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CONTENTS

Prediction of above ground biomass in *Dendrocalamus hamiltonii* using multiple linear regression in Uttarakhand state of India

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ABSTRACT: *Dendrocalamus hamiltonii* one of the promising species of clumping bamboos is known for its root system which spreads vertically and holds the soil strongly, effective measure to prevent soil erosion as well to accumulate large quantities of carbon in terms of biomass. Estimation of above ground biomass of this species was conducted through multiple regression at Agriculture Research Station, Majhera situated in Nainital District of Uttarakhand, India. Results highlighted accumulation of 35.61 kg biomass per clump contributed by culm, branches and leaves on fresh weight basis. Above ground biomass on per culm basis was at par with the reports available but total number of culms produced per clump was less. An increase of 293.87 per cent was observed on dry weight basis in two years interval after the plantation was well acclimatized. Correlation matrix of growth parameters of small micropropagated plants showed positive correlation between length and weight of twigs, weight of leaves and leaf area index. However, weight of leaf and leaf area index showed strongly positive correlation.

Key words: Above ground biomass, correlation, *Dendrocalamus hamiltonii,* Leaf area index

Dendrocalamus hamiltonii is classified under large and dense clump forming bamboo species. It is cultivated in many parts of India but grows abundantly in North East and Bengal. It is used for construction, handicrafts and food purpose. Root system spreads vertically and horizontally makes it a very good species for soil conservation and land erosion even in relatively dry areas. Leaves can be used as source of fodder in the hilly Himalayan regions in all the seasons (NMBA, 2005).

Himalayas are highly vulnerable to climate change and under big threat due to natural calamities. Bamboos being the fastest growing and highly versatile plants are the best plantation material for eco-conservation and restoration. They accumulate large quantities of above ground biomass in terms of culms, branches or twigs and leaves. Among these three major components, culms are the most important with highest share of 69.56 to 78.71 per cent contributing to biomass (Kaushal *et al*., 2021). Therefore, bamboos are good for the absorption of large quantities of carbon dioxide from the atmosphere and produce more oxygen. Importance of assessing carbon stock and sequestration potential of bamboo was highlighted by Abebe *et al*. (2021) by predicting the biomass accumulation of *Oxytenanthera abyssinica* in Northwestern Ethiopia. It was depicted that *O. abyssinica* forest area has significant stock and sequestration potential. Organic carbon storage of *Schizostachyum dullooa* was explored in Barak valley forest of North east, India. Among the 78 species of bamboos, *S. dullooa* is one of the prominent in the forest of Barak valley. *S. dullooa* accumulated total 34 Mg ha^{-1} carbon in terms of total biomass (Das *et al.,* 2019). A study on carbon storage and carbon sequestration in terms of above ground biomass accumulation was carried out on two common bamboo species i.e., *Bambusa tulda* and *Dendrocalamus longispathus* of North East India. AGB in *B. tulda* ranged from 73.58 to 127 Mg/ha and in *D. longispathus* 115 to 150 Mg/ha in $\geq$ 3 year age class. Despite having lower AGB carbon sequestration was higher in *B. tulda* (27.99 Mg/ha/year) than *D. longispathus* (15.36 Mg/ha/year) due to higher culm density and DBH (Devi and Singh, 2021). Biometric parameters of seven bamboo species namely *Dendrocalamus hamiltonii*, *D. stocksii*, *D. strictus*, *Bambusa balcooa*, *B. bambos*, *B. nutans* and *B. vulgaris* were analysed through Tukey's honest significant difference (HSD) test. It was found that among these seven species, *D. hamiltonii* has highest productivity for aboveground biomass. Further, it was revealed that the ratio of dry weight to fresh weight of different above ground biomass components significantly differed for seven bamboo species (Kaushal *et al*., 2021). Biomass production in seven bamboo species was reported to depict high positive correlation with diameter at breast height (DBH) and culm height but did not have significant relation with age (Kaushal *et al.,* 2021). Many studies on various bamboos for their carbon sequestration potential in the Himalayan region of Uttarakhand state of India have also

been conducted (Agarwal and Purwar, 2009; 2012; 2015; 2016; 2017; 2018). *D. hamiltonii* being very suitable species to grow in dry climate in the lower mountain region and for its special underground root network for holding the soil, needed attention to decipher it's contribution in carbon sequestration potential through the prediction of above ground biomass by non-destructive method. *D. hamiltonii* has also been reported as the fastest growing species by Alemayehu *et al*. (2015) among *B. vulgaris*, *D. membranaceus* and *Guadua amplexifolia*.

