Phylogeny of bamboos based on morphological key characters

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ABSTRACT

Exploration of bamboos resources in a sustainable manner needs more emphasis on evaluation of morphological characters-based species discrimination. In a present work, fifty-two various qualitative morphological characters and seven quantitative characters were studied in ten bamboo species. The cluster analysis and principal component revealed highest similarity between Ochlandra travancorica and Ochlandra ebracteata followed by Bambusa nutan, Bambusa oliveriana and Gigantichola rostrata, Ochlandra ebracteata respectively, whereas, Bambusa wamin showing separate evolutionary branching. ***Conclusion:*** *due to the long and irregular flowering in bamboos, it is essential to adopt the advance phylogentic clustering tools for generation of reliable and taxonomically supporting information for species discrimination, moreover, the time to time morphological characters studies are essential to trace the phenotypic plasticity and adaptability of bamboos with respect to non- predicted changing climatic conditions.*

Keywords: *Cluster analysis; Bamboos; taxonomy; morphological descriptors*

Introduction:

The bamboos are the world fastest growing plants, popularly known as green gold having enormous application in diverse field, the bamboos having about 1450 species and it is the only grass that found to be diversified in forest (BPG, 2012), due to irregular and delayed flowering in bamboos, it is very hard for the researchers to discriminates the species by only considering the general morphological features, therefore, the distinguished characters based species discriminations is one of the important tool to overcome the taxonomic ambiguities (Shalini A. *et al*., 2013). The morphological features like culm and culm sheath, branching pattern, rhizome/ root system etc. are traditionally considered for species identification; (Giordano, C. V *et al*., 2009). Bamboos having good adaptability in a different climatic conditions and rainfalls, it is one of the important plant having high demand in industrial sector, traditionally, the bamboos also utilized in various purposes *viz* construction of buildings, crafts making, agricultural practices (Dev, S. A *et al*., 2020). Due to overexploitation of important bamboos, lack of unexplored suitable species and other factors like forest fire, over grazing and irregular flowering leading to continuous loss of existing bamboo resource in India (NBM 2022). Therefore, exploration of bamboos with respect to their diverse utility is an urgent need to conserve the bamboo resources and its sustainable utilization.

Materials and methods:

Scoring of morphological descriptors: The 10 different species of Bamboos belongs to Bamboo Nursery, wadali Amravati maintained by Forest Department Govt. of Maharashtra, India was selected for present study, each species was considered as a separate independent operational taxonomic unit (OTU). Fifty-two key morphological descriptors (qualitative) and seven quantitative Characters were assessed from each of the 10 OTUs (5 replications per OTU) studied in the field (Nei and Li, 1979). The observed data were recorded in excel sheet for preparation of binary matrix. The qualitative and quantitative data were used in cluster analysis, preparation of UPGMA similarity matrix based on Jaccard Coefficient and Principal Component Analysis (PCA) by using Past 4.09 statistical tool (Hammer, Ø., Harper, D.A.T., and P. D. Ryan, 2001).

Table 1. Species under study

Name of Species	Code	Voucher no.
Bambusa assamica	A1	BA37: BOM:SGBAUBOT
Bambusa affinis	A2	BA22: BOM:SGBAUBOT
Bambusa cacharensis	A3	BC20: BOM:SGBAUBOT
Bambusa nutan	A4	BN29: BOM:SGBAUBOT
Bambusa oliveriana	A5	BO26: BOM:SGBAUBOT
Bambusa wamin	A6	BW23: BOM:SGBAUBOT
Gigantichola rostrata	B1	GR34: BOM:SGBAUBOT
Gigantichola atroviolacea	B2	GA19:BOM:SGBAUBOT
Ochlandra ebracteata	C1	OE30: BOM:SGBAUBOT
Ochlandra travancorica	C2	OT21: BOM:SGBAUBOT

Observation and Results:

Bamboos are one of the highly demanded plants in diverse sectors, but due their long and irregular flowering behaviour, it is not possible for researchers as well as conservational biologist to discriminate the difference between species, therefore, the key morphological characters based species discrimination is playing important role in bamboos identification and characterisation for their sustainable use. In the present investigation, ten different bamboo species were characterised based on fifty-two various morphological key descriptors (qualitative) and seven quantitative Characters (Table 3 and 4). The cluster analysis depicted the close and distant relationship between species, the whole dendrogram were split into two clusters, the out of ten species, eight species assembled in cluster-II and two species i.e. *Bambusa assamica* and *Bambusa oliveriana* were separated as a separate cluster from comman ancesteral clade. Moreover, the *Ochlandra ebracteata* and *Ochlandra travancorica* showing close association with the support of similarity index 0.74 (Table.2) and Principal Component Analysis two dimensional plot (figure.2), furthermore, the *Gigantichola rostrata* and *Gigantichola atroviolacea* were derived from common clade and grouped with *Ochlandra ebracteata* and *Ochlandra travancorica*, the later species showing separate evolutionary branches respectively (Figure.1). The morphological characters based species discrimination is not sufficient for correct species identification due to high phenotypic

plasticity, therefore, multidisciplinary approach including morphological and molecular characters need to be consider together for correct species identification and exploration of bamboo resources. (Das M., 2007)

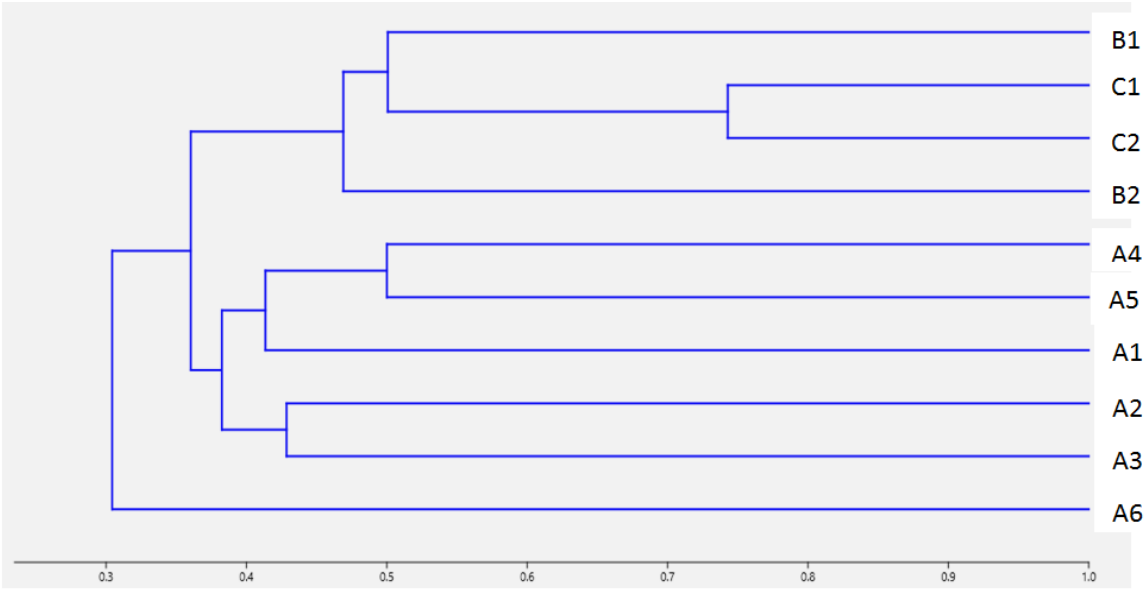

Figure.1. UPGMA dendrogram based on Jaccard Coefficient of Similarity Matrix of 10 different bamboos

