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Mensurational studies on *Schizostachyum dullooa* - a thin walled tropical clump forming bamboo

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Abstract: Mensurational attributes of *Schizostachyum dullooa,* at four culm ages of 7 girth classes (3-5 cm to 15-17 cm) were studied from Cachar district of Assam, North East India. Internode length, internode number per culms, internode circumference, total culm height, total culm green weight and total culm solid volume of the selected age classes culms were studied. A total of 144 numbers of culms were harvested for this study. Three replicates were taken from each girth class sizes of all age classes. Maximum culm height was observed in 3-yr-old culms (8.3 m) followed by 4, 2 and 1-yr-old culms. This may be due to competition for nutrients as the number of individual's increases in the clump. Maximum average internode length was observed 0.98 m. Total culm green weight ranges from 278 g to 4640 g. with average maximum in 3-yr-old culms. Total culm solid volume was observed maximum in 2-yr-old culms followed by 3, 4 and 1-yr. Best fitted regression models for all parameters were developed. Developed different regression models will enable sustainable utilization and management of the species.

Key words: Culm, age class, green weight, total volume, regression model.

INTRODUCTION

Culm characteristics are an important attribute for bamboo because of its species specific variation (Nath *et al*., 2015). Therefore, it is important to document such characteristics for better understanding of species ecology. Information on different culm characteristics like age, circumference at breast height (CBH) helps in commercial utilization of the species (Inoue *et al.,* 2013) and its mechanical properties (Correal and Arbelaez, 2010). However, bamboo properties have been reported to differ with species, age, location and environmental factors (Hisham *et al.,* 2006).

Schizostachyum dullooa, a thin walled tropical clump forming bamboo is one of the dominant bamboo species in the Barak Valley, North East India. The distribution of this species is sparse. Globally it is distributed in the Bangladesh, Bhutan, Myanmar, Nepal and India (Banik, 2000). In India it is specially found in North Eastern region, including Barak Valley (Nath and Das, 2011). This species is included among the 20 priority bamboo species identified by INBAR (International Network for Bamboo and Rattan) and IPGRI (International Plant Genetic Resource Institute) (Rao *et al.,* 1998). This small tufted clump forming bamboo species satiates different domestic purposes

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of the local villagers e.g., fencing, house construction, roofing and making different crafts. Moreover, the culm portion of the species is used for preparation of traditional food during harvest festival in North East India. Use of this species in craft and musical instrument preparation has also been reported (Nath *et al.*, 2007). Due to the long intermodal length the species is the most preferred species for kite fabrication especially in Gujarat and Rajasthan during annual kite festival. Therefore, a proper study on mensurational properties of this species from this region is significantly important for sustainable commercial utilization of this species. The present study was undertaken to investigate the different culm characteristics of *S. dullooa* at different age classes. Regression models developed for culm green weight and culm solid volume using CBH as a predictable variable. Such study can facilitate the culm selection, yield determination, sustainable and commercial utilization of the species.

MATERIALS AND METHODS

Study site

The study was conducted in the Sonachera forest village of Innerline Reserve Forest (IRF) of Cachar district, Assam. Forest vegetation of this district comes under Cachar tropical evergreen and semi evergreen forest (Champion and Seth 1968). Barak Valley consisting of three districts (Cachar, Hailakandi and Karimganj), which holds large area of *S. dullooa* stands under natural condition. The *S. dullooa* stand selected for the present study was a secondary forest of 15-18 years old, with culm age class represented by 1-yr. to 4-yr. old culms. The population structure of the stand was 4:3:2:1 for 1-yr., 2-yr., 3-yr. and respectively. Being the common forest non-timber resource for the villagers, the aged culms are harvested regularly and are less in number in stand. The climate of the area is subtropical warm and humid with average rainfall of 2380 mm, most of which is received during the Southwest monsoon season (May to September) (Data source: Tea Research Association, Cachar Advisory board, Silcoorie, Silchar, 2011-2014 data set).