The present study was aimed to predict above ground biomass of *D. hamiltonii* using multiple regression and its potential for carbon sequestration besides its role in holding the soil. Correlation between various parameters was also calculated for the small plants which were produced through micropropagation and used for plantation.

MATERIALS AND METHODS

Study site

The study site is located at Agriculture Research Station, Majhera which is situated at 905m (a.s.l) with latitude 29°30.137'and longitude 79°28.784' in Uttarakhand state of India. The centre has maximum of 27.8°C and minimum 14.8°C temperature and receives 598mm mean annual average rainfall. The major soil type of the centre is Sandy loam, with total land holding of 8 hectare.

Bamboo plantation

The plantation was established to evaluate the growth performance and adaptability of *Dendrocalamus hamiltonii* in the year 2011. Planting material was developed through micropropagation so was clonal. 09 plants were planted in a Randomized Block Design (RCBD) with 3 replications. The plants used for plantation ranged approximately 1.00m in height with 3-4 culms. Spacing between the plants was 5 x 5 m.

Above ground biomass estimation

Sampling for multiple regression model was done in the year 2020, almost 09 years after the plantation. Three culms from all the nine clumps were randomly selected with various height and thickness. They were harvested by felling them at above the first node. Total length, girth of culms at 1.0 and 1.5m, fresh and dry weight was recorded. For dry weight estimation shade drying was done until a constant weight achieved (shade drying duration was almost four months). On the basis of fresh and dry weight, linear regression equations were developed for the estimation of above ground biomass (Singh *et al*., 2009).

For the non-destructive estimation of AGB (on dry weight basis), length and girth of culms at 1.0m & 1.5m was recorded along with total number of culms in the year 2022. In each clump, data of three culms was used for the estimation of above ground biomass (kg $Pole^{-1}$) through linear regression equations (Table 1). Biomass accumulation per clump was extrapolated to per ha basis by multiplying with 400 with a spacing of 5 X 5 m.
Carbon sequestration potential was estimated on the basis of 50 per cent of the total aboveground biomass produced (Scurlock *et al*., 2000).

Data of micropropagated plants for correlation study

In vitro raised, hardened plants of *D. hamiltonii* approximately 0.5 to 1.5m height were selected randomly for correlation study of small plants. Total ten plants were selected with 3 to 4 twigs. Total fresh weight of whole plant (excluding roots), weight of twigs & leaves along with leaf are index (LAI) was recorded manually. For leaf area index square book was used by drawing the exact leaf shape, area was calculated in cm^2.

RESULTS AND DISCUSSION

Above ground biomass (AGB) produced by *D. hamiltonii* was estimated 9 & 11 years after the plantation on a hill slope at ARS, Majhera. Multiple regression equation indicated the dependence of AGB on length of culms, girth to height at 1.0 & 1.5m by 92 and 97 per cent on fresh and dry weight respectively. According to the regression equation it was estimated that unit increase in length of culm increased the biomass by 0.65 and 0.30 per cent on fresh and dry weight basis respectively (Table 1). Girth at 1.0m was also directly proportional to AGB on both fresh & dry weight basis. In *D. asper* also, AGB was directly proportional to culm height for both dry and fresh weight

Table 1: Linear relationship between above ground biomass (y kg $culm^{-1}$) and height (x_1, m), girth to height at 1m (x_2, m) & girth to height at 1.5m(x_3, m) of *D. hamiltonii*

