International Journal of Plant & Soil Science

Volume 34, Issue 24, Page 1005-1017, 2022; Article no.IJPSS.96078
ISSN: 2320-7035

Variation in Morphological Characters of Leaf and Culm Sheath of *Bambusa vulgaris* Schrad. ex.Wendl. in Central India

Irshad Ali Saudagar [a], Vineet Kumar Mehra [a], Trilok Gupta [a], Mukesh Kumar Sonkar [a], Sushma Maravi [a] and Fatima Shirin [a*]

[a] *Genetics and Tree Improvement Division, Tropical Forest Research Institute, Jabalpur, M.P., India.*

Authors' contributions

This work was carried out in collaboration among all authors. Author IAS designed the research work, carried out statistical analysis and wrote the first draft of the manuscript. Authors VKM and MKS executed research work in field. Author TG assist in statistical analysis. Author SM assist in designing the research work. Author FS supervised overall research work, managed the literature searches and correcting the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2022/v34i242730

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/96078

Original Research Article

Received: 02/12/2022
Accepted: 30/12/2022
Published: 31/12/2022

ABSTRACT

The feasibility of *Bambusa vulgaris* schrad. ex Wendl. has been assessed globally for a variety of uses. It is one of the fastest growing bamboo and can thrive in both moist and dry climates. To disseminate substantial baseline data on morphological variations of the species, morphological characteristics of leaf and culm sheath of Candidate Plus Clumps (CPCs) were evaluated followed by genetic analysis of growth attributes of three bamboo stands viz., MP-RJR, MH-AMR and OR-KLN, in three distinct states Madhya Pradesh, Maharashtra, and Odisha of central India. Significant differences in leaves and culm sheaths were noticed among the CPCs and bamboo stands during

**Corresponding author: E-mail: fatimashirin1997@gmail.com;*

the investigation. OR-KLN was observed with the longest leaf (22.77 cm) and the broadest leaf lamina at the top (1.58 cm). Longest average culm sheath blade (30.37 cm) in MH-AMR and maximum average sheath diameter (33.23 cm) in OR-KLN were recorded. High values for phenotypic coefficient of variations, genotypic coefficient of variations, heritability and genetic advance as mean percentage were obtained for clump diameter and number of culms per clump. This can be used as selection criteria in the improvement programme of *Bambusa vulgaris* var. Green.

Aims: To study morphological variation of leaf and culm sheath of *Bambusa vulgaris* schrad. ex Wendl. at three bamboo stands associated with genetic analysis in growth attributes.

Study Design: Complete Randomised design (CRD).

Place and Duration of Study: Morphological data of Candidate Plus Clumps (CPCs), leaf and culm sheath of *Bambusa vulgaris* was recorded at bamboo stands in Rajore, Madhya Pradesh, Kalinga, Odisha and Amravati, Maharashtra from September 2021 to November 2022. Further investigation, statistical analysis and other studies were carried out at Genetics and Tree Improvement Division, Tropical Forest Research Institute, Jabalpur, M.P., India.

Keywords: Bambusa vulgaris; candidate plus clumps; culm sheath; genetic analysis; morphological characters.

1. INTRODUCTION

“Bamboo thrives in tropical and subtropical climates” [1]. “It is a fast-growing woody grass [2], with a culm growth of 60 mm per day” [3]. Within 3-5 years, bamboo matures and can be used in a multitude of ways [4]. “Bamboo is also one of the most promising alternative raw materials for composite panel manufacture” [5]. It is most typically utilized in construction. Bamboo is affordable due to its mass availability specially in central India [6]. “Bamboo is not only a diverse resource for people's livelihoods, but it also helps to mitigate the effects of and adapt to climate change” [7].

There are 120 bamboo species in the genus *Bambusa* (Family Poaceae), which are native to Asia and the Americas. *Bambusa vulgaris* Schrad. ex D C. Wendl. is the most common bamboo in Asia, and it is planted all over the world. It is the only Asian species that grow in the New World. It naturalizes, producing monospecific stands along river banks, roadsides, and in the open ground since its culms and branches root rapidly. *B. vulgaris* can penetrate relatively undamaged woods as it moves along streams [8]. *B. vulgaris* is commonly used as a windbreak, support, and hedge plant. The culms are also used in the bamboo furniture sector and create high-quality pulp for paper production [9]. The total height of clumps, number of internodes per culm, internode length, internode diameter, culm wall thickness, girth, moisture content, and basic density are all regarded as key parameters in establishing the suitability of bamboo for various applications (Banik 2000) [10]. Many researchers worked for multi-trait selection viz., number of culms, height of culms, clump diameter, internode length, culm wall thickness, etc for CPCs [10,11,12,13].

