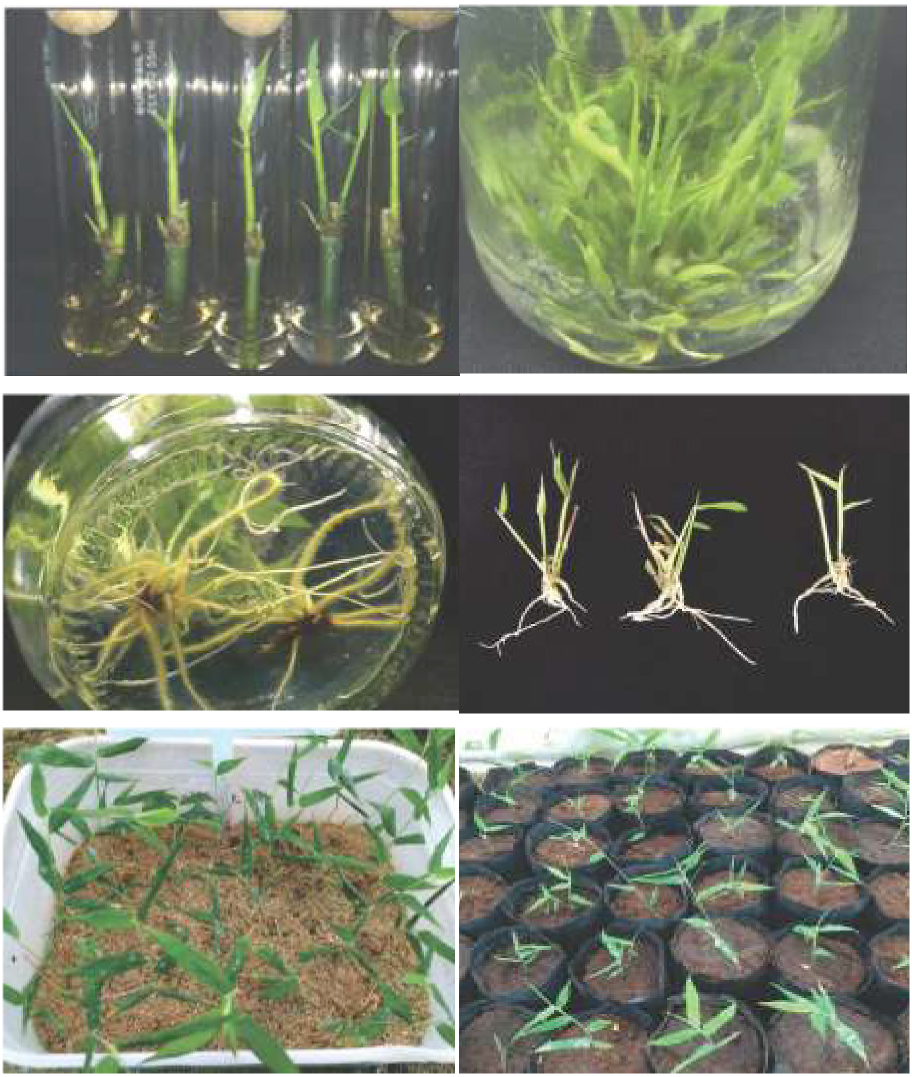


Figure 6: *In vitro* propagation of *B. balcooa*. A: Shoot initiation, B: Shoot multiplication, C: *In vitro* rooting, D: Rooted shoots, E: Primary hardening, F: Secondary hardening

Rooted shoots of *B. balcooa* can then be permitted to grow in the basal media until fresh leaves and a more robust root system could be developed. In about a week the plantlet begins to develop a healthy root and shoot system and after two weeks the plantlet is ready for hardening and planting out. Hardening can be successfully carried out in two weeks in polybags under humidity maintained by the cover provided in the inverted polybag.

Figure 7. Multiple shoot formation in *B. balcooa* on liquid multiplication medium

Initially high incidence of fungal contamination was observed in most cultures of *B. balcooa*, which was controlled by using Bavistin (1%) for 5-7 minutes followed by surface sterilization for 8 -12 minutes with 0.1% $HgCl_2$ (Arya et al., 2008). Liquid MS medium supplemented with 3.0-5.0 mg/l BAP is found to be the best for axillary bud induction in *B. balcooa*. The best shoot multiplication can be obtained on MS medium supplemented 3.0 mg/l BAP with 0.5 mg/l Kinetin.

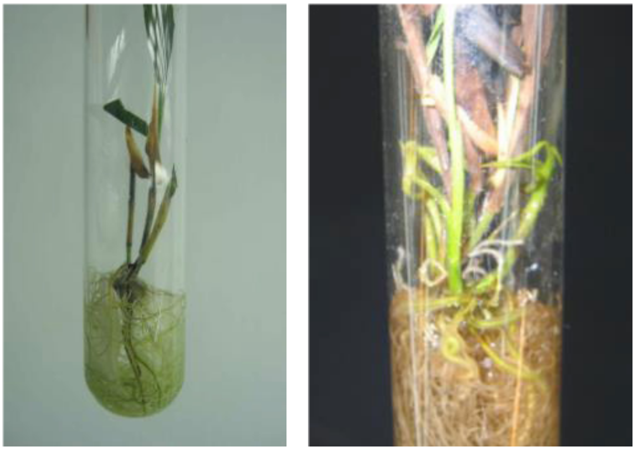


Figure 8. *In vitro* rooting in *B. balcooa* on filter paper

Table 2. Comparison of *in vitro* rooting treatments

Pre- rooting media	No. of replicates	Media used	Shoot status	Subculture media (root development)	Shoot status	% of Rooting
MS+ BAP (2 mg/l) +Kin (2 mg/l) + Sucrose 2% (Solid)	20	1/2MS + IBA (3 mg/l) + NAA (3 mg/l) + Suc 2% (Solid)	Dried	½ MS + Sucrose 2%+ Phytagel 0.2%	Green	45
	20	1/2MS+IBA (3mg/l) + NAA (3 mg/l) +Suc 2% (Liquid)	Green	½ MS + Sucrose 2%	Green	85
MS+BAP (2 mg/l) + Kin (2 mg/l) + Sucrose 2% (Liquid)	20	1/2MS + IBA (3 mg/l) + NAA (3 mg/l) +Suc 2 % (Solid)	Dried	½ MS + Sucrose 2%	Green	66.6
	20	1/2MS+IBA (3 mg/l) + NAA (3 mg/l) + Suc 2% (Liquid)	Green	½ MS + Sucrose 2%	Green	94.4

6. Plantation management

As a priority species, *B. balcooa* can tolerate drier conditions better than many other big leaved bamboos and is much easier to propagate from culm cuttings. The large size of this species along with its multiple branchlets also makes it a good choice for slope stabilization.