S. No.	Biomass (kg $culm^{-1}$)(y)	Intercept (a)	Slope (x_1)	Slope (x_2)	Slope (x_3)	R^2
1.	Fresh weight	-1.24	0.65	82.21	-87.83	0.92
2.	Dry weight	-0.56	0.30	34.32	-38.90	0.97

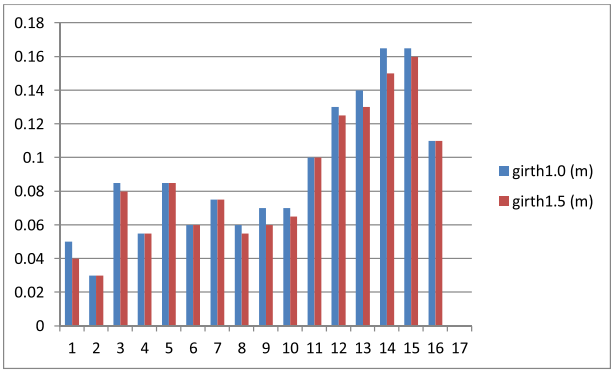

Fig. 1: Trend of girth recorded at 1.0m and 1.5m height in various culms of *Dendrocalamus hamiltonii*

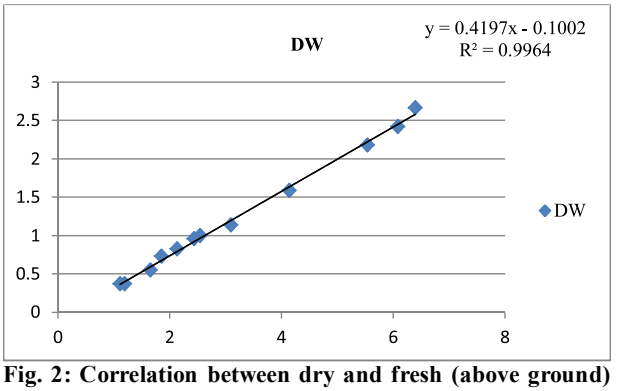

Fig. 2: Correlation between dry and fresh (above ground) weight of *Dendrocalamus hamiltonii*

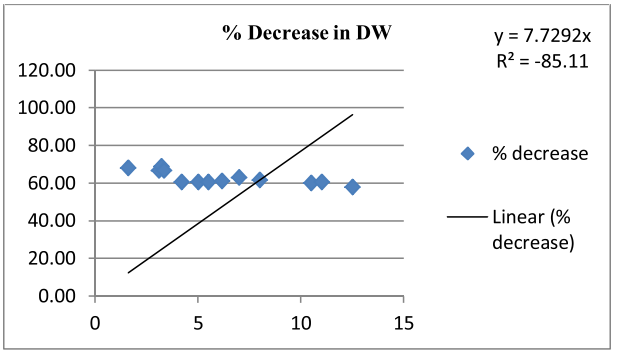

Fig. 3: Correlation between per cent decrease in dry weight and length of culm in *Dendrocalamus hamiltonii*

(Agarwal and Purwar, 2009). Girth at 1.5m was reported as the major deciding independent variable in many bamboo species. Unit increase in girth at 1.5m height increased dry biomass by 712.13 (*D. strictus*) & 363.98 (*B. bambos)* per cent (Agarwal and Purwar, 2012). Similar trend was observed in *B. tulda* in which AGB showed positive correlation with girth at 1.5m, however, *B. nutans* showed negative correlation with girth at 1.5m and length of culm for dry weight biomass (Agarwal and Purwar, 2017). However, in the present study, not much variation in girth at 1.0m and 1.5m was observed in *D. hamiltonii* (Fig. 1).

