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Defining growth, quality and biomass production of different bamboo species in central plains of Punjab

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Abstract
The present study was carried out at University Seed Farm Ladhowal, Punjab Agricultural University Ludhiana, Punjab (India) with six bamboo species *viz., Bambusa balcooa, Bambusa bambos, Bambusa nutans, Bambusa tulda, Bambusa vulgaris* and *Dendrocalamus strictus* to estimate the growing biomass for adopting new bamboo species in agroforestry system. Growth measurements were directly taken from six year old plantation in field and destructive sampling method was adopted to estimate the quality and biomass potential of different species. *Bambusa nutans* was found best for clump diameter, culm diameter and inter-node length, whereas, *Bambusa bambos* showed superiority for clump height and *Bambusa balcooa* for number of culms per clump. The highest biomass was recorded in *Bambusa nutans* and lowest in *Bambusa balcooa*. The study revealed that elasticity was high in *Bambusa balcooa,* which may be suitable for bamboo handicrafts. Maximum fibre length was recorded in *Dandrocalamus strictus,* which is suitable for pulp industries, whereas, specific gravity was in *Bambusa tulda,* which could be suitable for construction purpose.

Keywords: Bamboo species, growth, quality, biomass, index score

Introduction
Bamboo belongs to grass family Poaceae and it is a flowering perennial plant in the subfamily Bambusoideae. In recent times, it achieved worldwide attention as a resource of quickly renewable biomass and possible alternative fast growing woody plant for plantations in and outside forests. Each plant can reside up to 75 years and it attains harvesting maturity in three to six years [14]. Indicative estimates vary from 111 genera and 1575 species [13] to 1400 species in Bambusoideae [5]. Bamboo is grown in tropical, subtropical and temperate regions between 46ºN and 47ºS latitudes, in all continents except Europe and western Asia, up to 4000 m altitude [6]. Bamboo is a natural resource in most of the Asian countries, however, approximately 30% of the total area under bamboo is planted [7]. Bamboos have been cultivated in villages, by farmers to satisfy their social, ecological and economical needs. In Asia, India leads the bamboo producing countries with an estimated source area of 11.4 million hectares and is followed by China with 5.4 million hectares. Other major bamboo producing countries in the region include Indonesia (2 million hectares) and Lao PDR (1.6 million hectares). China has the highest bamboo diversity in Asia with over 500 species, followed by India, Indonesia, Myanmar and Malaysia, each with more than a hundred species. In India, 145 species of 23 genera are available, including both exotic and indigenous [2]. North-east India accounts nearly 50 per cent of the total bamboo resource of the country [18].
Bamboo plays a vital role in the livelihood of rural/tribal people and small-scale industry due to its various end uses. Bamboo’s rapid growth, ease of caring and wide distribution makes these plants an ideal renewable resource for the development of local economies. Bamboo is promising alternative raw material for the timber and supports agro-industries worldwide for manufacturing handicraft items, packaging materials, raw materials for paper industries, etc. The mass utilization of bamboo by the paper and pulp industry is increasing, thus it is going out of reach of the common man. This is in itself would serve to bring a new focus on the bamboo and help their conservation and replantation with the mission to harness the potential of bamboo crop. National Bamboo Mission (NBM) was implemented by Govt. of Indian, under this mission bamboo nurseries are supported in all the states to increase the availability of quality planting material of bamboo. Bamboo is an important part of the socio-cultural and religious life of Indian communities. It's not only ecologically balanced by using the synergy of nature and traditional socio-economical system but also economically sound fulfilling the

needs of growing population. The development and enhancement of bamboo cultivation can promote economic and environmental growth, mitigates deforestation and illegal logging, prevent soil degradation and restores degraded lands in both village as well as urban area of India.

Keeping in view the importance of mass scale propagation of superior genotypes through macro and micro-propagation to meet the ever-increasing demands, it was proposed to collect superior germplasm of bamboo species from different sources, evaluate them and use the available variability and introduce superior genotype of different species of bamboo in Punjab [4]. In the present scenario in the state, the bamboo has huge potential for biomass production for pulp and diversification of poplar/eucalypts based agroforestry systems in Punjab. Different species of bamboos were introduced in Punjab to widen the genetic base of the species. Breeding process was slow due to irregular flowering in bamboo and to enlarge this genetic base, we need to utilize the genetic variability available in differ bamboo species. The present study had been designed to record information on the growth, quality and biomass production of different bamboo species so that we can compare the productivity of bamboo with traditionally available species i.e., *Dendrocalamus strictus*.