	A1	A2	A3	A4	A5	A6	B1	B2	C1	C2
A1	1	0.333333	0.361702	0.410256	0.416667	0.266667	0.35	0.292683	0.285714	0.358974
A2	0.333333	1	0.428571	0.452381	0.390244	0.285714	0.428571	0.340909	0.395349	0.372093
A3	0.361702	0.428571	1	0.377358	0.38	0.271186	0.333333	0.392157	0.384615	0.365385
A4	0.410256	0.452381	0.377358	1	0.5	0.434783	0.465116	0.291667	0.285714	0.291667
A5	0.416667	0.390244	0.38	0.5	1	0.291667	0.439024	0.348837	0.404762	0.380952
A6	0.266667	0.285714	0.271186	0.434783	0.291667	1	0.354167	0.28	0.27451	0.28
B1	0.35	0.428571	0.333333	0.465116	0.439024	0.354167	1	0.418605	0.47619	0.525
B2	0.292683	0.340909	0.392157	0.291667	0.348837	0.28	0.418605	1	0.525	0.463415
C1	0.285714	0.395349	0.384615	0.285714	0.404762	0.27451	0.47619	0.525	1	0.742857
C2	0.358974	0.372093	0.365385	0.291667	0.380952	0.28	0.525	0.463415	0.742857	1

Table 2. Jaccard Similarity indices based on qualitative data Set

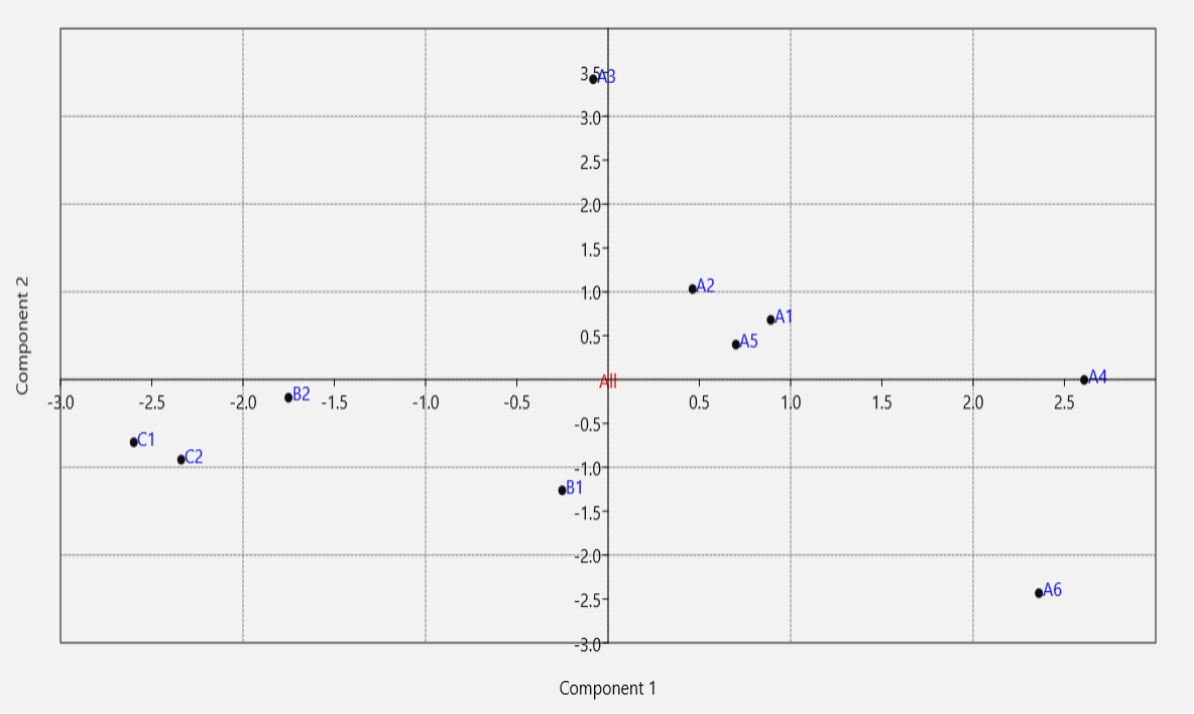

Figure 2. Two dimensional plot of Principal Component Analysis (PCA) showing clustering of 10 different species of bamboos.