Methods

Stand characteristics of the selected stand was studied by laying ten 5 m × 5 m quadrats randomly. The number of the culms within the quadrat was recorded according to the age of the culms and culm density was calculated per hectare. Age of the culms was determined on the basis of morphological characteristics, presence of culm sheath, culm colour, lichens and mosses on the culm surface (Banik, 2000; Pattanaik *et al.*, 2004).

A brief summary of age determination is as follows: (1) 1-yr.-old culm has culm-sheaths attached and the culm surface is covered with a clear white powder, only a few leaves developed, culm colour is pale green. (2) 2-yr.-old culms possess few culm sheaths on the base of culms, culm colour is dark green and well developed branches can be observed from 5^{th} / 6^{th} internode of the culms. (3) In 3-yr.-old culms lichens and mosses starts to appear in few numbers, culm colour is mature green. (4) In 4-yr.-old culms, culm sheath is totally absent; culm colour is light yellowish green. Incidence of lichens and mosses are high on culm surface.

The required data for the present study was gathered from the freshly harvested culms. After the selection of culms according to their age, girth of the culms was measured at the middle of fourth internode (~ 1.3 m) (Singnar *et al.,* 2015) from the ground and culms were separated into 7 girth classes viz. 3-5,5-7,7-9,9-11,11-13,13-15 and >15 cm. Three culms were harvested from each girth class of respective age class. Height of the culms, internode length and internode girth from bottom to top were measured and number of node in each culm was counted. Each culm was cut into three equal sections and the fresh weight was taken separately using digital weighing machine. Culm wall thickness of the base and apex of each section of the culms were measured using a vernier caliper to the nearest tenth of centimeter. The average culm wall thickness on all four directions and the average girth were also determined. The solid volume was also determined from each section.

The solid volume of each section of the culms was determined following Tandug and Torres (1985),

$V = ((Ba\text{-}Bh) + (bs\text{-}bh))/2XL$

Where:

V= solid volume in cubic centimeter of the section

Ba= area in square centimeter at the large end of the section

Bh= area in square centimeter at the large end of the hollow portion

bs= area in square centimeter at the small end of the section

bh= area in square centimeter at the small end of the hollow portion

L= length in centimeter of the section

RESULTS AND DISCUSSION

Culm characteristics

Schizostachyum dullooa is moderate sized bamboo. Culm height varies from 2--14 m. Maximum culm height was observed in three year old culms (Mean=8.36 m; Range=2—15m) followed by four, two and one year old culms respectively (Table 1). Correlation between CBH of culm and culm height was positive (R^2=0.73; p=<0.0001; Fig. 1). Culm growth characteristics stabilizes in 3-yr. of age in comparison to 3.5 year in *Gigantochloa scortechinii* (Hisham *et al.,* 2006; Mohamed *et al.,* 2011). Culm characteristics and properties are key factor in selection of culms for utilization (Liese, 1997).

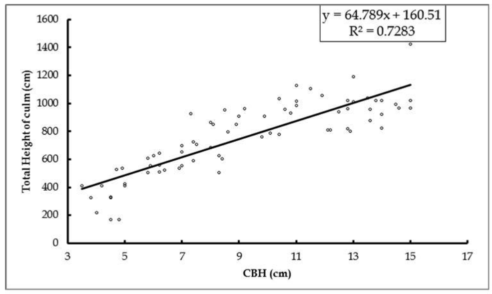


Figure 1: Relationship between circumference size (cm) and total height (cm) of *S. dullooa* culm (1-4 years old culms)

Internode number and internode length

Internode length increases gradually from base to middle of the culm and then decreases top onward. Internode length of bamboo is species specific (Guan *et al.,* 2012). Co-relationship developed between internode number and internode length showed the polynomial 3rd order model as the best fitted model (Fig. 2 A, B, C, D, E & F). Average number of internode was found highest in 3-yr.-old bamboo culms followed by 4 and 1-yr.-old culms. Maximum internodal length was observed in 2-yr.-old culms (98.8 cm) followed by 4, 3 and 1-yr. respectively (Table 1). Mean internodal length among different age classes vary significantly (Table 2).