Materials and Methods

Study Site and Experimental Details

The experimental material for the present study consisted of six bamboo species *viz*., *Bambusa nutans, Bambusa vulgaris, Bambusa bambos, Bambusa tulda, Bambusa balcooa* and *Dendrocalamus strictus*. The propagation material was collected from Forest Research Institute Dehradun. The evaluation trial was laid out at University Seed Farm Ladhowal of Punjab Agricultural University Ludhiana, Punjab (India) during July 2010. Site (University Seed Farm, Ladhowal, PAU Ludhiana) is located in the central plain zone of Punjab with subtropical climate. It lies at 30º58'N latitude, 75º45'E longitude and 776 feet amsl. It experience severe summer during May-June and during winter December-January. The average annual rainfall ranges from 300-500 mm. The evaluation of six species was done in randomized block design with 3 replications raised at spacing of 6×6m with plot size of five plants. Plantation site soil status is depicted in Table 1.

Field Sampling and Growth Measurements

Three randomly selected plants were from each plot at the age of 6 year were taken for measuring the plant height (m), clump diameter (cm), culm diameter (cm), number of culms per clump, intermodal length (cm). Culm diameter was measured in cm at three places i.e. base, middle and top. For measuring the culms weight (kg plant^{-1}), destructive sampling method was adopted, in which, three plants from each replication were selected randomly and uprooted. The shoot portion was separated from the root and it was weighed on an electronic balance to get fresh shoot weight. The shoots were dried in hot air oven at 70+2ºC and weighed to get dry shoot weight. The biomass recorded per plant thus was converted in to tons/hectare. To define stand dynamics, growing stock and biomass, a factor analysis was performed [9]. First, factors were obtained for qualifying culms growth. Thereafter, factors that described stand productivity and biomass were also defined.

Hollowness of bamboo plants was measured by using vernier calliper in cm. Three observations (each from base, middle and top were recorded to represent the whole culm. For fibres length (µm), small sliver of wood were placed in test tubes and macerated with nitric acid (30% HNO_3) and a few crystals of potassium chloride (KCl) were added [10]. Test tubes were heated in oven at 75ºC for approximately 24 hours till the slivers turned into white colour. Slivers were washed 2 to 3 times and shaken so the fibres get separated. Fibres were further stained with safranin and mounting on slide then observed under microscope at the power of 10X. Straightened and undamaged fibres were selected and measured with ocular micrometer. Twenty measurements were made for each sample then average was calculated. Same process was replicated 4 times to avoid error in recording obeservations. Calibrations made by stage micrometer for width and values were interpreted accordingly. For specific gravity, samples selected (without pith) for specific gravity were suitably numbered with copying pencil. They were then soaked in water till they sunk to the bottom. Saturated samples were then taken out and weighed on an electric balance after removing the surface water with filter paper. The samples were then oven dried at 103±2ºC until there was no further loss of moisture. Oven dry weight was determined and specific gravity calculated by the formula given by Smith (1954) [20] on the basis of three samples per plant.

Statistical Analysis

The factor procedure (Proc GLM) for factor analysis of the SAS/STAT® (SAS Software 9.3, SAS Institute Ltd. U.S.A.) statistical program was used [12]. Correlation studies irrespective of species were calculated according to the method suggested by Goulden (1952) [8]. General performance of each species was calculated by using index score analysis for growth, quality and biomass [1]. The class intervals used for different character are given in Table 2.