Taxa	A1	A2	A3	A4	A5	A6	B1	B2	C1	C2
Clump Circumference (cm)	276.6	216	300	21	236	400	260	625	223.3	250
No. of culms in clump (cm)	22	20	60	32	22	45	55	25	43	56.6
Culm Height (cm)	7.3	13.6	20	17	10	4.5	683	1066	433	533
Culm Diameter (cm)	3.16	2.36	4	7.6	3.5	7.3	3.13	6.5	3.3	4.4
Wall Thickness (cm)	1.8	2.1	3.5	1.5	2.06	1.5	1.46	0.68	0.433	0.2
Culm Sheath Length (cm)	19	22.2	13.6	14	11.8	18.4	10	15.66	14.83	14
Culm Sheath Breadth (cm)	7.5	8.5	26	8	5.1	12.1	6	12.66	3	6.1

Table.3. Quantitative Descriptors of Bamboo species under study

Taxa	A1	A2	A3	A4	A5	A6	B1	B2	C1	C2
Closely clumped	1	0	0	0	1	1	1	1	1	1
Freely clumped	0	1	1	1	0	0	0	0	0	0
Sparsely clumped	0	0	0	0	0	0	0	0	0	0
Habit Erect	1	1	1	1	1	0	1	1	1	1
Tree form	0	1	0	0	0	0	1	0	0	0
Over arching	0	0	1	0	0	1	0	0	0	0
Climbing	0	0	0	0	0	0	0	0	0	0
Creeping	0	0	0	0	0	0	0	0	0	0
Short	0	0	0	0	0	0	0	0	0	0
Culm colour Dark green	0	0	0	1	0	1	1	0	0	0
Light green colour	1	1	1	0	1	0	0	0	0	0
Grey green colour	0	0	1	0	0	0	0	0	0	0
Yellowish colour	0	0	0	0	0	0	0	0	1	1
Dark brown	0	0	0	0	0	0	0	1	0	0
Surface; Pubescent	1	1	1	1	1	1	1	1	1	1
Spiny	0	0	0	0	0	0	0	0	0	0
White coating	0	1	1	0	0	0	0	0	1	1
Height; 1-5 m	0	0	0	0	0	1	0	0	1	1
5-10m	1	0	0	0	1	1	1	1	1	1
10-15m	0	1	0	1	1	0	0	1	0	0
15-20m	0	0	1	1	1	0	0	0	0	0
20-25m	0	0	1	0	0	0	0	0	0	0
25-30m	0	0	0	0	0	0	0	0	0	0
30-35m	0	0	0	0	0	0	0	0	0	0
Hollowness; Hollow	0	0	1	0	0	0	1	1	1	1
Semi solid	1	1	0	1	0	1	0	0	0	0
Solid	0	0	0	0	1	0	0	0	0	0
Shape in cross section; Round	1	1	1	1	1	1	1	1	1	1
Sulcate	0	0	0	0	0	0	0	0	0	0
Solitary	1	1	1	1	1	0	1	1	1	1
In close succession	0	0	0	0	0	1	0	0	0	0
Shape; Sides parallel	1	0	0	0	0	0	0	0	0	1
Narrow below widening above	0	1	1	1	1	1	1	1	1	0
Surface; pubescent	1	1	1	1	0	0	1	0	1	1
White circular line above node	0	0	1	0	1	0	0	1	1	1
Internode length; 1-5cm	0	0	0	0	0	1	0	0	0	0
5-10cm	0	0	0	1	0	1	0	0	0	0
10-15cm	0	0	0	1	0	1	0	0	0	0
15-20cm	0	0	0	1	0	0	0	0	0	0
20-25cm	0	1	0	1	1	0	1	0	0	0
25-30cm	1	0	1	1	0	0	1	0	0	0
30-35cm	0	0	1	0	0	0	0	1	1	0
35-40cm	0	0	1	0	0	0	0	1	1	0
40-60cm	0	0	1	0	0	0	0	1	1	1
Lower shorter than upper	0	0	0	0	0	0	1	1	1	1
Diameter; 1-3cm	0	0	1	0	1	0	1	0	0	1
3-6cm	1	1	1	1	1	0	1	1	1	1
6-9cm	0	0	0	0	0	1	0	1	0	0
9-12cm	0	0	0	0	0	1	0	0	0	0
12-15cm	0	0	0	0	0	0	0	0	0	0
15-20cm	0	0	0	0	0	0	0	0	0	0
20-25cm	0	0	0	0	0	0	0	0	0	0
Colour; Dark green	0	1	0	1	0	1	1	0	0	0
Greyish green	0	0	1	0	0	0	0	0	0	0
Light green	1	0	1	0	1	0	0	0	0	0
Dark brownish	0	0	0	0	0	0	0	1	0	0
Green with yellow strips	0	0	0	0	0	0	1	0	0	0