The sympodial clump of *Bambusa vulgaris* is open tufted. Internodes 20–25 cm long, culms glossy green, glabrous; nodes prominent, the lower ones bearing aerial roots; culm erect and arching over, slightly zigzag, internodes 20–25 cm long, glossy green. From each node, 4–5 branches develop, with the principal branch dominating. Culm sheath blade found erect, triangular in shape, remaining attached at base, ligule slightly serrated, and auricles relatively big. Leaves are lanceolate in shape, green in color, glabrous in texture, and 20–26 cm long. Ligules are flat and surrounded by tiny rounded lobes of auricles [14].

“Genetic diversity is considered as the building block for speciation and evolution of any species. Bamboos are such a diverse group and provide many good examples to analyze and discuss the morphological and genetic concepts of species. Variation also exists concerning morphological and anatomical features. Lack of broad genetic background has triggered improved plant varieties less tolerant to biotic and abiotic stresses” [15-17]. “Narrow genetic variability in the plants increases vulnerability to pests and climatic variability. Genetic variability and heritability provide basic information for the genetic improvement of crops. Genetic variability is the measure of the tendency of individual genotypes in a population to vary from one to another for certain traits of interest, which is the base of tree improvement” [18].

Leaves are found highly specialized in structures in members of Poaceae. Many of them are protective structures that cover the shoot apices, rhizome's developing sections, and axillary buds. The taxonomy of bamboo is mostly based on spikelet structure [19]. Therefore, the limitations imposed by infrequent flowering materials for study are obvious. Hence, attempts are also made to use vegetative characters and on the morphology of culm sheath and leaves [19,20]. "Although bamboo possesses fairly conservative structures many variations are seen at subspecific or varietal levels. In culm- leaves, the sheath represents the greater part of the 'culm leaf' while the blade is under-developed, especially towards the base of the culm. The size and shape of the culm sheath blade in bamboo varies with the point of insertion" [21].

The foliage leaves are borne on the upper order branches. They possess well-developed blades, borne on a fragile sheath. Just like the culm-leaves, the culm-sheaths have ligules, auricles, and oral setae at the junction of sheath and blade [22,23]. The presence or absences of these elements of the leaf, as also the variations in their morphology, are of diagnostic value. The variations in size, shape, thickness, and indument of foliage leaves, also offer characters of taxonomical importance.

2. MATERIALS AND METHODS

2.1 Study Area

For the current study, three sites were selected in three states viz., Odisha, Madhya Pradesh and Maharashtra (Fig. 1, Fig. 2). All three bamboo stands viz., MP-RJR, MH-AMR and OR-KLN have a tropical climate. MH-AMR is situated in the northern hemisphere. The relative humidity ranges from August (82.26 %) to April (22.08 %). The average annual temperature is 26.7 °C. MH-AMR has annual rainfall of 1052 mm. The relative humidity at OR-KLN observes from August (85.56 %) to April (36.17 %) with annual rainfall of 1499 mm. The temperature here averages 27.0 °C. At MP-RJR the relative humidity was found from August (85.49 %) to April (20.79 %). The average annual temperature in MP-RJR is 25.1 °C and rainfall is around 979 mm per year (Table 1).

2.2 Field Survey and Selection of CPCs

The forest stands were thoroughly surveyed for the selection of Candidate Plus Clumps (CPCs) for the study. To study the morphological and phenological variations, in current investigation three different populations of *Bambusa vulgaris* var. green were selected randomly. 12 healthy and actively growing clumps each were selected in Odisha at Kalinga (OR-KLN), in Madhya Pradesh at Rajore (MP-RJR) and in Maharashtra at Amravati (MH-AMR). As the representative of bamboo stands, three random CPCs of *Bambusa vulgaris* (var. green) at each location were selected. The culm sheath and leaves were collected from each CPC to study the morphological differences between the bamboo stands.