Broadly there are two categories of plantation, the intensively managed plantation (Figure 9) with high density and regular nutritional inputs to the soil for good growth despite high density and the regular plantations (Figure 10). Irrespective of the type of plantation regime followed, it is well known that bamboo thrives on adequate water availability and needs adequate moisture content in the soil for good growth. Hence, irrigation forms an important input for better growth and productivity of the bamboos. Further NMBA suggests a soil NPK ratio of 5:2:1/4:2:1 (NMBA, 2005) for good growth performance. Harvesting of bamboo is suggested in two methods. A regular felling of few culms/clump is the standard in harvesting (Figure 11). Many farmers also perform clear cutting of all culms in a clump (Figure 12) for harvesting. The soil fertility management may vary between the two management regimes.

6.1. Intensively managed plantations

Precision farming of *B. balcooa* is extremely popular in the growth of bamboo plantations and as advocated by Growmore Biotech Limited. In this scenario, 1000clumps/ha can be maintained. The planting regime for *B. balcooa* requires input not just in the form of Farm Yard Manure (FYM) and Urea, but also DAP, potash and biofertilizer. The requirements of each of these ingredients per plant along with a timeline advocated by Growmore Biotech is shown in Table 3.

Table 3. Suggested application on inputs for intensively managed B. balcooa plantation

Particulars	Details of Application
Addition of Urea	60g/plant - 1st year; 120g/plant - 2nd year; 180g/plant - 3rd year (spread over 6 doses)
Addition of DAP	
Addition of Potash	45g/plant - 1st year; 90g/plant - 2nd year; 135g/plant - 3rd year (spread over 6 doses)
Addition of Biofertilizer	10g/plant

6.2. Regular plantations

However, many farmers who initially practiced intensively managed precision farming techniques have expressed their major concern in terms of management of the plantation especially harvesting of culms. There has also been concern due to bud rot of emerging shoots in high intensity plantations which create a macro-environment with high relative humidity. The high humidity level in dense plantations may have facilitated ideal environment for fungal infestation. With this in view ideally for medium to large sized bamboo species like *B. balcooa*, a spacing of 5m × 5m size should be appropriate. This has been endorsed by farmers growing *B. balcooa* especially in the humid tropics in Peninsular India.

Figure 9: Intensely Managed Precision farming of *B. balcooa* at Thiruvanamalai, Tamil Nadu

Figure 10: Regular *B. balcooa* plantation in Chikmagalore, Karnataka

Figure 11: Harvesting of bamboo culms at *B. balcooa* plantation in Gaddchiroli, Maharashtra

Figure 12: Complete harvesting of *B. balcooa* clumps in Nammakkal, Tamil Nadu

7. Growth, biomass production and productivity

On an average the number of culms per ha of *Bambusa balcooa* at the age of seven years reported was 7799 (planting density of 400 plants in a ha at 5 × 5 m spaces) and frequency distribution of culms in different girth classes on a per ha basis showed that, 45 per cent of the culms belonged 20-25 cm girth class and 32 per cent in 15-20 cm girth class. It has found that *B. balcooa* attained largest dimensions with higher number of culms in largest girth class (20-25 cm) compared to other bamboo species like *B. bambos* and *T. oliveri.* Generally, studies show that in *B. balcooa* the culm dimensions increased with age like *B. bambos* (Jijeesh, 2014). Annual productivity of sixth- and seventh-year old plantations in Palakkad, Kerala of B. balcooa (18.57 Mg ha^{-1}) compared to other bamboos like *B. bambos* (7.07Mg ha^{-1}), O. travancorica (0.89 Mg ha^{-1}) and *T. oliveri* (5.92 Mg ha^{-1}) is higher which is mainly due to its higher culm wall thickness, faster growth and biomass production.

Table 4. Details of biomass from different parts of *B. balcooa* 6th and 7th years old plantations at 5 × 5 m spacing.

Part	Biomass (kg)/clump		Biomass (mg ha^{-1})	
	Age		Age	
	6 years	7 years	6 years	7 years
Culm	77.93	105.40	31.172	42.160
Branch	22.44	35.99	8.976	14.396
Leaf	7.42	7.13	2.968	2.852
Above Ground Biomass	107.79	148.52	43.116	59.408
Rhizome	4.10	5.65	1.640	2.260
Root	4.19	5.77	1.676	2.308
Below Ground Biomass	8.29	11.42	3.316	4.568
Total	116.08	159.94	46.432	63.976

The moisture content of base, middle and top portions of the culm was 44.04±4.56, 47.67±8.34 and 46.63±15.73 percent, respectively. In the above ground components, branch and leaf moisture content were comparatively lower (32.27±2.74 and 25.07±6.60 per cent). Below ground components (root and rhizome) recorded higher moisture content (45.60±9.79 and 56.72±6.53 percent). In *B. balcooa*, the moisture content of base, middle and top portions of the culm was 44.04±4.56, 47.67±8.34 and 46.63±15.73 percent, respectively. In the above ground components, branch and leaf moisture content were comparatively lower (32.27±2.74 and 25.07±6.60 percent). Below ground components (root and rhizome) recorded higher moisture content (45.60±9.79 and 56.72±6.53 per cent) (Jijeesh, 2014).

Table 5. Comparison of carbon concentration (per cent of dry mass) in clump components of the bamboo species

Components	Carbon concentration (%)	
	B. balcooa	*B. bambos*
Culm base	49.72±0.68	48.66±0.62
Culm middle	47.37±0.45	47.54±0.63
Culm top	45.44±1.02	46.56±0.52
Branch	43.75±0.55	45.30±0.73
Leaf	40.25±0.53	39.12±1.01
Root	42.29±0.87	39.93±0.41
Rhizome	38.62±0.50	40.33±0.80

The total biomass of *B. balcooa*, *B. bambos*, *O. travancorica* and *T. oliveri* clumps during 2011 (six years) was to the tune of 116.079, 31.660, 12.145 and 99.067 kg per clump respectively (Table 4), and that during 2012 (seven years) was in the tune of 159.935, 51.334, 17.731 and 111.286 kg per clump respectively. The highest biomass accumulation was observed in *B. balcooa* followed by *T. oliveri*, *B. bambos* and *O. travancorica*.

Generally, the culm constituted the major share of dry weight in most of the bamboo species whereas in the case of *B. balcooa*, with some exceptions, the branch constituted second highest biomass content followed by leaf, rhizome and root at different ages.