AGB on fresh and dry weight basis in *D. hamiltonii* is reported in Table 2. The data on AGB for the year 2020 is actual of the culms harvested to develop multiple linear regression whereas data of the year 2022 is estimated through regression by the measurements of culm parameters. AGB estimated after 11 years of plantation was 35.61 kg/clump on fresh weight basis. Reports indicate that culm height and DBH are the major contributing factors and have positive correlation with biomass accumulation irrespective of the age which shows no significant correlation (Kaushal *et al*., 2021). *D. hamiltonii* showed the best performance among the four species of bamboo undertaken for study in Ethiopia. Faster growth performance and highest total biomass accumulation was observed in *D. hamiltonii*. Average DBH, height and basal area was reported 3.44 ± 0.213 cm, 10.58 ± 0.47m and 9.71 ± 1.25 cm respectively. The total above ground biomass estimated with an average of 26 culms clump^{-1} was 71.76 ± 1.12 kg/clump (Alemayehu *et al.,* 2015). Though, total above ground biomass reported in the present study is lower than this report but culm growth pattern is similar showing more DBH for the same height of culm. For 10.5 m long culm, diameter at 1.5m (DBH) was measured 4.77 cm but average number of culms per clump was recorded lesser, only 8.5 in comparison to 26 (as in Ethiopia). *Melocanna baccifera* and *Bambusa tulda*

Table 3: Correlation matrix of the biometric parameters of micropropagated plants of *Dendrocalamus hamiltonii* used for plantation

	length twig	wt twig	LAI	wt leaf
length twig	1			
wt twig	0.908107	1		
LAI	0.870085	0.691118	1	
wt leaf	0.918687	0.791511	0.987888	1

Table 2: Estimation of above ground biomass of *Dendrocalamus hamiltonii* on fresh and dry weight basis

Above ground biomass	2020		2022		Per cent increase in two years	
	FW	DW	FW	DW	FW	DW
Biomass (kg culm^{-1})	1.36	0.49	4.32	1.71	217.65	248.98
Biomass (kg clump^{-1})	9.90	3.59	35.61	14.14	259.70	293.87
Biomass (t ha^{-1})	3.96	1.44	14.24	5.66	259.60	295.05

are two most common bamboo species in Mizoram, North East state of India. In a study performed by Devi *et al.* (2018), total above ground biomass of *M. baccifera* (106.68 Mg/ha) was estimated higher than *B. tulda* (97.00 Mg/ha). Significant positive correlation between culm, branch and leaf biomass and their respective C content was reported in *M. baccifera* whereas in *B. tulda* only culm component have significant positive correlation with C content. This group reported carbon storing capability of *B. tulda* was more than *M. baccifera* due to its thick-walled culm structure. Carbon sequestered in the present study by *D. hamiltonii* on the basis of fifty per cent of the dry weight in 11 years was 2.83 t/ha in the mountain region. From the year 2020 to 2022, per cent increase in above ground biomass was 293.87 on per clump basis. There was a positive correlation between fresh and dry weight. The regression equation y =0.419x-0.100 indicated 9.96 per cent variation (Fig. 2). High level of significance and positive correlation between fresh and dry weight was reported in inter and intra species study of *Bambusa bambos*, *B. tulda*, *B. nutans*, *B. balcooa* and *D. asper* (Agarwal, 2020). Per cent decrease in dry weight over fresh weight ranged from 58.01 (12.5m long culm) to 68.18 (1.6m long culm) showed negative correlation with length of culm (Fig. 3).

Correlation matrix of micropropagated plants (with an average length of 1.0m) used for plantation described that correlation coefficients between several variables contribute to plant's fresh weight (Table 3). Significant ($p < 0.05$) positive correlation was observed among all the variables i.e., length & weight of twigs, leaf area index and weight of leaf. Weight of leaf and leaf area index showed very strong positive correlation indicating the contribution of broader leaves of *D. hamiltonii* in adding the more AGB.

CONCLUSION

Above ground biomass of *Dendrocalamus hamiltonii* estimated using multiple linear regression in Uttarakhand state was lower than the reports available on this species but there is lot of potential of this particular species to bring under cultivation on slopes and dry lands for its ecological significance in soil restoration and ecosystem management.

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