2.3 Data Collection and Analysis

Physical characteristics and properties such as total height of clump (m), internode length of culm at the fifth node (cm), culm diameter at fifth node (cm), clump diameter (m), and total number of culms were taken into consideration for the selection of Candidate Plus Clumps of *Bambusa vulgaris*, and data were recorded in a systematic manner (Fig. 3). The diameter of the leaf (cm) was measured at the top, middle, and base of the leaf, the length of the leaf (cm), length of sheath (cm), diameter of sheath (cm), the length of the sheath blade (cm), the diameter of the sheath blade (cm), length of sheath ligule (cm), and width of sheath ligule (cm) were all measured (Fig. 4) for fifteen leaves and culm sheath in three replicates of each clump for observation on variations among clumps of same species according to Bakshi et al. [24] (Fig. 4).

The method used for the physical study of clumps was adopted from the work of Razak et al. [25], Sulthoni [26] and ASTM [27]. Statistical data analysis packages WASP 2.0 [28] and OPSTATS [29] were used to analyse the data. The data recorded for various parameters were subjected to Analysis of Variance. When comparing the means of various treatments, the F-test and Critical Difference (C.D.) values at 0.05 were used to determine the significance of the data.

The method provided by Johnson et al. [30] was used to evaluate genetic characteristics such as Phenotypic and Genotypic variances. Phenotypic and Genotypic coefficients of variation (PCV and GCV) were calculated as described by Burtons (1952). According to Lush (1940), heritability was estimated in a broad sense. Following Johnson et al. [30], the genetic advance was calculated.

Table 1. Geographical and climatic description of three bamboo stand areas of *Bambusa vulgaris*

Bamboo stand	MP-RJR	OR- KLN	MH-AMR
Latitude	22°18’N	22°16’N	20°92’N
Longitude	76°53’ E	84°41’E	77°79’ E
Elevation	248m	721m	383m
Climate	Sub-tropical	Tropical	Hot semi-arid
Max. Temp.	41.1 °C	34.0 °C	44.9 °C
Min. Temp.	10.3 °C	15.9 °C	18.9 °C
Rainfall	979 mm	1499 mm	1052 mm
Precipitation	345 mm	437 mm	329 mm
Forest type	Narmada Valley dry deciduous	Tropical-moist-deciduous	dry deciduous forests
Soil type	Layered Black Soil	Black Gravelley Soil	Sandy Soil

**Max.- Maximum, Min.- Minimum, N- North, E- East, m- Meter, Temp.- Temperature, mm- Millimeter, °C-Degree Celsius*

3. RESULTS AND DISCUSSION

Bamboo identification is heavily influenced by the shape of the leaves and culm sheath. The anatomy of bamboo leaves was previously investigated by Metcalf [31]. To distinguish between several species of bamboo, Raizada and Chatterjee [32] looked at the morphology of the culm sheaths. Culm sheath and leaf morphology play a significant role in the identification of bamboo. However, these characters were basically on the overall shape and size of culm sheath. Also, On the other hand, sometimes the same species may show some minor differences in characteristics concerning size and shape etc. depending on site, climatic conditions, etc.

Bamboo culms are made up of nodes and internodes. The node appears as a diaphragm between the cavities within a culm. The internode length between two successive nodes varied in length [33]. Zakikhani et al. [34] observed comparable findings in other bamboo species.

There is very little information on how to choose candidate plus clumps of a bamboo species. However, the performance of selected superior clumps obtained from these techniques operating in actual field conditions must be evaluated. Clumps were chosen as per the criteria for selection of CPCS of National Bamboo Mission, New Delhi. The length of the internodes increases from the base to the centre of the culms then reduces at the top. Bamboo, unlike timber, does not undergo secondary thickening and hence reaches its full diameter during the sprouting period [35].

3.1 Variation on Growth Parameters

Data of different growth parameters such as clump height (m), clump diameter (m), culm diameter at breast height (cm), number of culms per clump and internodal length of 36 CPCs of *Bambusa vulgaris* Schrad. ex Wendl. from three bamboo stands of Madhya Pradesh, Odisha and Maharashtra are presented in Table 2. Maximum clump height (22 m) was recorded in MP-RJR-4, MP-RJR-12, OR-KLN-3, OR-KLN-4, OR-KLN-5, MH-AMR-7 and MH-AMR-8. Maximum clump diameter (30 m) was observed in MP-RJR-12 and OR-KLN-2. In MH-AMR-2 maximum culm diameter at breast height of 11.9 cm was noted, while maximum number of culms (29) was recorded in OR-KLN-6 and MH-AMR-9 and longest intermodal length of 21.8 cm was observed in MH-AMR-1. Amlani et al. (2017) recorded the maximum clump height (18.80 m) in *Bambusa vulgaris* during the study of growth variation among 15 different bamboo species whereas in our study maximum mean clump height of 20.18 m was recorded.