In *B. balcooa* the percentage contribution of culms to total AGB was 72.30 during 6-year-old plantation and 70.97 per cent in 6-year-old (Jijeesh, 2014). The contribution of branch biomass to total AGB was high in *B. balcooa* compared to *B. bambos* (22.52%) and (18.95%) whereas the contribution of leaves to total biomass low (*B.*

Table 6. Mean Above Ground Biomass (AGB) and Carbon (C) Content in *B. balcooa* across different location in Humid zones

Sl. No.	Location	Spacing	Age (Years)	AGB			C Content (in %)
				Culm (in $Mgha^{-1}$)	Side Branches (in $kgha^{-1}$)	Twigs and Leaves (in $kgha^{-1}$)	
1	Kanur, Chandgad, Kolhapur, Maharashtra	5m × 5m	6	71.108	4.6	0.580	42.99
2	Khamdale, Chandgad, Kolhapur, Maharashtra	5m × 5m	2	16.02	0.97	0.121	39.14
3	Khamdale, Chandgad, Kolhapur, Maharashtra	5m × 5m	2.5	21.39	1.15	0.238	40.71
4	Devon Estate, Koppa, Chika-magalore, Karnataka	5m × 5m	8	191.89	5.19	0.914	39.91
5	Devon Estate, Koppa, Chika-magalore, Karnataka	5m × 5m	10	201.22	5.26	0.917	43.31
6	Devon Estate, Koppa, Chika-magalore, Karnataka	5m × 5m	12	195.46	4.81	0.829	42.55

bambos - 14.13 per cent & *B. balcooa* 5.85 percent). The comparison of carbon concentration (per cent of dry mass) in clump components of *B. balcooa* compared with *B. bambos* is shown in Table 5.

The allometric equations corresponding to models to explain the total biomass of *B. balcooa* culms are

1. Ln Y = -3.358+ 1.954*Ln G.......................... Model 3

2. Ln Y = -3.016+ 1.188 Ln*G+ 0.804*Ln (H)... Model 6

Above Ground Biomass in bamboo is usually calculated by destructive sampling of culm and its analysis through standard procedures. A six-year-old *B. balcooa* in Chandgad coming under the humid zone had a mean culm AGB of 71.102 Mgha-1, while in Koppa the values were much greater averaging to approximately 200 Mgha-1. The mean above ground Biomass (AGB) and Carbon content in *B. balcooa* across different location in humid zones is provided in Table 6 and Figure 13.

Biomass distribution of different components of the bamboo, biomass contribution per culm, side branches and twigs and leaves were also calculated. In *Bambusa balcooa,* the percentage contribution of culm, side branches and twigs and leaves to total biomass

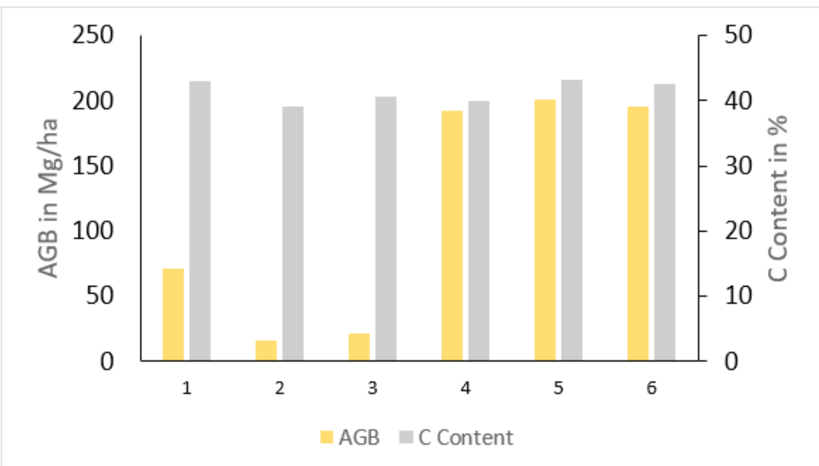


Figure 13: Comparison of mean Above Ground Biomass (AGB) and Carbon (C) Content in *B. balcooa* across different location (1-6) in Humid zones.

Table 7. Clump and Culm characteristics of *B. balcooa* in humid zones

Sl. No.	Location	Age	Clump diameter (cm)	Clump height (m)	Total culms (Nos.)
1	Kanur, Chandgad, Kolhapur, Maharashtra	6	105 ± 2.7	13.325 ± 0.45	29 ± 0.71
2	Khamdale, Chandgad, Kolhapur, Maharashtra	2	82.75 ±0.72	8.55 ± 0.31	14.75 ± 0.86
3	Khamdale, Chandgad, Kolhapur, Maharashtra	2.5	78.83 ± 1.74	9.93 ± 0.89	15 ± 1.53
4	Devon Estate, Koppa, Chikamagalore, Karnataka	8	91.5 ± 1.26	18.05 ± 0.67	33.67 ± 0.94
5	Devon Estate, Koppa, Chikamagalore, Karnataka	10	115.17 ± 1.88	18.2 ± 0.24	35.67 ± 0.53
6	Devon Estate, Koppa, Chikamagalore, Karnataka	12	132.67 ± 1.78	18.03 ± 0.36	36.33 ± 0.86

of bamboo species in different sample locations was culms>side branches>twigs and leaves. In *B. balcooa*, the maximum biomass was accumulated in culms (95%), followed by side branches (4%) and then in leaves and twigs (<1%) (Figure 14).

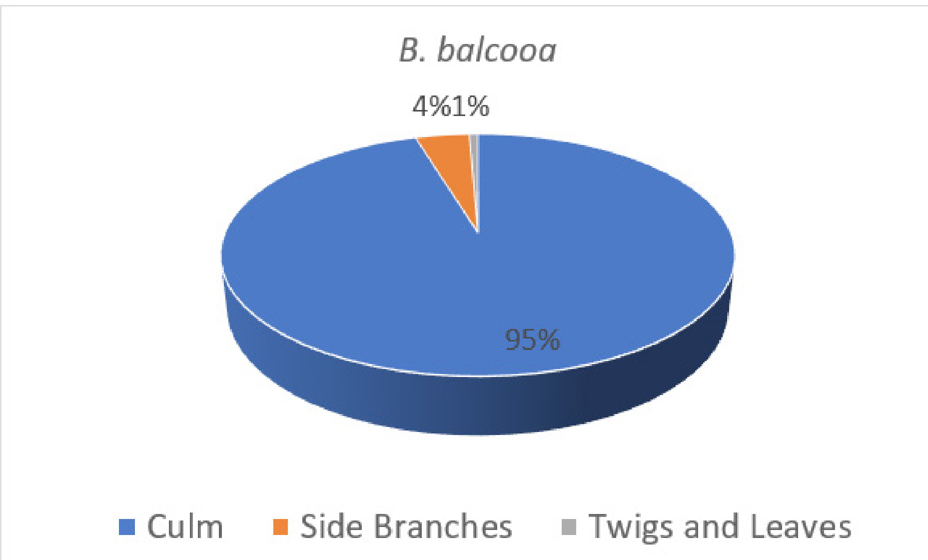


Figure 14: Percentage contribution of different components in *B. balcooa* above ground Biomass