Results and Discussion

Selection of particular species for specific use has been practiced for millennia, contributing to the development of many cultures and livelihoods. Nowadays, there is an increasing demand for bamboos with specific characteristics. Pioneering work in improving bamboo was initiated by Beniwal and Singh (1988) [3] in North-eastern states of India. Several researchers have attempted to identify superior genotypes among bamboo species by ascertaining variation in morphological characters. In the present study, significant differences were observed for the different parameters for different bamboo species. Huge variation in different growth, quality and biomass characteristics for *Bambusa nutans, Bambusa vulgaris, Bambusa bambos, Bambusa tulda, Bambusa balcooa* and *Dendrocalamus strictus* were observed (Table 3). Culm diameter differences among different species at top were found non-significant. *Bambusa bambos* attained maximum height with culm diameter, while, *Bambusa nutans* had maximum clump diameter, intermodal length. Biomass production depends on the size of the culms and the number of culms production, which was maximum in *Bambusa nutans*, however, *Bambusa balcooa* produced maximum number of culms per clump with the high elasticity. *Dendrocalamus strictus* had the longest fibre among all species studied. Pathak *et al.* (2015) [15] also recorded significant differences in culms height among seven bamboo species. Sharma *et al.* (2014) [17] reported similar variation in fiber length of *D. strictus* 24.49 µm greater than all other species. Specific gravity was found non-significant for species studied.

The goal of genetic evaluation trial always envisages high expression of all or most of the desirable traits in single genotype. In view of this, the knowledge of correlation among quantitative trait is useful in two ways. Firstly, it helps to predict the response of other characters when we select for one. The implication positive or negative or no correlation can help in selection of suitable individuals for formulation of appropriate selection procedure for simultaneous improvement of more than one character. Secondly, for complex compound like yield and biomass, selection based highly correlated compound character is more effective than the direct selection [11, 16]. The correlations in all possible combinations among all characters under study are presented in Table 4 to make use in future studies to reduce the number of character for observations depending on degree of relationship.

The results pertain that the plant height of different bamboo species was significantly (P<0.01) correlated (r > 0.9) with culm diameter and inter-node length but inter-node length showed negative correlation. There was also significant (P<0.01) positive correlation between clump diameter and culms fresh (r > 0.9) and dry weight (r > 0.9) and also significant (P<0.01) correlation between number of culms per clump and culm diameter (r > -0.9) and it showed negative correlation. There was also significant (P<0.01) positive correlation between culms fresh weight and culms dry weight (r > 0.9), but some characters like clump diameter and hollowness, culm diameter and hollowness had significant (P<0.1) positive correlation (r > 0.77). The highly significant positive correlation was also observed between plant height and culm diameter (0.995), culms fresh weight and culms dry weight. Singh and Rai (2012) [19] found the significant positive correlation observed between biomass production and clump circumference was also in conformity with present findings. Biomass of the culms showed positive correlation with culms characteristics such as plant height, clump diameter, culm diameter, inter-node length and hollowness.

Index score analysis was carried out in six bamboo species. Superiority was given to the species on the basis of index scores as presented in Table 5. Index score ranged from 10 to 27 among different species. Maximum index scores of 24 was given to *Bambusa nutans* and *Dendrocalamus strictus*, which indicated overall superiority followed by *Bambusa vulgaris*, *Bambusa bambos*. Minimum index score of 7 was recorded for *Bambusa balcooa*. *Dendrocalamus strictus* was found best in terms of quality characters, whereas, *Bambusa nutans* and *Dendrocalamus strictus* were equally found best for growth characters. *Bambusa nutans* was found best for biomass character.

Table 1: Physico-chemical properties of soil

Depth (cm)	Texture	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	pH
0-15	Loamy sand	151.5	8.32	220.1	8.4
15-30	Loamy sand	146.3	8.50	215.2	8.2
30-60	Loamy sand	150.4	6.50	195.3	8.4
60-90	Loamy sand	147.4	7.25	212.0	8.4

Table 2: Class intervals for index scoring for different bamboo species

Characters	1(0)*	2(2)*	3(4)*
Plant height (m)	<6.3	6.3-7.7	>7.7
Clump diameter (cm)	<378	378-483	>483
Numbers of culms per clump	>144	144-85	<85
Culm diameter (cm)	<2.2	2.2-2.9	>2.9
Inter -node length (cm)	>30	30-25	<25
Culms fresh weight (t ha^{-1})	<78	78-116	>116
Culms dry weight (t ha^{-1})	<46	46-68	>68
Hollowness(cm)	<0.8	0.8-1.1	>1.1
Fiber length (µm)	<18	18-21	>21
Specific gravity	<0.44	0.44-0.49	>0.49

***The values in the parenthesis are the respective index values for the insect infestation

Table 3: Data for growth, quality and biomass parameter for different bamboo species