3.2 Variation in Morphology of Culm Sheath and Foliage Leaf

“The foliage leaf blades are well-expanded as thinner, green structures with complete tissue for gas exchange and photosynthesis. These leaf blades are linked to less noticeable, lower sheath sections that have a protective role by encasing the immature branch internodes” (Generoso et al. 2016). During the study of leaves, significant variations were observed in total leaf length (Table 3). The longest leaf was observed in OR-KLN (22.77 cm) closely followed by MP-RJR (22.66 cm) and minimum leaf length in MH-AMR with 20.59 cm. For Leaf lamina, significant variations were seen for top part. Widest leaf lamina at top (1.58 cm) was recorded in OR-KLN, middle (1.98 cm), and at base (0.70 cm) was found in MH-AMR. Narrowest leaf lamina was recorded in top (1.03 cm) at MP-RJR, middle (1.85) and base (0.50 cm) at OR-KLN. In general, the foliage leaf blades yield fewer useful characters for identification. "In a few cases, size, hairiness and variegation are distinctive, as are leaf auricles or ligules" [36].

Table 2. Morphometric data on the growth of candidate plus clumps of *Bambusa vulgaris* from three bamboo stands

Bamboo stand	CPC	Clump height (m)	Clump diameter (m)	Culm diameter (cm)	Number of culms	Internodal length (cm)
MP-RJR	MP-RJR-1	16	28	8	15	21.5
	MP-RJR-2	16.6	27	7.5	13	20.4
	MP-RJR-3	17	27	8	18	20.8
	MP-RJR-4	22	25	9.5	20	18.9
	MP-RJR-5	21	23	11.4	18	16.5
	MP-RJR-6	20	24	10.2	19	18.5
	MP-RJR-7	18	29	7.8	18	21.5
	MP-RJR-8	19	22	6.4	19	21
	MP-RJR-9	17.6	28	8.9	18	20.5
	MP-RJR-10	20	30	8.1	11	20.6
	MP-RJR-11	21.5	22	7.4	13	21
	MP-RJR-12	22	30	8.5	11	20.9
OR-KAL	OR-KLN-1	21	21.3	7.4	16	18.7
	OR-KLN-2	20	30	7.3	19	18.9
	OR-KLN-3	22	21	8.2	17	16.4
	OR-KLN-4	22	19.4	10.6	28	18.5
	OR-KLN-5	22	20	11	26	15.8
	OR-KLN-6	20.4	16	11.7	29	18.5
	OR-KLN-7	19.4	29.6	9.7	21	20.8
	OR-KLN-8	21.4	28	9.5	22	20.4
	OR-KLN-9	20.5	27	10.4	21	19.7
	OR-KLN-10	18.2	21.4	8.5	18	20.5
	OR-KLN-11	18.9	21	8.1	17	20.4
	OR-KLN-12	19	22	7.9	18	24
MH-AMR	MH-AMR-1	20	22	10.3	14	21.8
	MH-AMR-2	21	22	11.9	11	22
	MH-AMR-3	21	21	10	13	21
	MH-AMR-4	20	27	9.8	15	20.5
	MH-AMR-5	21	28	11	12	18.6
	MH-AMR-6	20	27	12	17	19.4
	MH-AMR-7	22	19.4	10.6	28	18.5
	MH-AMR-8	22	20	11	26	15.8
	MH-AMR-9	20.4	16	11.7	29	18.5
	MH-AMR-10	19.4	29.6	9.7	21	20.8
	MH-AMR-11	21.4	28	9.5	22	20.4
	MH-AMR-12	20.5	27	10.4	21	19.7
Mean		20.12	24.41	9.44	18.72	19.77
SD		1.63	4.10	1.54	5.14	1.78
CV %		2.61	16.84	2.36	26.45	3.19

**CPC- Candidate Plus Clump, SD- Standard Deviation, CV- Coefficient of Variation*

"Physical and anatomical features of bamboo culms have long been known to influence their strength and durability" [35,37,38,39]. The information gathered on various attributes can be utilized to determine the best way to use bamboo. According to Liese and Köhl, the leaves of bamboo can be categorized into two types, each having its function. The culm sheath, mostly the thickened, rigid, scroll-like structure that wraps around and encloses a large portion of an internode as it lengthens during early culm growth is an example of one of the types. The foliage leaf on the finer branches is the other type of photosynthesis. At the top of the culm sheath, each shape has a blade. During the analysis of morphological data, significant variations were observed for all the characters except for blade diameter (Table 4).