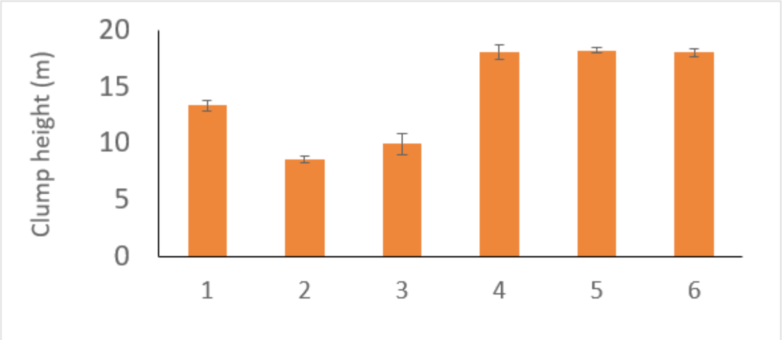


Figure 15: Mean clump height in *B. balcooa* across six different location in humid zones

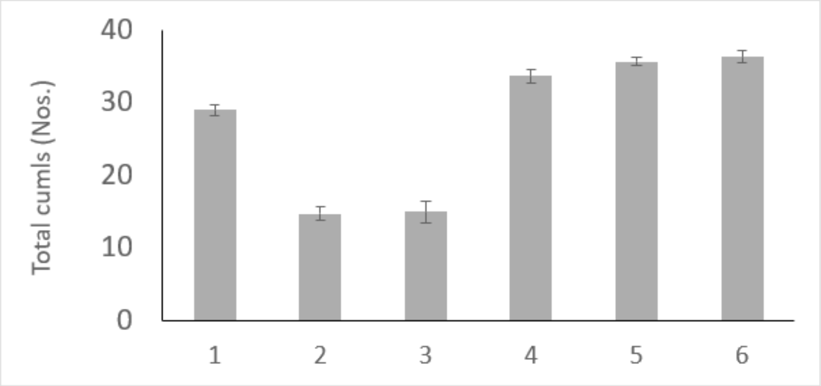


Figure 16: Mean total culms in *B. balcooa* across six different location in humid zones

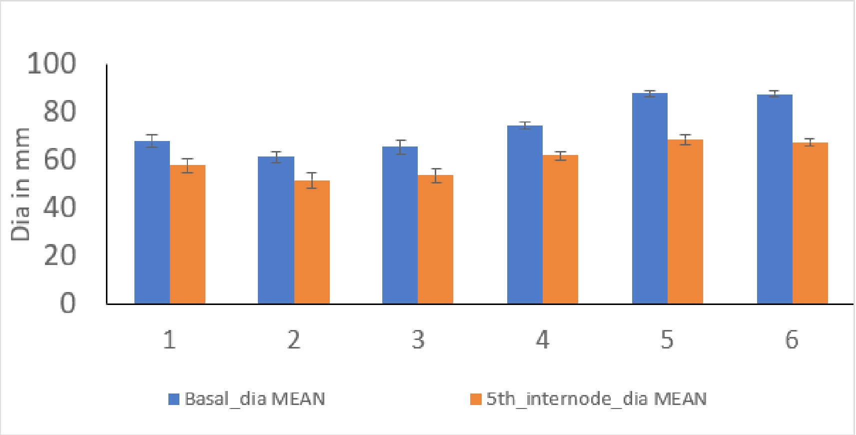


Figure 17: Mean basal and fifth internode diameter in *B. balcooa* across six different location in humid zones

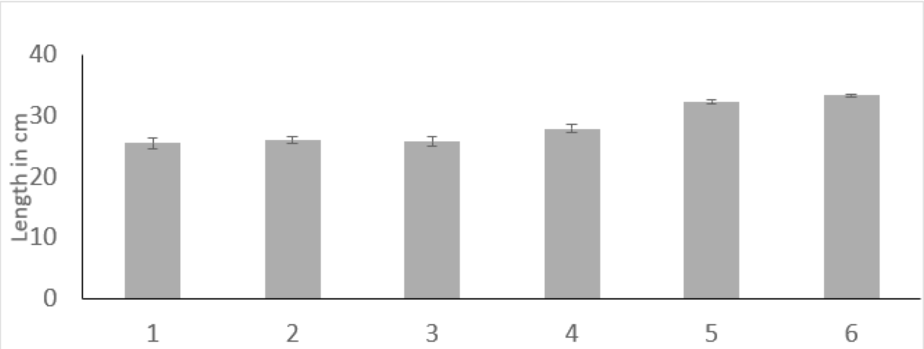


Figure 18: Mean 5th internode length in *B. balcooa* across six different locations in humid zones.

The Ecological Niche Model results indicate that the species grows best in humid zones. Empirical field study (Subbanna, 2020) on that culm and clump parameters of a ten-year-old *B. balcooa* plantation in semiarid region is comparable to that of a six-year-old *B. balcooa* plantation in humid region. It was typically observed that harvesting of B. balcooa although can be done from third year itself and has best culm parameters from fifth year onwards. Differences in biometric parameters of *B. balcooa* like basal diameter, fifth internode diameter and culm fifth internode length amongst the new clumps of age less than four years was not significant. For plantations of *B. balcooa* less than four years, the mean total number of clumps were 14.96 ± 1.93, while it was 35 ± 9.21 (Figure 11) for plantation age greater than four years old (Figures 15 -18)

The average culm height amongst two humid locations wherein matured clumps were observed varied from 13.325m in Chandgad, Maharashtra to 18.2m in Koppa, Karnataka which could be correlated to better rainfall and agro-climatic conditions (Table 7)

At 5 × 5 m with a density of 400 clumps/ha the maximum productivity observed in tropical humid conditions was 48 Mg/ha^{-1}/year. The average productivity in tropical humid zones in Peninsular India ranges from 25 to 48 Mg/ha-1/year (Table 8). As compared to other cultivated species like *Dendrocalamus stocksii* and *D. strictus* etc. this seems to be higher. Higher planting density (3 × 3 m) did not seem to increase the productivity levels as the individual size of the culm and culm weight recorded was lesser in high density plantations.

The culm parameters observed in a 30-year-old *B. balcooa* clump in KFRI campus (Photo in back cover) recorded culm length of around 25m and fresh culm weight (including culm weight of branches, twigs and leaves) came to around 60 kg.

Table 8. Estimated productivity of some mature *B. balcooa* plantations in Kerala, Karnataka, and Maharashtra.