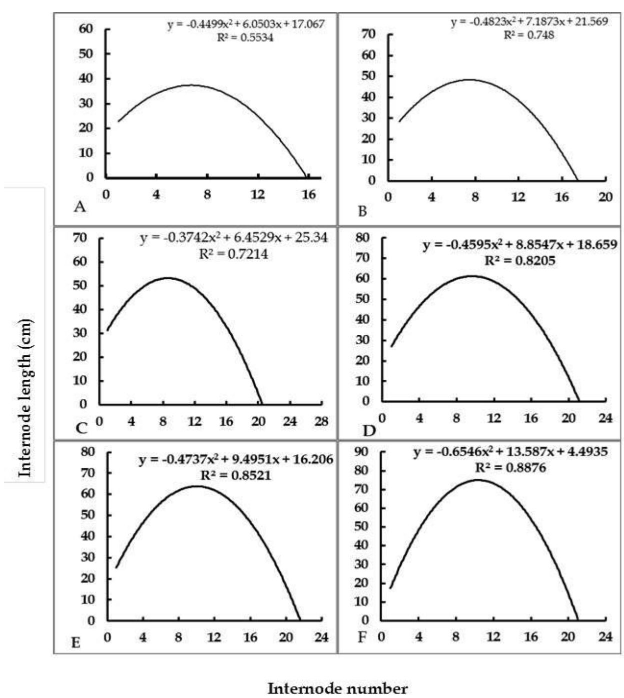


Figure 2: (A, B, C, D, E , F) : Plotted curve showing the relationship between internode number and internode length (cm) of 1-4 year old culms of different girth classes (A=3-5 cm; B=5-7 cm; C=7-9 cm; D=9-11 cm; E=11-13 cm and F=13-15 cm)

Table 1: Descriptive statistics of culm characteristics of various parameters of different culm age classes

Parameters	Culm age	N	Mean	Max	Min	SD
Culm Height (m)	One year	36	6.69*	9.23	3.03	1.77
	Two year	36	7.6*	13.63	2.40	2.56
	Three year	36	8.36*	13.63	4.06	2.71
	Four Year	36	7.54*	14.41	2.59	2.85
Internode No.s ($culm^{-1}$)	One year	36	20.45**	24	15	3.52
	Two year	36	21.23**	25	15	3.42
	Three year	36	23.11**	27	16	3.41
	Four Year	36	17.83**	28	14	3.72
Internode length (cm)	One year	1130	36.99^{a}	88.9	8	17.46
	Two year	1200	42.56^{a}	98.8	10.7	23.59
	Three year	1180	45.48^{a}	92.8	3.9	24.28
	Four Year	1080	42.13^{a}	97.8	8.9	24.20
Internode circumference (cm)	One year	1130	9.33	14	5.2	2.78
	Two year	1200	9.09	14	4.5	3.05
	Three year	1180	8.3	15	4.2	3.33
	Four Year	1080	9.0	15	3.5	3.47
Total culm green weight (g/culm)	One year	36	1318.63^{a}	2765	278	721.34
	Two year	36	2103.61^{a}	3825	478	1267.52
	Three year	36	2385.19^{a}	4640	400	1538.79
	Four Year	36	2179.55^{a}	3956	578	1358.14
Culm solid volume (cm^3/culm)	One year	36	3020.12^{a}	6378.25	563.02	2047.68
	Two year	36	3228.55^{a}	6624.48	555.82	2195.50
	Three year	36	3995.04^{a}	6227.79	557.42	2266.94
	Four Year	36	3859.09^{a}	6141.98	531.25	2162.67
Culm thickness (cm)	One year	216	0.28	0.98	0.17	0.16
	Two year	216	0.28	0.86	0.11	0.13
	Three year	216	0.27	0.64	0.12	0.11
	Four Year	216	0.25	0.71	0.18	0.13

