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Variation in Morphological Characteristics of Four Important Bamboo Species

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Abstract: *The study was conducted in the (i) experimental bamboo field of BN College of Agriculture, AAU, Biswanath Chariali and in the (ii) farmer's field of Golia village, Biswanath Chariali, Assam. The variation in morphological characteristics of four common bamboo species having socioeconomic importance viz. Bambusa tulda, B. nutans, B. balcooa and Dendrocalamus hamiltonii were studied. The result revealed that, the culm height, DBH, culm circumference, length of internodes and number of node per culm were significantly different in different bamboo species. But these parameters were not significantly different with respect to ages of culm and the interaction effect of age and species were also not significantly different. On the other hand the culm thickness were significantly different in different species and they significantly increased with culm age up to 4th year. However, the length, breadth and area of leaf significantly varied with different bamboo species and they increased with the increase in the age of culm from one year to second year then again they decreased significantly from 3rd year onward. The interaction effect between species and age of culm were also found significant.*

INTRODUCTION

The bamboo is a group of woody grass and regarded as 'Emperor' among the grasses. It belongs to the family poaceae and sub family bambusoidae. India has the second largest bamboo reserve in Asia after China. It is commonly known as "poor man's timber", keeping in mind the variety of its end use from cradle to coffin (Yeasmin *et. al*., 2015).

Bamboo, a monocot plant of the family Poaceae, comprises about 75 genera and more than 1200 species. It is present in the tropical, subtropical and temperate regions and found in all continents except Europe. Several factors like latitude, altitude, temperature, soil etc. influence the performance of it so there is a need to know the morphological structure of bamboo to better manage the plant and to provide more economic gains for both the farmer and to the industry that makes use of that crop plant (Santos *et. al*., 2015).

In India, it grows abundantly almost all over India, except in Kashmir Valley and represented by 20 genera and 136 species. On the basis of genetic diversity of bamboo India is second richest country after China. The forest of bamboo cover 10.3 million hectare which contributes 12.8% of total forest area of country (Rai and Chauhan, 1998). In Asia about 30% of bamboo forests are planted and 70% are natural and only a part of that is managed. However, outside the forest, large scale cultivation is practiced in villages. In India, 9.57 million hectare is covered by bamboo plantation (Sharma, 1980). The bamboo species are identified based on the morphological and anatomical descriptions of the

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plants (Nirala *et. al.*, 2015). Bamboo can reach up to 40 m in height and over 30 cm in diameter and can sequester carbon at a rate of 27-77 t/ha/yr (Lou *et. al.*, 2010).

MATERIALS AND METHODS

The present study was carried out during 2009-14 in two locations, the experimental bamboo field of BN College of Agriculture [on station trial (OST)] and Golia village [on farm trial (OFT)] of Biswanath Chariali, Assam. The study area is lying at 26°42′N Latitude, 94°15′E Longitude having an elevation of 104 m above mean sea level. The variation in morphological characteristics of four most common bamboo species *viz. Bambusa tulda, B. nutans, B. balcooa* and *Dendrocalamus hamiltonii* were studied. The design of experiment was Factorial RBD having two factors, the species and age of culm, with four replications.

The bamboo fields were established in 2008 with the financial and technical support of National Bamboo Mission, Government of India and are being maintained for the experimental purposes. The morphological parameters of individual bamboo at four different age groups *viz.* one year, two years, three years and four years old culm were recorded (Choudhury *et. al.*, 2015) both at OST and OFT. The culm heights were taken from five representative one year old culm from each bamboo species in April, 2011. The average values of the five culms were recorded species wise. These five bamboos were marked with zinc label and their height were measured in the first week of April every year from 2011 to 2014 to get culm height of 1, 2, 3 and 4 year old culm. The culm thickness was taken at two different positions *viz.*, bottom and at top.

The second internodes from the base of culm was considered as the bottom and third internodes from the tip of the culm was considered as the top for culm thickness measurement. The diameter of culm at breast height (DBH) and circumference of culm of the representative culms were recorded at 1.25 m height from the soil surface. The circumference of the randomly selected culm at that height was measured with measuring tape and then diameter was calculated out. For estimating the leaf length and breadth, ten representative third leaves from the tip of branch were taken and the length was measured from the base of the leaf to the tip of the leaf. Similarly, the leaf breadth was measured in the position of the leaf where it was maximum. The leaf length and breadth were measured in the first week of April every year from 2011 to 2014 from one, two, three and four year old culms. Ten representative third leaves from the tip of branches of each bamboo were taken and their leaf area were measured with leaf area meter (Model CI-203) and the average values were considered as the area of a leaf.