Data analysis revealed that MH-AMR had the longest blade (30.37 cm) and shortest blade in MP-RJR (28.27 cm) followed by OR-KLN (29.10 cm). Maximum sheath diameter (33.23 cm) was observed in OR-KLN and minimum in MH-AMR (20.93 cm). Longest blade (3.67 cm), maximum blade diameter (1.10 cm), maximum height of ligule (0.30 cm) and widest ligule (10.41 cm) were recorded in MP-RJR (Table 4). Because it is either stiffly upright to reflexes in many species, the position of the culm sheath blade is frequently diagnostic. At various phases of culm development, the blade orientation is only variable in a small number of species. Size, Colors and blade shapes can also aid with identification [36].

B. vulgaris has different physical features in terms of culm sheath and leaves. Razak et al. [25] obtained similar observations while studying *G. scortechinii*. Most current classifications of the bamboo depend on morphological characteristics [40], however, only few of the species have been properly documented, making it hard to use phenotypic features.

3.3 Genetic Analysis

"Then approaching to the results of genetic estimates namely phenotypic coefficient of variation, genotypic coefficient of variation, environmental coefficient of variation, broad spectrum heritability and genetic advance as percentage of mean for the biometric and physiological parameters of *Bambusa vulgaris* were computed in Table 5. The probable reason for variation in growth parameters among the same bamboo species may be due to the genetic make-up of the species or due to the wide range of rainfall, temperature, altitude, and soil type concerning habitat. Secondly, it may be due to positive relation and adaptability of the species with the rainfall, temperature, altitude, soil type in relation to habitat" (Amlani, 2015). These results are in close proximity with the earlier findings of Annapurna et al. [41] in 14 candidate plus clumps (CPCs) of bamboos originated from different regions and revealed variability; Tewari et al. [11] found "*B. balcooa, B. nutans* and *B. vulgaris* performed better in terms of survival and growth among different species of bamboo"; Adhikari and Shrestha [42] got "significant differences in phenotypic characters of *B. nutans*, giving a clue of significant genetic differences which leads to variation among plants"; Nath et al. [43] reported "similar phenological pattern in *B. balcooa* and *B. vulgaris* and their difference with *B. cacharensis* reflects differential ecological adaptability among the species growing under the same environmental condition"; Nath et al. [43] studied "culm characteristics and population structure of Dolu bamboo (*Schizostachyum dullooa*)"; Nath et al. [44] studied "different phenology and culm growth of *Bambusa cacharensis"*; Qiu et al. [45] found "growth variation in *Phyllostachys pubescens* collected from nine Chinese provenances".

Table 3. Morphological data of length and diameter of leaf lamina of *Bambusa vulgaris* in three bamboo stands

Bamboo stands	Leaf length (cm)	Leaf Diameter (cm)		
		Top	Middle	Base
OR-KLN	22.77	1.58	1.85	0.50
MP-RJR	22.66	1.03	1.93	0.58
MH-AMR	20.59	1.19	1.98	0.70
CD (0.05)	1.90	0.40	NS	NS
SE	0.54	0.11	0.07	0.05
SD	0.76	0.16	0.10	0.07
CV %	4.89	17.79	7.63	16.67

**CD- Critical Difference at 0.05 level, SE- Standard Error, SD- Standard Deviation, CV- Coefficient of Variation*

Table 4. Morphological data of culm sheath of *Bambusa vulgaris* in three bamboo stands

Bamboo stands	Sheath length (cm)	Sheath diameter (cm)	Blade length (cm)	Blade diameter (cm)	Height of ligule (cm)	Ligule diameter (cm)
OR-KLN	29.10	33.23	3.47	0.80	0.23	8.63
MP-RJR	28.27	31.60	3.67	1.10	0.30	10.41
MH-AMR	30.37	20.93	1.87	0.90	0.23	6.17
CD (0.05)	1.19	4.33	1.16	NS	0.05	2.47
SE	0.29	1.08	0.29	0.16	0.01	0.61
SD	0.42	1.52	0.41	0.23	0.02	0.87
CV %	1.74	6.51	16.61	29.99	8.53	12.62

**CD- Critical Difference at 0.05 level, SE- Standard Error, SD- Standard Deviation, CV- Coefficient of Variation*

Table 5. Genetic estimates of three bamboo stand for the morphometric traits of *Bambusa vulgaris*