**Different letters denotes significance difference at 5% level of significance

Table 2: ANOVA table of internode length and internode number regression equation

ANOVA Table of Regression of the IL=f(IN)**					
Age Class	N	SS	MS	F	p
One year	660	9229.82	9229.828	32.77	<0.0001
Two year	726	20430.14	20430.14	41.84	<0.0001
Three Year	726	19489.91	19489.91	36.59	<0.0001
Four Year	892	11235.29	11235.29	20.69	<0.0001

**IL=Internode length (cm); IN=internode number

Internode circumference and internode number

Internode circumference decreased gradually from base to top of culm. The circumference from base to 3rd to 4th number of internode remains almost same and then decreases gradually for all age classes. Regression analyses for all the age classes according to CBH category (small, medium and large) showed second order polynomial model as the best fitted model (Fig. 3. A, B, C, D).

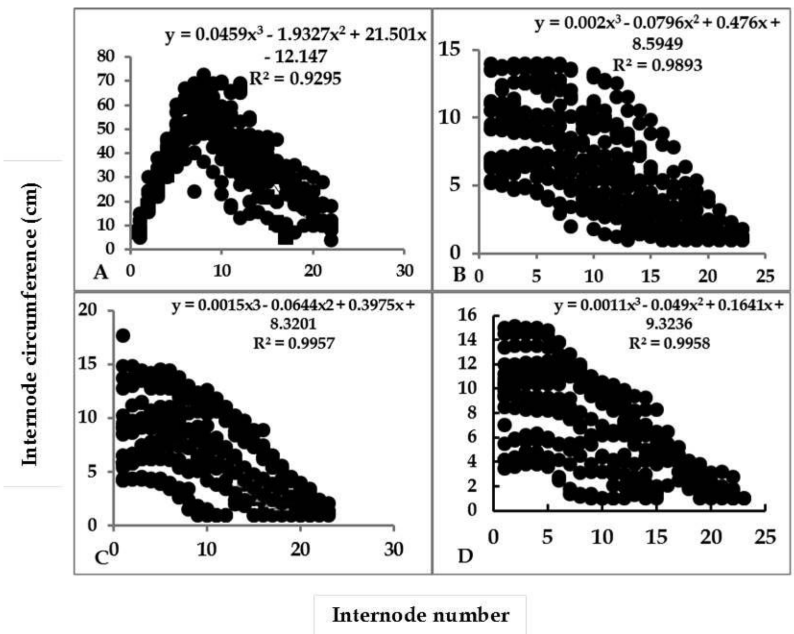


Figure 3: (A, B, C, D): Scatterplot showing the relationship between internode number and internode circumference of (A= One year old; B= Two year old; C= Three year old and D= Four year old bamboo culms)

Culm height and culm CBH

The average culm height was found highest in 3-yr. and lowest in 1-yr.-old culm (Table 1). Pattanaik *et al.,* (2004) developed a third order polynomial regression for *Melocanna baccifera*, whereas Watanabe and Ueda, (1976) developed an exponential type model for culm height of Japanese bamboo (*Phyllostachys bambusoides*). In this study the relationship between culm height and CBH is best represented by a third order polynomial regression model (Fig. 4). Developed regression models between culm height and culm CBH among different age classes varies significantly at 0.05 levels (Table 3).

Culm green weight and culm CBH

Total culm green weight was observed maximum in three years old culms with an average value 2.38 kg culm^{-1} while the lowest was observed in one year old culms

(1.318 kg culm^{-1}, Table 1). The developed co-relationship between culm green weight and culm CBH showed 2nd order polynomial regression as best fitted model (Fig. 5). All regression equations of culm green weight are significant at 0.05 levels (Table 4). Culm CBH was positively correlated to total green weight for all age classes *S. dullooa* culms. Same trend of observation was reported by Singnar *et al.,* (2015) in *Melocanna baccifera*.