Sl. No	Location	Agro-climatic Zones	Age of plantation (years)	Number of Clums/year	Culm Dry weight (kg)	Total number of clumps/ha	Spacing (m)	Annual productivity (Mg/ha^{-1}/yr
1	Palakkad, Kerala	Humid	6	7	10	400	5 × 5	28
2	evon plantation, Chickmaglor, Karnataka	Humid	8	6	20	400	5 × 5	48
3	Kolhapur, Maharashtra	Humid	7	6	7	1000	3 × 3	42
4	Devon plantation, Chickmaglor, Karnataka	Humid	10	8	8	400	5 × 5	25
5	KFRI, Peechi, Kerala*	Humid	30	8	30	400	5 × 5	25

*Individual clump of around 30 years inside KFRI campus

8.Litter production and decomposition dynamics

Litter dynamics studies are crucial in the nutrition budgeting of tropical ecosystems where vegetation depends on the recycling of the nutrients contained in the in the plant debris (Prichet and Fisher 1987). The various studies on litter production and decomposition dynamics of *B. balcooa* shows that this species has tremendous potential in regulating soil nutrient pool through faster litter turnover and, therefore, can help in soil nutrient restoration vis-à-vis ecosystem restoration. It is reported that there is an intense seasonal variation in litter accumulation in *B. balcooa* with more than 70 per cent of the litterfall recorded during November to March which could be correlated with climatic factors like monthly rainfall maximum and minimum temperature (Jijeesh and Seethalakshmi, 2015). Litter decomposition rate constant reported is 0.01 g day^{-1} and the time taken for 50 and 99 % decomposition was 77 and 556 days respectively. With regard to the nutrient dynamics, Nitrogen was in highest concentration in the litter and initial decrease in concentration was observed in N, P, K, Ca and Mg indicating the nutrient release and was followed by accumulation phases in due course. The nutrient release from the decomposing litter mass was in the order Mg > N >Ca> P > K (Jijeesh and Seethalakshmi, 2015).

The highest litterfall in *B. balcooa* was observed in February, where 22-23 per cent of the total litter accumulated on the floor. The litter production pattern was bimodal with a major peak in February and a minor peak in December as observed in two consecutive years. Litter production increased with the ageing of the clumps. With regard to proximate composition of litter, leaf litter accounted for more than 94 per cent of the total litterfall and branches contributed about 4 per cent followed by culm sheath.

Table 9. Litter chemistry of *B. balcooa*

Parameters	**Value**
Nitrogen (%)	1.409±0.037a
Phosphorus (%)	0.757±0.071a
Potassium (%)	0.716±0.016c
Calcium (%)	0.453±0.009b
Magnesium (%)	0.086±0.002b
Carbon (%)	26.50±1.14a
C: N ratio	18.82±0.86a
C: P ratio	35.28±4.69a
C: K ratio	37.04±2.22a

The litter chemistry of *B. balcooa* as seen in Table 9 shows that phosphorus content in litter of *B. balcooa* is almost similar to other bamboo species like *T. oliveri* and *B. bambos* and whereas nitrogen content is almost similar to *T. oliveri*. The potassium content is lowest *B. balcooa* which was approximately half compared to *B. bambos, T. oliveri* and *O. travancorica*. The C: K ratio is highest in *B. balcooa* compared to the above-mentioned species.

Another study (Arunachalam et al., 2005) on litter decay and nutrient release rates of leaf and leaf sheath litter of 9-year-old bamboo forest in a fallow agricultural land in north-eastern India shows that N and lignin concentrations were greater in *B. balcooa* litter compared to *B. pallida*. In *B. balcooa*, during the initial 120 days of incubation, the rate of decomposition was slow both in leaf (0.14% weight loss day^{-1}) and leaf sheath (0.15% weight loss˙day^{-1}) litter, and then the decay rate continued to increase further. N immobilization and release rates were different through time and P release patterns of leaf litter and leaf sheath were also different. In general, it is noticed that P release was faster, showing little difference in decay rate among various litter types, whereas N release was rapid only in leaf litter samples. Similarly, most of the litter quality parameters showed significant relationships with weight loss and N release patterns, whereas P release was significantly correlated only to initial P content and C/P ratio in litter materials.

9. Carbon storage and above ground biomass

Accumulation of biomass and carbon in bamboo clumps and their partitioning in the clump components like culm, branch, leaf, rhizome and root in *B. balcooa* indicated that highest biomass accumulation which is 50.50 and 69.06 Mg ha^{-1} at the age of six and seven years, respectively (Jijeesh, 2014). The total carbon storage of *B. balcooa* clumps at the age of six and seven years was to the tune of 55.86 ± 17.18 and 76.66±25.02 kg respectively and culm carbon storage during six and seven years in *B. balcooa* was 37.03±12.58 and 50.08±16.52 kg respectively. In *B. balcooa*, the second highest carbon storage was observed in branches (9.82±3.14, 15.75±6.23 kg in 2011 and 2012 respectively) and least biomass accumulation was found in rhizome (Jijeesh, 2014). The above ground carbon sequestration (per ha) at the age of six and seven years of *B. balcooa* was 19.93 and 27.48 Mg ha^{-1} respectively and that of *B. bambos* was 4.96 and 7.81 Mg ha^{-1} respectively. Carbon storage of *B. balcooa* was comparable to *Dendrocalamus stritcus* (19.5) at the age of six years (Agarwal and Purwar, 2010). The carbon sequestration potential of six- and seven-years old *B. balcooa* and *B. bambos* plantation at a spacing of 5 × 5 m was 22.34±6.87; 30.66±10.01 Mg ha^{-1} and 7.19±0.53; 10.33±2.58 Mg ha^{-1} respectively.