Bamboo stand	Traits	Variance		Coefficient of Variation (%)		Genetic parameters		
		GV	PV	GCV	PCV	H%	GA	GAM%
MP-RJR	**Clump height**	5.889	10.472	3.702	8.957	17.085	0.828	3.152
	Clump diameter	14.931	15.786	11.381	12.355	84.851	4.152	21.596
	Culm diameter	4.559	5.330	13.701	17.179	63.609	1.908	22.511
	Number of culms	32.704	35.510	19.933	22.490	78.556	5.853	36.394
	Internodal length	6.355	6.837	7.030	7.827	80.662	2.624	13.006
OR-KLN	**Clump height**	4.072	5.022	5.249	7.097	54.691	1.631	7.996
	Clump diameter	48.679	56.059	16.563	20.326	66.402	6.411	27.804
	Culm diameter	7.523	7.683	17.106	17.650	93.931	3.139	34.152
	Number of culms	68.546	70.240	22.574	23.409	92.989	9.417	44.842
	Internodal length	10.097	12.796	8.580	12.061	50.610	2.437	12.574
MH-AMR	**Clump height**	0.644	1.089	1.640	3.613	20.604	0.318	1.534
	Clump diameter	64.457	65.443	19.282	19.724	95.571	9.287	38.831
	Culm diameter	0.700	1.308	2.942	7.886	13.921	0.241	2.261
	Number of culms	138.778	140.695	35.476	36.210	95.986	13.664	71.599
	Internodal length	8.137	8.957	8.054	9.267	75.522	2.848	14.418

**GV- Genotypic Variance, PV-Phenotypic Variance, GCV-Genotypic Coefficient of Variation, PCV- Phenotypic Coefficient of Variation, H%-Heritability in Percentage, GA-Genetic Advance, GAM%-Genetic Advance Mean Percentage*

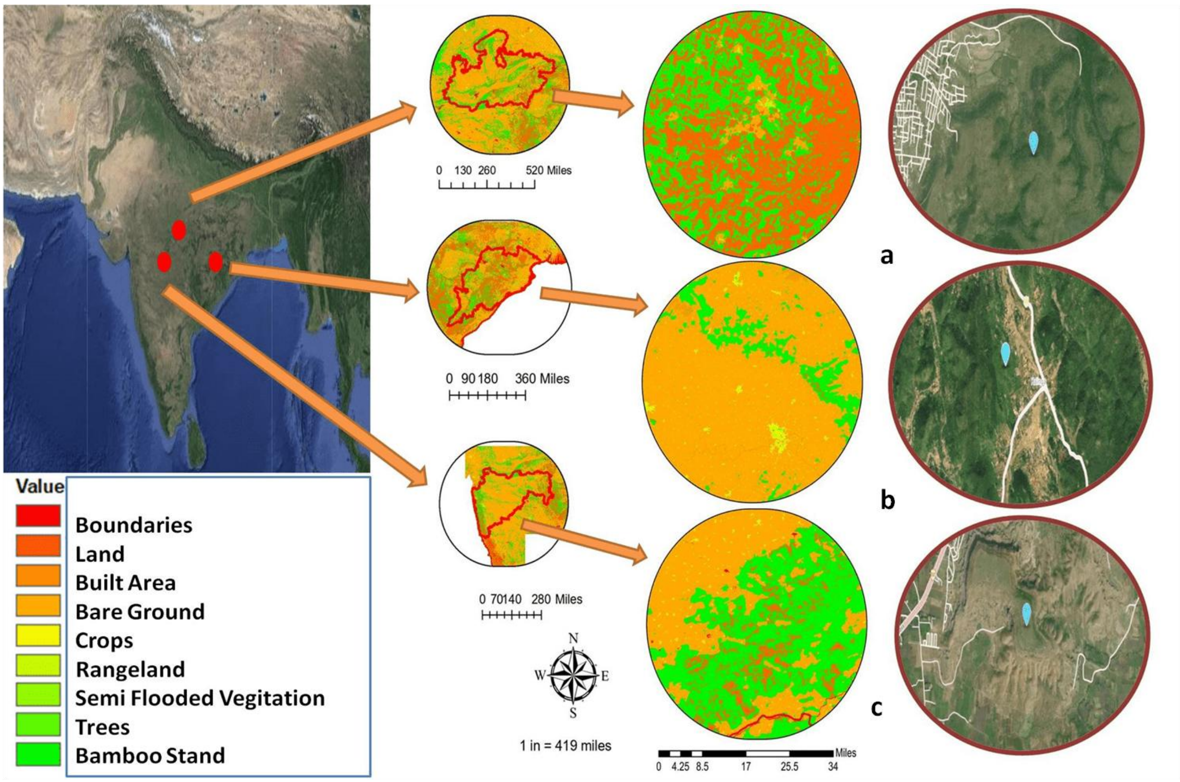

Fig. 1. Map highlighting Bamboo stands of *Bambusa vulgaris* at, a) MP-RJR, b) OR-KLN, and c) MH-AMR, India