RESULTS AND DISCUSSION

The study revealed that culms are the most visibly distinguishable feature of a bamboo. Culms can vary in size, shape, color, and even smell. Bamboo species grow multiple branches from a single bud, located at the node. Leaves are present at every main portion of the bamboo plant, which includes the rhizomes, culm, and branches. The leaf includes a blade, sheath, and ligule. Leaves are first present in the rhizome where they are almost completely comprised of the sheath. At this stage, leaves serve as a protective cover to encase the rhizome as it travels underground. The morphological parameters of four bamboo species were measured at four different age groups in two situations, OST and OFT and the results are presented in tabular form.

Culm Height, Diameter of Culm at Breast Height (DBH) and Culm Circumference

During the study the culm height, DBH and culm circumference were found to be significantly different in different bamboo species (Table 1). However, these traits failed to show any significant difference with different age of culm. Moreover, the interaction effect of age and species were also non significant.

The *D. hamiltonii* produced the longest culm (18.98 and 18.43 m), highest DBH (11.92 and 10.60 cm) and circumferences (37.43 and 33.28 cm) in OST and OFT respectively while *B. nutans* produced the shortest culm (12.39 and 12.16 m at OST and OFT respectively). On the other hand the lowest DBH (6.67 and 6.46 cm) and circumferences (20.95 and

Table 1
Culm height, culm diameter at breast height (DBH), culm circumference, internodes length and number of node per culm of different bamboo species

Bamboo species	*Age of culm*	*Culm height (m)*		*DBH (cm)*		*Culm circumference (cm)*		*Internodes length (cm)*		*Number of node culm^{-1}*	
		OST	*OFT*	*OST*	*OFT*	*OST*	*OFT*	*OST*	*OFT*	*OST*	*OFT*
S_1*(B. tulda)*	1 year	17.93	17.35	6.65	6.44	20.88	20.22	60.70	59.33	29.51	29.21
	2 years	17.95	17.37	6.67	6.45	20.94	20.25	60.71	59.35	29.53	29.23
	3 years	17.98	17.37	6.68	6.47	20.98	20.32	60.73	59.35	29.54	29.24
	4 years	17.99	17.38	6.68	6.47	20.98	20.32	60.73	59.36	29.55	29.25
	Mean	17.96	17.37	6.67	6.46	20.95	20.28	60.72	59.35	29.53	29.23
S_2*(B. nutans)*	1 year	12.35	12.14	8.91	8.57	27.98	26.91	31.23	31.30	39.46	38.74
	2 years	12.38	12.15	8.93	8.58	28.04	26.94	31.24	31.32	39.47	38.75
	3 years	12.39	12.16	8.94	8.59	28.07	26.97	31.25	31.33	39.49	38.77
	4 years	12.42	12.17	8.94	8.60	28.07	27.00	31.26	31.33	39.49	38.78
	Mean	12.39	12.16	8.93	8.59	28.04	26.96	31.25	31.32	39.48	38.76
S_3*(B. balcooa)*	1 year	16.33	15.93	10.85	9.76	34.07	30.65	33.85	32.62	48.23	48.80
	2 years	16.36	15.94	10.86	9.77	34.10	30.68	33.85	32.64	48.24	48.81
	3 years	16.39	15.94	10.87	9.79	34.13	30.74	33.86	32.64	48.24	48.83
	4 years	16.41	15.95	10.88	9.79	34.16	30.74	33.87	32.65	48.25	48.83
	Mean	16.37	15.94	10.87	9.78	34.12	30.70	33.86	32.64	48.24	48.82
S_4*(D. hamiltonii)*	1 year	18.94	18.41	11.90	10.58	37.37	33.22	41.71	39.21	45.36	46.91
	2 years	18.97	18.43	11.92	10.59	37.43	33.26	41.72	39.23	45.37	46.93
	3 years	18.99	18.44	11.93	10.61	37.46	33.32	41.73	39.24	45.39	46.94
	4 years	19.02	18.44	11.93	10.61	37.46	33.32	41.73	39.25	45.39	46.95
	Mean	18.98	18.43	11.92	10.60	37.43	33.28	41.72	39.23	45.38	46.93
CD 0.05	Species	0.09	0.04	0.04	0.05	0.28	0.29	0.78	0.63	0.05	0.04
	Age	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CD 0.01	Species	0.11	0.10	0.06	0.06	0.37	0.38	1.03	0.83	0.07	0.06
	Age	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

20.28 cm) at OST and OFT respectively were found in case of *B. tulda*.. These differences in culm height, DBH and culm circumference of different bamboo species were might be because of the differences in their genetic make up. Dransfield (1991), Tewari (1992) and Wong (1995) also illustrated the morphological characteristics of different bamboos from different parts of the globe. Since bamboo completes its culm growth within few months and then it becomes stable (Choudhury *et. al.,* 2015) so the above mentioned parameters were not changed with the ages of culm from one year to four years.