10. Agroforestry possibilities

The importance of bamboo-based agroforestry in enhancing productivity, sustainability and resource conservation is gaining importance in recent years. In Northeast India, *B. balcooa, B. bambos, B. cacharensis, B. tulda, B. nutans* and *B. vulgaris* are the commonly cultivated species in homesteads and trees like *Albizia lebbeck, Emblica officinalis, Melia azedarach* and plantation crops like *Musa paradisiaca, Piper betle*, and *Cocos nucifera* are in combination with bamboos. *B. balcooa* can be selected as a promising potential agroforestry species intercropped with traditional horticultural trees like mango (*Mangifera indica*), cashewnut (*Anacardium occidentale*), jackfruit (*Artocarpus hetrophyllus*), Kokum (*Garcinia indica*) and rubber (*Hevea brasilensis*) (Malik and Raj, 2014). In West Bengal and in Assam (Baruah and Borah, 2019), different spacing trials (3×3m, 4×4m and 5×5m) have been adopted for culm cutting of *B. balcooa* intercropped with paddy (upland), groundnut, cowpea, lady's finger, bottle gourd, pigeon pea, turmeric, maize and colocasia as per local demand of the people. The highest numbers of newly emerged bamboo shoot and maize cob were recorded in 5 × 5m spacing. Yield of maize (22.89 q/h) and colocasia (3.54 q/h) was recorded less in the initial of year cultivation at 3×3m spacing, gradually increase in yield was observed in subsequent years (maize-33.8 q/h and colocasia-5.27 q/h) up to third year cultivation at 5x5 spacing. In Terai region of Uttarakhand it was reported that Bengali migrants were cultivating *B. balcooa, B. tulda, Dendrocalamus hamiltonii* with Bael (*Aegle marmelos*), Citrus (*Citrus aurantium*), Kathal (*Artocarpus hetrophyllus*), Moringa (*Moringa oleifera*), Neem (*Melia azedarach*) and Semul (*Bombax ceiba*) in homesteads (Banik et al., 2008). This combination may have potential for providing livelihood security to the poor farmers. In Dinajpur, Haldibari, Mayanaguri and Jalpaiguri areas in India, the clumps of *B. balcooa* have been cultivated in close spacing of one to two rows along the north western sides of paddy fields as windbreaks against the dry and cold wind blowing from Nepal and Bihar (Banik, 2016). The study conducted in G. B. Pant University of Agriculture and Technology, Pantnagar (GBPUAT, 2010), cowpea was intercropped with eight bamboo species at spacing of 5 × 5 m. The result shows that during initial two years maximum height of 12.5m was obtained by *B. balcooa*. The intercropping of *B. balcooa* with banana, pineapple and turmeric shows that yield was 10.7 q ha^{-1}, 16.0 q ha^{-1}, and 222.8q ha^{-1} respectively. From available data on intercropping, it may be inferred that intercropping possible in *B. balcooa* only in the initial years up to 3-4 years. Beyond that root competition and shady effects take a toll in intercropping yield.

11. Anatomy and culm properties

The Information on physical and mechanical properties of bamboo is necessary for assessing its suitability for various end products (Sattar et al., 1990) and appropriate use of any material depends on its properties to a large extent (Kamruzzaman et al., 2008). The studies on physical and mechanical properties of *B. balcooa* compared to *B.*

tulda, B. salarkhanii and *Melocanna baccifera* shows that moisture content of *B. balcooa* was substantially higher than others (Kamruzzaman et al., 2008). It varied varied from 133 to 119% for bottom, 122 to 108% for middle and 109 to 99% for top. Sharma et al., (2011) studied the anatomy, fiber morphology and derived wood properties of *B. balcooa* with other bamboos. The various properties of *B. balcooa* compared with *B. tulda, B. bambos* shows that *B. balcooa* has lower ash content which indicates its suitability of bioenergy and gasification process (Table 10 & 11).

The study conducted by Vena et al. (2013) on *B. balcooa* in South Africa shows that average fiber length is 2.9 mm. The chemical composition shows that 4.1% and 3.0% extractive contents in EtOH/cyclohexane and water. It also includes 2.4% ash, 54.6% glu-

Table 10. The various properties of *B. balcooa* compared with *B.tulda* and *B. bambos*

Property particulars as weight in %	*B.tulda*	*B. balcooa*	*B. bambos*
Ash	3.2	2.0	2.1
Cold Water Soluble	3.5	3.4	3.8
Hot Water Soluble	6.8	7.0	6.0
1/10N NaoH solubility	22.6	20.8	23.7
Alcohol: benzene soluble	2.3	2.6	2.5
Pentosan	15.9	16.9	16.7
Holocellulose	15.9	16.9	16.7
α-cellulose	47.0	47.2	44.9
β-cellulose	14.9	17.4	18.5
Ƴ-cellulose	11.1	10.3	10.7
Acid soluble lignin	25.7	24.8	24.1
Acid insoluble lignin	0.90	1.03	0.76

Table 11. Morphological characteristics of fibrous and non-fibrous cells of *B. balcooa* compared with *B. tulda* and *B. bambos*

Particulars	*B. tulda*	*B. balocoa*	*B. bambos*
Fibrous Cells			
Fiber length (weight weighted) (L=0.20 – 4.0), (mm)	1.89	2.18	2.01
Minimum Fiber length (mm)	0.46	0.57	0,51
Maximum fiber length (mm)	5.67	4.87	4.89
Mean fiber width (7-45) µm	17.0	17.4	18.0
Lumen diameter, µm	3.45	3.60	3.69
Cell wall thickness, µm	6.78	6.90	7.16
Slenderness ratio	111.2	125.3	111.7
Solids factor	0.52	0.63	0.62
Runkel ratio	3.93	3.83	3.88
Fiber curl index	0.19	0.20	0.19
Fiber kink index	1.79	1.69	1.82
Total kink angle, degree	45.68	49.50	51.5
Kink per mm	0.78	0.90	0.86
Non-Fibrous Cells			
Length of vessel, µm	256.3	202.1	267.4
Width of vessel, µm	34.4	41.9	48.4
Length of parenchyma, µm	58.1	48.3	67.8
Width of parenchyma, µm	31.9	36.5	34.2
Arithmetic fines	39.8	38.7	46.8
Length weighted fines	4.34	4.23	5.17

can, 21.6% xylan, 1.1% arabinan and 25.2% Klason lignin. The improvement in tensile strength, tensile modulus and chemical resistance of bamboo fibres are were observed after coating with polymers especially PU/PMMA system (Kumar and Siddaramaiah, 2004). When the physical properties of three bamboo species are compared it is found that *B. balcooa* has some key parameters indicating its suitability in pulp and paper industry. This species is generally preferred for industrial use due to its rapid growth, excellent flexibility and tensile strength fibers isolated from different accessions shows higher cellulose contents and superior physical properties (Bhattacharya et al., 2010). The fibers with lower Runkel ratios (<1.0) in *B. balcooa* shows that it is preferred for making quality products. The studies on physical properties of *B. balcooa*, compared, to *B. vulgaris* and *B. bambos* shows that *B. balcooa* performed consistently better over and registered significantly higher values for moisture content, basic density (Krishnakumar et al., 2017)