Fig. 2. Bamboo stands of *Bambusa vulgaris* at, a) OR-KLN, b) MP-RJR and c) MH-AMR

The phenotypic coefficient of variation and genotypic coefficient of variation for the height of clump and culm diameter in MH-AMR and for clump diameter, number of culms per clump and intermodal length in OR-KLN were found to be with the least value. A little similar trend was observed for the heritability with highest percentage of clump height (84.851%) and Internodal length (80.662%) in OR-KLN and clump diameter (95.571%) and number of culms per clump (95.986%) in MH-AMR and culm diameter (93.931%) in MP-RJR. Genetic advance as percentage of mean was found to be high for clump height (4.154%) in OR-KLN, clump diameter (9.287%), number of culms per clump(13.664%) and Internodal length (2.848%) in MH-AMR and culm diameter (3.139%) in MP-RJR.

Fig. 3. Measurement of, a) clump diameter of *Bambusa vulgaris* at OR-KLN, b) internodal length and c) culm diameter at MP-RJR

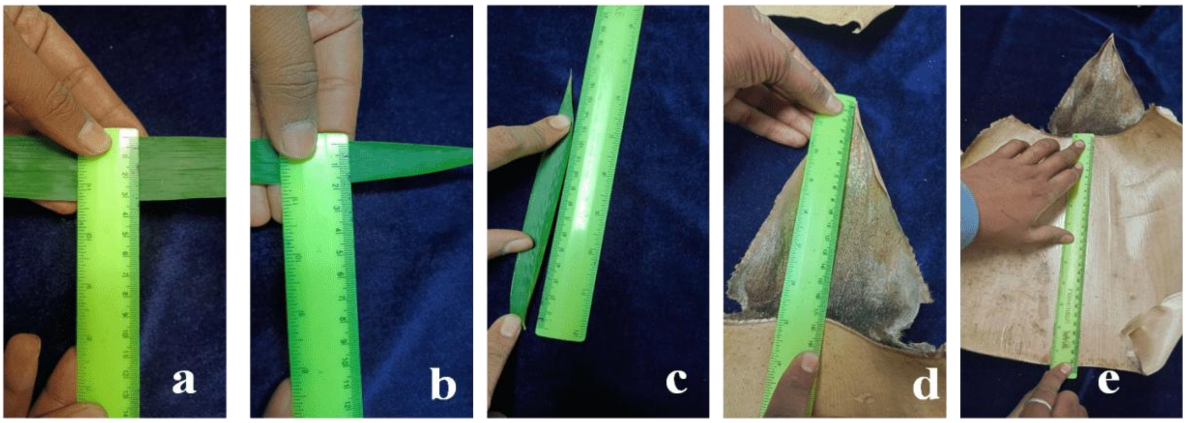

Fig. 4. Measurement of morphometric data of, a) Diameter of leaf o at middle, b) at top, c) length of leaf, d) Blade length, and e) length of sheath

For the populations, high and moderate genotypic and phenotypic coefficients of variance (PCV %) were obtained for the number of culms in MH-AMR followed by clump diameter in MH-AMR. In MH-AMR population the genotypic variance (GV) was greater than the phenotypic variance (PV) in the number of culms in MH-AMR followed by clump diameter in MH-AMR.

Wide differences have been recorded for variance components of growth parameters of *Bambusa vulgaris*. The highest phenotypic variance was found for the number of culms (140.695) in MH-AMR while the least for clump height (1.089) in MH-AMR. The genetic variance varied from 0.644 to 138.778 for the same parameters. The clump height in MH-AMR exhibited the highest value of PCV (36.210) and GCV (35.476). Heritability values were recorded over 60% for the majority of the traits except for Clump height in MP-RJR, clump height and intermodal length in OR-KLN, and clump height and culm diameter in MH-AMR. The genetic advance ranged from 13.664 (number of culms in MH-AMR) to 0.318 (clump height in MH-AMR) while genetic gains were recorded maximum of 71.599 for number of culms in MH-AMR and minimum of 1.534 for clump height in MH-AMR.