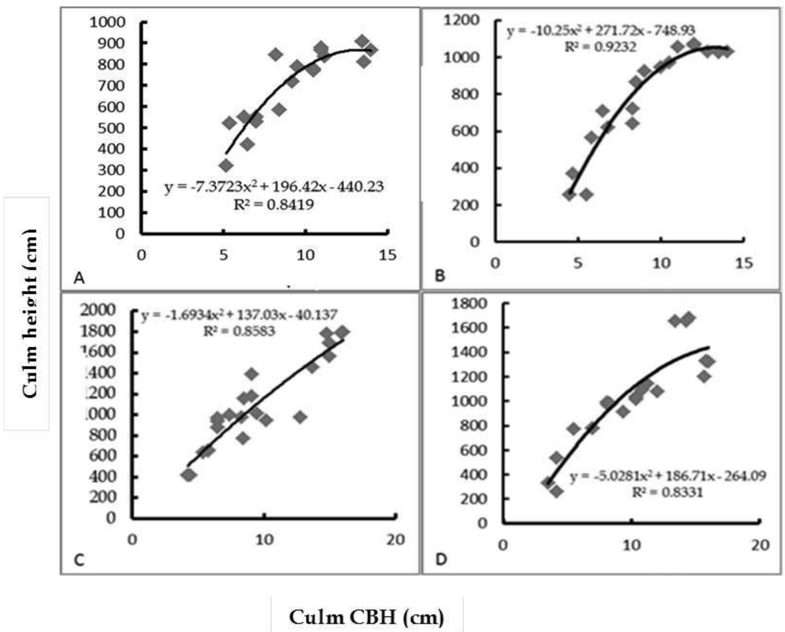


Figure 4: (A, B, C, D): Scatterplot showing the relationship between culm CBH and culm height (cm) of 1-4 year old *S. dullooa* bamboo culms

Table 3: ANOVA table of regression of culm height and culm circumference at breast height

ANOVA Table of Regression of the CH=f(CCBH)**					
Age Class	N	SS	MS	F	p
One year	36	1215.45	1215.45	158.16	<0.0001
Two year	36	1118.31	1118.31	82.540	<0.0001
Three Year	36	3796.11	3796.11	130.85	<0.0001
Four Year	36	2358.61	2358.61	74.45	<0.0001

**CH= Culm Height; CCBH=Culm Circumference at Breast Height

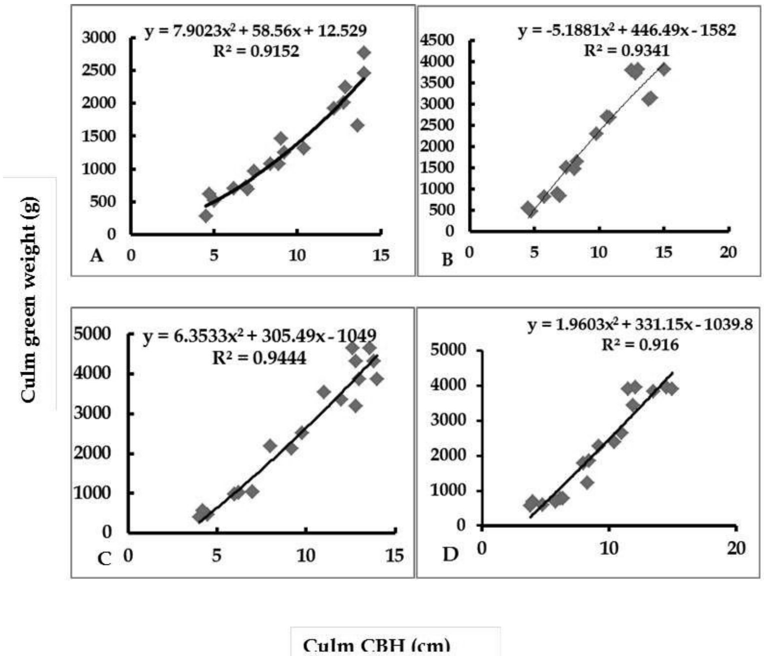


Figure 5: (A, B, C, D): Scatterplot showing the regression equations between culm CBH and culm green weight of 1—4 year old *S. dullooa* bamboo culms respectively