12. Uses, value addition potential and utility aspects

B. balcooa is one of the most useful species of bamboo supplying material for building and scaffolding, paper and pulp, boards and mats, handicrafts, and its young shoots are even consumed as vegetable. The siliceous secretion of the culm is believed to be aphrodisiac and can also be used as tonic (Manandhar and Manandhar 2002). In Dibrugarh district, Assam, India crushed leaves combined with *Cucumis sativus* is consumed orally to treat epitaxis (Kalita and Phukan, 2010). Similarly, the young leaves decoction is consumed orally to treat diabetes traditionally by the Moran folk of Tinsukia district of Assam, India (Kalita and Phukan 2009). *In vitro* antidiabetic studies of *B. balcooa* have shown promising results (Middha and Usha 2012). The analysis of toxic, antidiabetic and antioxidant potential of *B. balcooa* leaf extracts identified three compounds such as rutin, gallic acid, and β sitosterol detected have the potential to treat diabetes individually (Goyal et al., 2017). The pharmacological analysis of *B. balcooa* leaves in methanol extract revealed anti- ulcer activity of with 14.66% protective ratio (Upreti et al., 2016)

The macronutrient composition, mineral elements composition and HCN content (ppm) in freshly emerged juvenile shoots of *B. balcooa* (Tables 12 & 13) was found to be at par with other species like *B. bambos, D. asper* etc., (Sowmya and Viswanath, 2015a and 2015b) The volume of edible shoot of *B. balcooa* was observed to be more than *B. bambos, D. strictus* and *G. angustifolia*, though less than *D. asper* a popular edible bamboo species. Further calorific value and Fuel Value Index was observed to be highest (Ritesh Kumar and N. Chandrashekar, 2014). It was observed that calorific value *B. balcooa* was at 19.6 MJ kg^{-1} while its fuel value index was 2120 (Table 14).

13. Farmers perception on *B. balcooa*

B. balcooa cultivation is treated as being extremely lucrative to farmers. The recommended spacing to farmers by Growmore Biotech ie. 2.4 m and 3.6 m does not apparently consider problems faced by farmers at a later stage. Most farmers, especially in the humid regions were of the opinion that within four years it becomes difficult to manage *B. balcooa* plantations recommended at 2.4 m distance between plants and have hence started reducing the plantation density. This is especially seen in the humid tropics. There is also concern with regard to excessive branching pattern observed by farmers. In regions where there are biomass based electricity generation plants and other market opportunities like paper and pulp industry, farmers may prefer growing *B. balcooa* at higher densities.

Table 12: Macronutrient composition in freshly emerged juvenile shoots of six species in Koppa (K) and Hosakote (H) - Moisture (%), Ash, Fat, Protein, Carbohydrate, Crude fiber (g/100g).

Species	Moisture %		Ash		Protein		Fat		Carbohydrate		Crude fibre	
	K	H	K	H	K	H	K	H	K	H	K	H
B. balcooa	89.77	85.13	1.07	1.07	3.27	1.94	0.03	0.07	5.63	6.17	3.23	2.10
B. bambos	92.2	90.8	0.93	1	3.45	1.84	0.02	0.04	6.83	5.83	3.7	2.23
D. asper	93.27	91.47	0.53	0.93	2.55	1.66	0.03	0.02	8.63	7.63	2.15	1.57
D. stocksii	90.3	91.4	1.47	0.93	2.66	1.94	0.04	0.02	7.1	6.37	3.19	2.19
D. strictus	90.73	91.8	0.93	1.07	2.40	2.2	0.02	0.01	6.53	5.53	2.75	2.60
G. angustifolia	91.23	90.8	1.27	1.33	2.85	2.39	0.01	0.04	4.9	4.87	3.45	2.55

K – Koppa, Chikmagalore, Karnataka (Humid); and H – Hosakote, Bengaluru Rural, Karnataka (Semiarid)

On empirical field work involved in a survey four states in central and southern India wherein reasons to grow *B. balcooa* was analyzed along with its economic analysis (Subbanna, 2020). It was observed that there are eight factors in the order of decreasing significance that has impacted farmers decision to grow *B. balcooa*. These factors include ease of availability of *B. balcooa*, expectation on economic economic benefit, low management inputs, less labour inputs, involvement of forest department in encouraging growth of bamboo, involvement of NGOs in encouraging growth of bamboo, motivation from friends and family, government schemes and programmes promoting growth of bamboos, involvement of agriculture department in encouraging growth of bamboo and self-motivation.

Overall, the ease of management which is a direct result of need for reduced labour along with the economic benefit has influenced farmer's decisions in choosing the bamboo project. The ease of availability of the species also makes it easier for farmers to choose a particular bamboo species which is the case seems to be *B. balcooa*.

14. Economic Analysis

The economics of *B. balcooa* appears to be lucrative in the humid zones but did not seem to be a better option than *Dendrocalamus stocksii* (Subbanna and Viswanath, 2018). In humid zones, *B. balcooa* plantation was observed in two planting densities

Table 13: Mineral elements composition (mg/100 g fresh weight), HCN content (ppm) in the freshly emerged juvenile shoots of six species in Koppa (K) and Hosakote (H).

Species	Sodium		Potassium		Calcium		Iron		Copper		Manganese		Zinc		HCN	
	K	H	K	H	K	H	K	H	K	H	K	H	K	H	K	H
B. balcooa	11.35	9.23	503.00	408.33	4.17	3.17	1.58	2.58	0.55	0.44	0.70	0.71	0.77	0.84	1879.15	2378.74
B. bambos	12.23	13.14	367.33	284.67	5.43	4.37	2.23	2.42	0.36	0.57	0.94	0.88	0.82	0.77	1034.88	1117.68
D. asper	15.04	14.15	515.67	416.67	6.37	7.10	1.97	2.97	0.50	0.39	0.76	0.80	0.86	0.73	366.96	1831.50
D. stocksii	10.47	12.87	314.67	270.33	4.07	5.03	1.81	2.81	0.34	0.42	0.61	0.88	0.73	0.65	1025.90	1734.93
D. strictus	13.14	12.63	343.67	268.33	5.17	6.10	1.01	2.01	0.58	0.48	0.77	0.84	0.88	0.65	2500.08	2485.92
G. angustifolia	12.63	11.11	456.67	365.33	5.40	5.4	2.54	1.95	0.24	0.37	0.87	0.92	0.72	0.67	1421.9	1952.21

Source: Viswanath and Soumya (2016)

Table 14: Comparison of CV (Calorific Value) and FVI (Fuel Value Index) across different bamboo species

Sl. No	Bamboo species	CV (MJ kg^{-1})	FVI
1	*Dendrocalamus strictus*	18.8	586
2	*D. brandisii*	19.1	933
3	*D. stocksii*	18.7	1399
4	*Bambusa bambos*	19.2	1827
5	*B. balcooa*	19.6	2120

Source: Ritesh Kumar and Chandrashekar, 2014

viz. 1000 clumps ha^{-1}; and 600 clumps ha^{-1}, and economics of cultivation were calculated for both (Table 15 & 16).