3.4 Estimation of Phenotypic and Genotypic Parameters

The present study revealed that phenotypic coefficient of variability (PCV) values ranged for clump diameter from 12.355 in MP-RJR to 20.326 in OR-KLN and number of culms 22.409 in OR-KLN to 36.210 in MH-AMR, whereas the genotypic coefficient of variability (GCV) ranged from 11.381 in MP-RJR to 19.282 in MH-AMR (clump diameter) and 19.993 in MP-RJR to 35.476 in MH-AMR (number of culms). The estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were high for number of culms in MH-AMR. Similarly, high PCV and GCV values for grain yield and number of tillers were also found by Kifle et al. [46] and Dergicho et al. [47] in bread wheat. In general, phenotypic coefficient of variation value was relatively greater than genotypic coefficient of variation value although the differences were small. Narrower difference between the values of GCV and PCV indicated that the environmental effect was small for the expression of these characters and these traits are governed by additive gene action.

3.5 Heritability

According to Singh [48], "heritability of a character is very high if 80% or more, moderate if ranging from 40-80%, but low heritability for a character with less than 40%. In the present study heritability estimated ranged from 17.085% to 95.986%, showing the traits are grouped into low, moderate and highly heritable" (Table 4). High heritability was recorded for clump diameter, number of culms and internodal length. These traits which exhibited high heritability suggested improvement through selection could be fairly easy and successful because there would be a close correspondence between genotype and phenotype due to a relatively smaller contribution of the environment to phenotype. Rest of the traits show moderate heritability value (40-80%) except for Clump height in MP-RJR, clump height in MH-AMR, and culm diameter in MH-AMR. Clump diameter was observed to be a high to moderate heritability character with heritability ranging from 95.571% to 66.402%.

3.6 Estimates of Genetic Advance

Genetic advance expressed as a percentage of the mean for clump diameter ranged from 21.596% in MP-RJR to 38.831% in MH-AMR (Table 4). Deshmukh et al. [49] classified genetic advance as low (0-10%), medium (10-20%) and high (≥20%). Based on classification, high genetic advance as percentage of mean (GA%) was observed for clump diameter in MP-RJR, culm diameter in MP-RJR, number of culms in MP-RJR, number of culms in OR-KLN, clump diameter in MH-AMR, number of culms in MH-AMR. Clump diameter, number of culms and intermodal length exhibited high genetic advance mean percentage across all three stands. This implies these characters can be used during selection for achieving high genetic advance [50,51]. "The estimates of genetic advance help in understanding the type of gene action involved in the expression of various polygenic characters. High values of genetic advance are indicative of additive gene action, whereas low values are indicative of non-additive gene action" [52].

The importance of considering both the genetic advance and heritability of traits rather than considering them separately in determining how much progress can be made through selection was suggested [28,53]. In this study, high heritability accompanied by high genetic advance was observed for number of culms. This indicated that these traits were highly heritable and selection of high performing genotypes is possible for genetic improvement of the species.

An earlier report by Xia et al. [54] evaluated *Dendrocalamus latiflorus* and *Bambusa vulgaris* based on vegetative morphological descriptors and found both of them to be fairly similar.

Additionally, in studies involving different individuals of the same species, *Bambusa tulda*, Bhattacharya et al. [55] found little diversity as would be expected. Further studies involving a large number of bamboo from different places are therefore required to achieve a better understanding of their diversity.

4. CONCLUSION

This study has disclosed some important facts with regard to different morphological characteristics of *Bambusa vulgaris*. The species is easily distinguishable through the culm sheath. The morphological characteristics of *Bambusa vulgaris* vary from clump to clump. In the present study, significant variability was noted among bamboo genotypes for most of the characters and there are opportunities for the genetic gain through selection. Clump diameter and number of culms per clump are some of the important characteristics for the selection of CPCs. Thus we can conclude that the highly heritable character with high genetic advance mean percentage viz., clump diameter, and number of culms can be used as selection criteria in the improvement programme of *Bambusa vulgaris* var. green.

ACKNOWLEDGEMENTS

The authors are thankful to the Director, Scientists and staff of Tropical Forest Research Institute, Jabalpur who provided all the needful scientific help and infrastructural facilities. We also thank Compensatory Afforestation Fund Management and Planning Authority (CAMPA), New Delhi, India for financial support in conducting this study under All India Coordinated Research Project on Bamboo.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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