Our results corroborated the earlier findings of Lee *et. al.*(1994) and Wong (1995) that bamboo matured at a faster rate than many other plants and it could reach its maximum height within 4 to 6 months with a daily increment of 15 to 18 cm. Lee *et. al.* (1994a) found most of the bamboo cums with

a diameter ranging from 0.25 inch to 12 inches and height ranging from 1 foot to 120 feet. A fully grown bamboo plant had a diameter of 10-12 cm and a height of 15-20 m within 40-45 days after shoot emergence (Zhou, 1998). The maximum height, DBH and basal area girth of *D. hamiltonii* bamboo were 13 m, 3 cm and 5.5 cm respectively (Shanmughavel and Francis, 2003). Yong *et. al.* (2011) also found that usually the shape of bamboo was formed within three months after a new shoot had sprouted and after that bamboo height and diameter barely changed.

Internodes Length and Number of Node Per Culm

The internodes length and number of nodes per culm of bamboo were significantly different in different bamboo species, but they did not differ significantly in different ages of culm (Ταβλε 1). Similarly no significant interaction effect of age of the culm and bamboo species was observed during the study. The longest internodes (60.72 and 59.35 cm at OST and OFT respectively) were recorded in *B. tulda* and the shortest internodes (31.25 and 31.32 at OST and OFT respectively) were found in *B. nutans*. The highest number of node per culm (48.24 and 48.82 at OST and OFT respectively) were recorded in *B. balcooa* and the lowest was found in *B. tulda* (29.53 and 29.23 at OST and OFT respectively).

The differences observed in internodes length and number of nodes per culm of different bamboo species were attributed to their differences in genetic make up. The number of node per clump of bamboo (*D. hamiltonii*) was registered in between 39 to 43 (Shanmughavel and Francis, 2003). The culm growth was completed within few months, so the internode length and number of nodes per culm were not changed in the subsequence ages of culm. Aminuddin and Latif (1991), Anonymous (2009) and Nath *et. al.* (2009) also reported different internodes length and number of nodes per culm in different bamboo species including the species studied in the present investigation.

Culm Thickness

The cum thickness at bottom and top of bamboo were significantly different in different species and they significantly increased with the increase in culm age up to 4th year (Table 2). The highest cum thickness at bottom (2.78 and 2.61 cm at OST and OFT respectively) was recorded in *B. balcooa* and the lowest was found in *B. tulda* (1.71 and 1.60 cm at OST and OFT respectively). The same trend was observed in case of cum thickness at top also (Table 2). The culm thickness gradually but significantly increased with the enhancement of culm age from one year to four years in all four bamboo species. Therefore, the highest culm thickness were recorded in four years old culm while the lowest were found in one year old culm. With the maturity of culm, the accumulation of dry matter in culm might increase resulting in narrowing of the central hole and increase in culm thickness.

Since, the culm diameter did not increase with age of culm it indicated that the body building materials were deposited at the inner wall of culm resulting in increase in culm thickness. Yusoff *et. al.* (1992) reported the chemical composition of one, two, and three year old bamboo (*Gigantochloa scortechinii*) which revealed that the holocellulose, alfa-cellulose, lignin, pentosan, ash and silica content of bamboo increased from one to three years age of bamboo. Shupe *et. al.* (2007) also showed that lignification continued after the first year's growth, especially in the parenchyma cell walls and most parenchyma cell walls thickened during culm growth to form a polylamellate structure and the lignification process of these cells might last up to seven years.

Length, Breadth and Area of Leaf

The length, breadth and area of leaf significantly increased with the increase in the age of culm from one year to second year then again they decreased significantly at 4th year in all four bamboo species (Table 2). The longest leaves (36.54 and 36.25 cm at OST and OFT respectively), highest leaf area (170.94 and 166.40 cm^2) were found in *D. hamiltonii* while the shortest leaves were observed in *B. balcooa* (25.01 and 24.17 cm at OST and OFT respectively). However, the lowest leaf area (45.15 and 42.75 cm^2) were observed in the *B. tulda.* The highest leaf area were recorded in two years old culm and the lowest were recorded in four years old culm. Again, the longest leaves were found in two year old culm and the shortest leaves were found in four years old

Table 2
Culm thickness at bottom and top, leaf length, breadth and leaf area of different bamboo species