Treatments	Plant height (m)	Clump diameter (cm)	Number of culms per clump	Culm diameter (cm)			Inter-node length (cm)	Hollowness (cm)			Fiber length (µm)	Specific gravity	Culms weight (t ha^{-1})	
				Base	Middle	Top		Base	Middle	Top			Culm fresh	Culm dry
Bambusa nutans	8.7	587	70	4.6	3.7	2.0	35	1.0	2.0	1.4	17	0.39	154	91
Bambusa vulgaris	8.7	423	35	4.9	3.7	1.8	27	1.8	2.0	1.0	16	0.46	96.4	57
Bambusa bambos	9.2	347	26	5.5	3.6	1.8	23	1.2	1.1	0.7	17	0.43	106	62.2
Bambusa tulda	8.5	320	27	4.9	3.2	1.6	22	1.2	1.5	0.8	17	0.54	67	39.1
Bambusa balcooa	4.9	273	204	2.1	1.6	0.8	32	0.5	0.8	0.3	15	0.42	39.4	23.3
Dendrocalamus strictus	9.0	365	39	4.8	3.4	2.1	20	0.7	1.8	0.6	25	0.45	80	50.3
Range	4.9-9.2	273-587	26-204	2.1-5.5	1.6-3.7	0.8-2.1	20-35	0.5-1.8	0.8-2.0	0.3-1.4	15-25	0.39-0.54	39.4-154	23.3-91
CD(p=0.05)	1.70	75.00	30.00	0.80	0.70	NS	2.00	0.50	0.60	0.30	4.60	NS	57.66	33.24

Table 4: Correlation studies among different bamboo species

	Plant height (m)	Clump diameter (cm)	Number of culms per clump	Culm diameter (cm)	Inter-node length (cm)	Culms fresh weight (t ha^{-1})	Culms dry weight (t ha^{-1})	Hollowness (cm)	Fiber length (µm)	Specific gravity
Plant height (m)	1.000									
Clump diameter (cm)	0.466	1.000								
Number of culms per clump	-0.969*	-0.295	1.000							
Culm diameter (cm)	0.995**	0.509	-0.962*	1.000						
Inter-node length (cm)	-0.491	0.510	0.616	-0.433	1.000					
Culms fresh weight (t ha^{-1})	0.643	0.928	-0.474	0.681	0.331	1.000				
Culms dry weight (t ha^{-1})	0.660	0.929	-0.486	0.694	0.303	0.998**	1.000			
Hollowness (cm)	0.717	0.770	-0.684	0.767	0.075	0.738	0.732	1.000		
Fiber length (µm)	0.434	0.010	-0.374	0.369	-0.592	0.016	0.074	-0.002	1.000	
Specific gravity	0.195	-0.477	-0.418	0.163	-0.659	-0.468	-0.473	0.066	0.063	1.000

*Significant at 5% ($P<0.05$), **Significant at 1% ($P<0.01$)

Table 5: Index scores for different characters recorded for different bamboo species

Species	Plant height (m)	Clump diameter (cm)	Number of culms per clump	Culm diameter (cm)	Inter-node length (cm)	culms fresh weight (t ha^{-1})	culms dry weight (t ha^{-1})	Hollowness (cm)	Fiber length (µm)	Specific gravity	Total score
Bambusa nutans	3	3	3	3	1	3	3	3	1	1	24
Bambusa vulgaris	3	2	3	3	2	2	2	2	1	2	22
Bambusa bambos	3	1	3	3	3	2	2	2	1	1	21
Bambusa tulda	2	1	3	3	3	1	1	2	1	3	20
Bambusa balcooa	1	1	1	1	1	1	1	1	1	1	10
Dendrocalamus strictus	3	1	3	3	3	2	2	2	3	2	24

Conclusions

It is concluded that bamboo culms and their stands could be characterized by individual growth and biomass variables and the factors developed in the present study might be used as an overall measurement to obtain integrated information on correlation about the culm condition. Therefore, this may be a useful tool for planning silvicultural and management practices in bamboo plantations in Punjab. The correlation study provided an important approach for reducing data dimensionality and also for providing information about groups of variables, which described a specific condition. Considering the complexity of these bamboo species associated with their growth and biomass variables required to qualify culms, factors are an important tool for foresters responsible for the management of bamboo resource under Punjab.

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