Table 4: ANOVA table of regression of the green weight of culm and culm circumference at breast height

ANOVA Table of Regression of GW=f(CCBH)**					
Age Class	N	SS	MS	F	p
One year	36	8016.53	8016.53	154.64	<0.0001
Two year	36	2547.703	2547.703	221.42	<0.0001
Three Year	36	4466.77	4466.77	315.46	<0.0001
Four Year	36	2871.48	2871.48	173.85	<0.0001

**GW= Green Weight; CCBH=Culm Circumference at Breast Height

Culm CBH and total culm solid volume

The 3-yr-old culms possess the maximum solid culm volume (3995.40 cm^3 $culm^{-1}$) (Table 1). Data on Table 5 shows the regression equations between culm CBH and total solid volume. Second order polynomial equation was found to be best fitted regression equation for the culm CBH and culm total solid volume. Developed regression models among different age classes culms vary significantly at 0.05 levels (Table 6).

Table 5: Regression equation of total solid volume of culms and culm circumference at breast height of *S. dullooa* bamboo culms

Regression equation of TSV=f(CCBH)**		
Age Class	Equation	R^2
One year	$TSV=17.035(CCBH)^2+266.82(CCBH)-1100.5$	0.907
Two year	$TSV=15.39\ (CCBH)^2+313.42(CCBH)-1271$	0.950
Three Year	$TSV=59.579(CCBH)^2-483.41(CCBH)+1674$	0.956
Four Year	$TSV=-47.38(CCBH)^2+145.99(CCBH)-484.86$	0.961

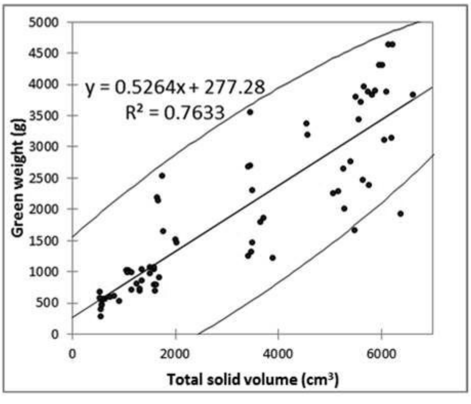
** CCBH=Culm Circumference at Breast Height; TSV=Total solid volume of culm (cm^3)

Table 6: ANOVA table of regression of the total solid volume of culm and culm circumference at breast height

ANOVA Table of Regression of TSV=f(CCBH)**					
Age Class	N	SS	MS	F	p
One year	36	6429.24	6429.24	147.185	<0.0001
Two year	36	7754.096	7754.096	281	<0.0001
Three Year	36	9345.500	9345.500	190.28	<0.0001
Four Year	36	7160.34	7160.34	144.8637	<0.0001

TSV=Total solid volume of culm (cm^3); CCBH=Culm Circumference at breast height (cm)

Figure 6: Scatter plot showing the relationship between total solid volume of culm and green weight of 1-4 year old bamboo culms.



Culm solid volume and green weight

The relationship between culm solid volume and green weight was found positive (R^2= .874; p<0.0001; Fig. 6). Linear regression equation was found best fitted to explain the variability between culm solid volume and culm green weight (Green weight= 0.524 x total solid volume + 277.8; R^2 =0.77; Fig. 6). The relationship between culm solid volume and culm green weight is useful in determination pulp yield (Tandung and Torres., 1985 and Mohamed *et al.,* 1991; Singnar *et al.,* 2015).