Bamboo species	*Age of culm*	*Culm thickness at bottom (cm)*		*Culm thickness at top (cm)*		*Leaf length (cm)*		*Leaf breadth (cm)*		*Leaf area (cm^2)*	
		OST	*OFT*	*OST*	*OFT*	*OST*	*OFT*	*OST*	*OFT*	*OST*	*OFT*
S_1(*B. tulda)*	1 year	1.64	1.52	0.71	0.67	25.67	24.59	2.18	2.15	44.77	42.29
	2 years	1.69	1.57	0.77	0.72	25.74	24.76	2.28	2.24	46.94	44.37
	3 years	1.72	1.63	0.82	0.76	25.73	24.73	2.17	2.14	44.67	43.34
	4 years	1.77	1.68	0.83	0.78	25.70	24.75	2.15	2.07	44.20	40.99
	Mean	1.71	1.60	0.78	0.73	25.71	24.71	2.20	2.15	45.15	42.75
S_2(*B. nutans)*	1 year	1.76	1.64	0.75	0.71	25.31	24.32	2.45	2.41	49.61	46.89
	2 years	1.83	1.72	0.81	0.77	25.65	24.67	2.48	2.46	50.89	48.55
	3 years	1.86	1.75	0.85	0.80	25.30	24.12	2.39	2.40	48.37	46.31
	4 years	1.88	1.79	0.86	0.82	24.53	23.89	2.31	2.23	45.33	42.62
	Mean	1.83	1.73	0.82	0.78	25.20	24.25	2.41	2.38	48.55	46.09
S_3(*B. balcooa)*	1 year	2.66	2.48	0.79	0.75	25.23	24.18	3.47	3.43	70.04	66.35
	2 years	2.75	2.59	0.85	0.81	25.65	24.35	3.63	3.57	74.49	69.54
	3 years	2.81	2.65	0.91	0.85	24.74	24.17	3.63	3.55	71.85	68.64
	4 years	2.88	2.72	0.92	0.87	24.41	23.97	3.42	3.38	66.79	64.81
	Mean	2.78	2.61	0.87	0.82	25.01	24.17	3.54	3.48	70.79	67.34
S_4(*D. hamiltonii)*	1 year	2.65	2.41	0.79	0.74	36.63	36.05	6.37	6.15	173.67	166.28
	2 years	2.73	2.52	0.85	0.79	36.85	36.59	6.52	6.38	180.21	175.08
	3 years	2.78	2.57	0.88	0.83	36.47	36.31	6.28	6.24	171.23	169.93
	4 years	2.83	2.67	0.89	0.85	36.22	36.03	5.82	5.71	158.64	154.30
	Mean	2.75	2.54	0.85	0.80	36.54	36.25	6.25	6.12	170.94	166.40
CD 0.05	Species	0.02	0.02	0.01	0.01	0.19	0.13	0.10	0.08	3.08	2.75
	Age	0.02	0.02	0.01	0.01	0.19	0.13	0.10	0.08	3.08	2.75
	Interaction	0.02	0.03	0.01	0.01	0.27	0.18	0.14	0.12	4.36	3.89
CD 0.01	Species	0.02	0.03	0.01	0.01	0.26	0.17	0.13	0.11	4.05	3.62
	Age	0.02	0.03	0.01	0.01	0.26	0.17	0.13	0.11	4.05	3.62
	Interaction	0.03	0.04	NS	NS	0.36	0.24	0.18	0.16	5.73	5.11

culm in all four species. The broader leaves were found in *D. hamiltonii* (6.25 and 6.12 cm at OST and OFT respectively) while lowest leaf breadth (2.20 and 2.15 cm) were observed in *B. tulda*. Whereas, broader leaves were found in two years old culm and the narrower leaves were found in four years old culm in all four species. The significant interaction effects between culm age and bamboo species were also observed in terms of leaf length, leaf breadth and leaf area. Tewari (1992) and Wong (1995) also illustrated similar morphological characteristics of different bamboos from different parts of the globe. In the present study, the highest length, breadth and area of single leaf were registered in the second year of culm growth, which suggested that maximum production and accumulation of food materials took place in the second year of culm growth. The process of

senescence started in third year of culm growth that progressed till fourth year of culm growth when the above mentioned parameters were recorded the lowest. According to Lee *et. al.* (1994), Choudhury *et. al.* (2015) and Choudhury *et. al.* (2015a) most of the bamboo matured in about 3 to 5 years. Similarly, Li *et. al.* (1998) also found that before shedding of old leaves of bamboo a large amount of nutrients was remobilized and translocated to other parts to support further growth. During the study better performances were found at OST than OFT that might be because of the application of recommended cultural practices in appropriate time and dozes at OST.

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