The detailed input and output cost involved in cultivation of B. balcooa was worked out. An additional cost of ₹ 54,000 was added during the first four years of bamboo cultivation for initial protection of plants which forms the major input cost for the first four years to grow any bamboo species. In the case of humid zones, total input cost in maximum for the first year at ₹ 148,073, ₹ 121,478, ₹ 115,605 and ₹ 111,825 respectively. It has found that the flow of costs stabilizes from fifth year onwards to ₹34,038, ₹ 24,675, ₹ 17,325 and ₹ 15,750 respectively. The next big contributor to the input cost is the cost of seedlings and labour involved at different stages of planting and harvesting. For *B. balcooa*, because there is regular addition of fertilizers in the form of Urea and DAP, along with addition of potash and biofertilizer, these too play a significant contribution in the input costs. The income is generated from plantations from the third year to the tenth year. The income has been calculated based on mean clump characteristics of block plantations in the study villages.

For economic analysis of *B. balcooa* in humid zones, three factors Benefit to Cost (B/C) ratio, Internal Rate of Return (IRR) and Net Present Value (NPV) have been calculated and tabulated based on empirical field work. B/C Ratio is an indicator used to assess the financial viability of land-use practices (Table 17). The agriculture loan interest rates considered 10% for the calculations of discounted benefits and costs. The results show that the ratio is positive at 4.00 and 3.93 for *B. balcooa* at planting density of 1000 and 600. IRR determines the earning power of money invested in a particular venture. The values can also be deemed high for *B. balcooa*, wherein IRR was calculated at 33 percent and 31 percent for planting density 1000 and 600 respectively for a period of forty years. NPV is the sum of net discounted benefit at the selected discount rate of 10 percent.

Table 15: Flow of costs from *B. balcooa* plantation in one hectare at humid regions

Particulars	Cost per year (₹)									
	First year		Second year		Third year		Fourth year		Fifth year onwards	
	A	B	A	B	A	B	A	B	A	B
No. of clumps/ha	1000	600	1000	600	1000	600	1000	600	1000	600
Survival/ha	900	540	900	540	900	540	900	540	900	540
Casualty	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Cost of seedlings	25000	15000	2500	1500						
Labour: Site preparation	9000	9000								
Labour: Alignment & staking	1250	1250								
Labour: Land Preparation	1250	1250	250	250						
Addition of Farm Yard Manure	15000	9000	9000	5400	9000	5400	9000	5400	9000	5400
Addition of Urea	330	198	660	396	990	594	990	594	990	594
Addition of DAP	1080	648	2160	1296	3240	1944	3240	1944	3240	1944
Addition of Potash	1012.5	607.5	2025	1215	3037.5	1822.5	3037.5	1822.5	3037.5	1822.5
Addition of Biofertilizer	5400	3240	5400	3240	5400	3240	5400	3240	5400	3240
Addition of Insecticide			250	200			250	200	250	
Transportation and planting of seedlings	15000	9000	900	900						
Labour: Planting & replanting	2750	2750	2750	2750	1250	1250	500	500	500	500
Labour: Soil fertility management	3750	3750	3750	3750	3750	6250	6250	6250	6250	6250
Labour: Tending, marking cleaning & harvesting of culms annually			2500	2500	2500	2500	2500	3750	3750	3750
Fencing	4000	4000	1000	1000						
Irrigation	2200	2000	2200	2000	2200	2000	2200	2000		
Watch and ward	54000	54000	54000	54000	54000	54000	54000	54000		
SUB TOTAL	141022	115693	88345	81147	85367	79000	87367	79700	32417	23500
CONTINGENCY 05%	7051	5784	4417	4057	4268	3950	4368	3985	1620	1175
GRAND TOTAL	**148073**	**121478**	**92762**	**85204**	**89635**	**82950**	**91735**	**83685**	**34038**	**24675**

USD = ₹74 (October, 2020)

Table 16: Benefits from *B. balcooa* and *D. stocksii* plantation in one hectare at humid regions

Year	*B. balcooa* at planting density of 1000/ha				*B. balcooa* at planting density of 600/ha			
	Avg culms/ clump	Culms/ Ha	Biomass productivi-ty/culm (kg)	Income (₹)	Avg culms/ clump	Culms/ Ha	Biomass productivi-ty/culm (kg)	Income (₹)
3	2	1800	3.8	49248	2	1080	3.8	29548
4	3	2700	5.2	101088	3	1620	5.2	60652
5	4.1	3690	6.7	178005	4	2160	6.7	104198
6	4.9	4410	7.3	231789	6	3240	7.62	177759
7	5.4	4860	10.8	377913	7.2	3888	11.1	310729
8	5.4	4860	10.8	377913	7.2	3888	11.1	310729
9	5.4	4860	10.8	377913	7.2	3888	11.1	310729
10 & ABOVE	5.4	4860	10.8	377913	7.2	3888	11.1	310729

Expected price/Ton of dried biomass for B. balcooa = ₹ 7200

NPV was calculated at ₹ 19,53,021 ($26,909) and ₹ 15,53,599 ($21,405) for B. balcooa at planting density of 1000 and 600 respectively. The economic analysis clearly indicates that B. balcooa is lucrative to farmers. An increase in planting density of *B. balcooa* was more lucrative despite having lower culm emergence.

15. Advantages and disadvantages of B. balcooa

a. Advantages

- Grows well in tropical humid conditions
- High Calorific value and Fuel Value Indices (FVI) makes its suitable for Bio- energy plantations and gasification
- Suitable for pulp and paper industry.
- Superior strength properties including good culm wall thickness
- Life cycle of clump >50 years
- Minimal pest problems and no gregarious flowering in India.

Table 17: Economic analysis of *B. balcooa* across different plating regimes in the humid zones.

Species	**Planting density**	**Benefit to Cost Ratio**			**Net Present Value**			**Internal Rate of Return**			**Equated Annual Income**		
	Ha^{-1}	**B/C Ratio**			**NPV (₹)**			**IRR (%)**			**EAI (₹)**		
		8%	10%	12%	8%	10%	12%	8%	10%	12%	8%	10%	12%
Bambusa balcooa	1000	4.67	4.00	3.45	27,14,638	19,53,021	14,32,830	33%	33%	33%	2,77,597	1,99,715	1,46,520
	600	4.65	3.93	3.34	21,81,548	15,53,599	11,25,904	31%	31%	31%	2,23,084	1,58,870	1,15,134

1 USD = ₹74 (October, 2020)

- Non thorny nature makes it easy for management
- Edible shoot value and nutritional parameters make it as an attractive option.
- Multiple utility attractive for furniture, handcrafts, and agarbathi sectors.
- Medicinal properties also recorded.

b. Disadvantages

- Too much branchiness in lower half the culm makes harvesting and extraction difficulties.
- Poor growth in semi-arid zones even with intensive management.
- Viable seeds not available.

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