CONCLUSION

Mensurational attributes of any species helps in utilization of the species. *Schizostachyum dullooa* is a thin walled bamboo and mostly used in handicraft sector, therefore, the findings of the study will help in selection of culm for its specific uses. The result of the study suggests that 1-yr.-old culms possess the lower green weight and lowest culm solid volume which, indicates its unsuitability for uses. The developed different regression models between age and CBH specific will enable industrialists, researchers, forest departments and those policy makers in sustainable utilization and management of the species.

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REFERENCES

Banik, R. L. 2000. Silviculture and field-guide to priority bamboos of Bangladesh and SouthAsia. Government of the People's Republic of Bangladesh, Bangladesh Forest Research Institute, Chittagong.

Champion, H. G. and Seth, S. K. 1968. A Revised Survey of the Forest Types of India. Natraj Publishers, Dehradun (Reprinted 2005).

Guan, M., Yong, C., Wang, L. and Zhang, Q. 2012. Selected properties of bamboo scrimber flooring made of India *Melocanna baccifera*. Proceedings of the 55th International Convention of Society of Wood Science and Technology, Beijing, China.

Hisham, H. N., Othman, S., Rokiah, H., Latif, M. A., Ani, S. and Tamizi, M. M. 2006. Characterization of bamboo *Gigantochloa scortechinii* at different ages. *J. Trop. For. Sci*. 18: 236-242.

Inoue, A., Sakamoto, S., Suga, H., Kitazato, H. and Sakuta, K. 2013. Construction of one-way volume table for the three major useful bamboos in Japan. *J. For. Res.* 18: 323- 334.

Kleinhenz, V. and Midmore, D. J. 2001. Aspects of bamboo agronomy. *Adv. Agr*. 74: 99–153.

Latif, M. A., Tarmeze, W. A., and Fauzidah, A. 1990. Anatomical features and mechanical properties of three Malaysian bamboos. *J. Trop. For Sci*. 2: 227-234.

Liese, W. 1997. Structural research issue on bamboo. Special Focus. INBAR. 5: 27-29.

Mohamed, A. H., Othman. S., Razak, W. and Rokiah, H. 2011. Physical characteristics and weight relationship of *Gigantochloa scortechinii* (Buluh Semantan) 1-2-and 3- year old natural stand bamboos. *Pert. J. Agri. Sci*. 34: 25-32.

Nath, A. J. and Das, A. K. 2011. Population status and regeneration of a tropical clumping bamboo *Schizostachyum dullooa* under two management regimes. *J. For. Res*. 22: 43−46.

Nath, A. J., Lal, R. and Das, A. K., 2015. Managing woody bamboos for carbon farming and carbon trading. *Gl. Ecol. Con.* 3: 654-664.

Pattanaik, S., Pathak, K. C., Bhuyan, T. C., Khobragade, N., Das, P. and Prasad, K. G. 2004. Mensurational studies in *Melocanna baccifera*. *J. Trop. For. Sci.* 16: 62-70.

Rao, A. N., Rao, V. R. and Williams, J. T. 1998.Priority species of bamboo and rattan. IPGRI-APO Serdang, Malaysia

Shigematsu, Y., 1958. Analytical investigation of the stem form of important species of bamboo. *Bull. Fac. Agri*. 3: 124-135.

Singnar, P., Nath, A. J. and Das. A. K. 2015. Culm characteristics and volume weight relationship of a forest bamboo (*Melocanna baccifera*, (Roxb.) Kurz) from northeast India. *J. For. Res*. DOI: 10:1007/s11676-0150099-8.

Tandug, L. M. and Torres, F. G. 1985. Mensurational attributes of five Phillippine erect bamboos. In: Recent Research on Bamboos. Proceedings of the International Bamboo Workshop. October 6-14, 1985. Hangzhou, People's Republic of China, pp. 91-98.

Watanabe, M. and Ueda, K. 1976. On the structure of Madake (*Phyllostachys bambusoides)*. *Rep. Fuji Bam. Gar*. 21: 9-26.