Yellowish green	0	0	0	0	0	0	0	0	1	1
Surface; Pubescent	1	1	1	1	1	1	1	1	1	1
Rough Sulcate	0	0	0	0	0	0	1	0	0	0
Width ; 1-5cm	0	1	0	0	1	0	0	0	1	0
5-10cm	1	0	0	1	0	1	1	0	0	1
10-15cm	0	0	1	1	0	1	0	1	0	0
15-20cm	0	0	1	0	0	1	0	0	0	0
20-25cm	0	0	0	0	0	0	0	0	0	0
25-30cm	0	0	0	0	0	0	0	0	0	0
Blade length ; 1-5cm	1	0	1	1	1	0	0	0	0	0
5-10cm	1	1	1	1	1	1	1	1	1	1
10-15cm	0	1	0	0	0	1	0	0	0	0
15-20cm	0	0	0	0	0	1	0	0	0	0
Width ; 1-3cm	1	1	1	1	1	1	1	0	1	1
3-5cm	1	1	1	1	0	1	0	1	0	0
5-9cm	0	0	1	0	0	1	0	0	0	0
9-15cm	0	0	0	0	0	0	0	0	0	0
15-20cm	0	0	0	0	0	0	0	0	0	0
20-30cm	0	0	0	0	0	0	0	0	0	0
Appendages of culm sheath; Auricle present	0	1	1	1	1	1	1	1	1	1
Auricle hairs	1	1	1	0	0	1	1	1	1	1
Ligules	0	0	0	0	0	0	1	1	1	1
Leaf length ; 3-6cm	0	0	0	0	0	0	0	0	0	0
6-10cm	0	0	0	0	0	0	0	0	0	0
10-15cm	1	0	0	1	1	0	0	0	0	0
15-25cm	0	0	0	0	0	1	0	0	0	0
25-30cm	0	1	1	0	0	0	1	1	0	0
30-35cm	0	1	1	0	0	0	0	0	1	1
35-40cm	0	1	1	0	0	0	0	0	0	0
Width ; 1-2cm	1	0	1	1	1	1	0	0	0	0
2-4cm	0	0	1	1	1	1	1	0	0	0
4-7cm	0	1	1	0	0	0	0	1	0	1
7-10cm	0	0	0	0	0	0	0	0	1	0
Appendages on leaf sheaths; Auricles: hairs	0	1	0	1	1	1	1	1	1	1
Ligule	0	0	0	1	1	1	1	1	1	1
Colour; Green on both the surface	0	1	1	1	1	1	1	0	1	1
Yellowish green	0	0	0	0	0	0	0	0	0	0
Lighter on one surface then another	1	0	1	0	0	0	0	1	0	0

Table.4. Qualitative Descriptors of Bamboo species under study

Conflict of Interest: The authors declare that there is no conflict of interest regarding the publication of this paper.

Acknowledgement: The authors are highly acknowledged and express their gratitude for valuable support from Department of Botany, Sant Gadge Baba Amravati University and Deputy Conservator of Forests (Territorial), Amravati Division, Maharashtra, India.

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