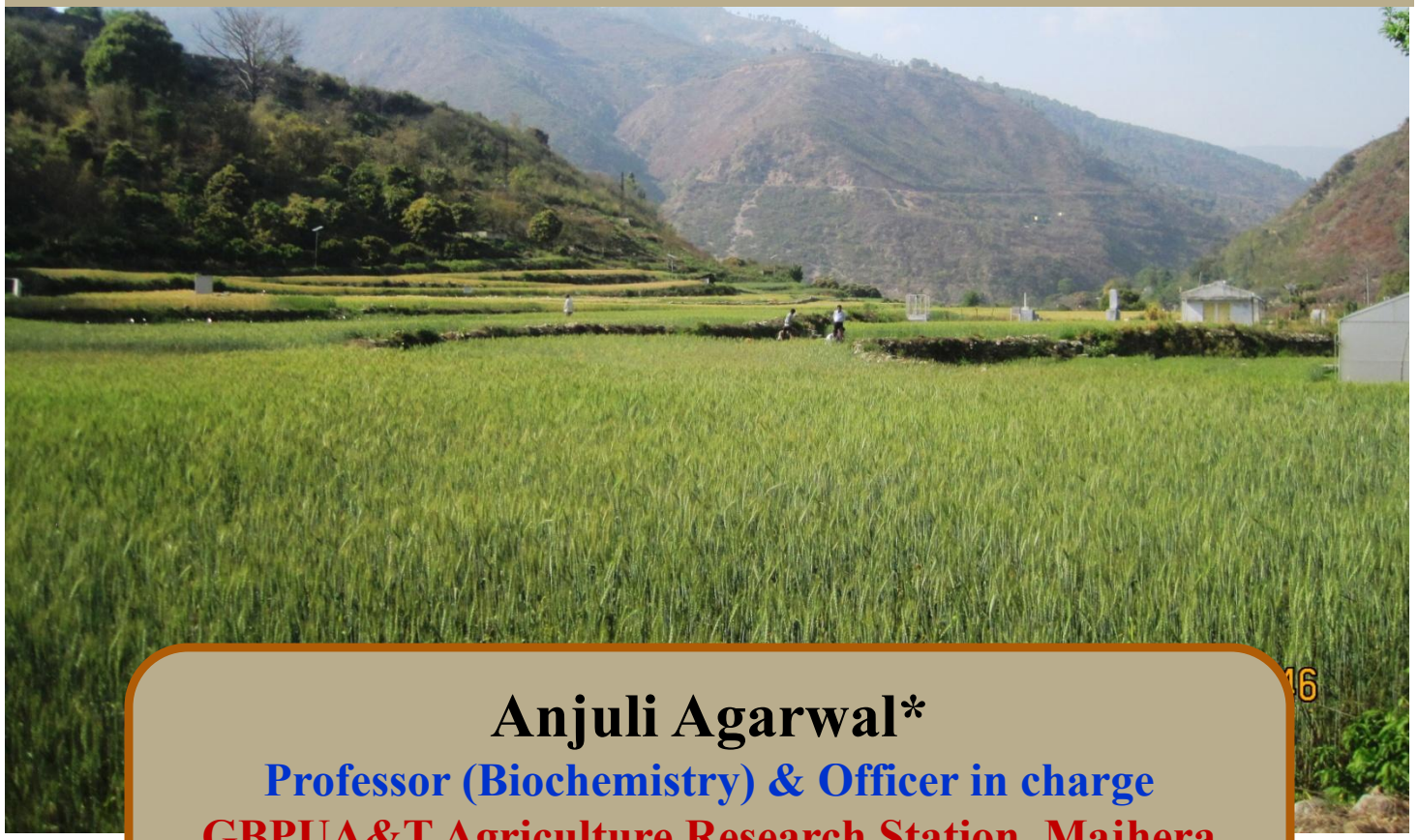
A Study on carbon sequestration potential of *Bambusa balcooa* through above ground biomass estimation in Uttarakhand: a Himalayan state of India



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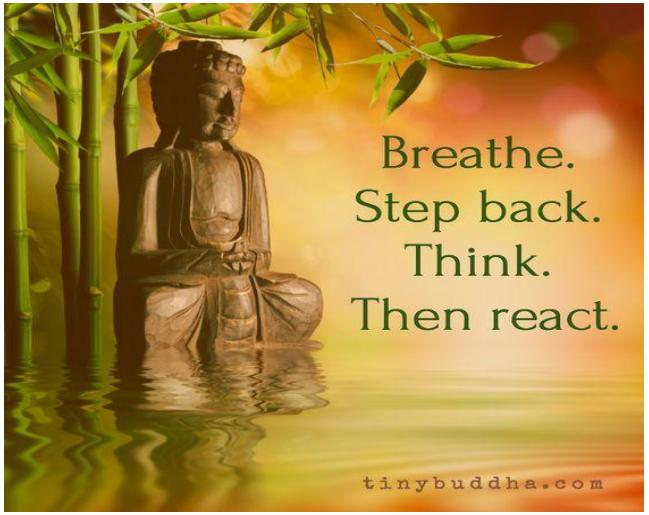
Bamboo: A boon to environment, mankind and mother earth

- In Buddhism, bamboo is a **symbol of purification** and cleansing
- It is a plant that easily adapts and **grows in any environment**.
- In Chinese folktales, bamboo is a representation of **wisdom and courage.**
- In some stories, bamboo's hollow center symbolizes **inner peace and emptiness**



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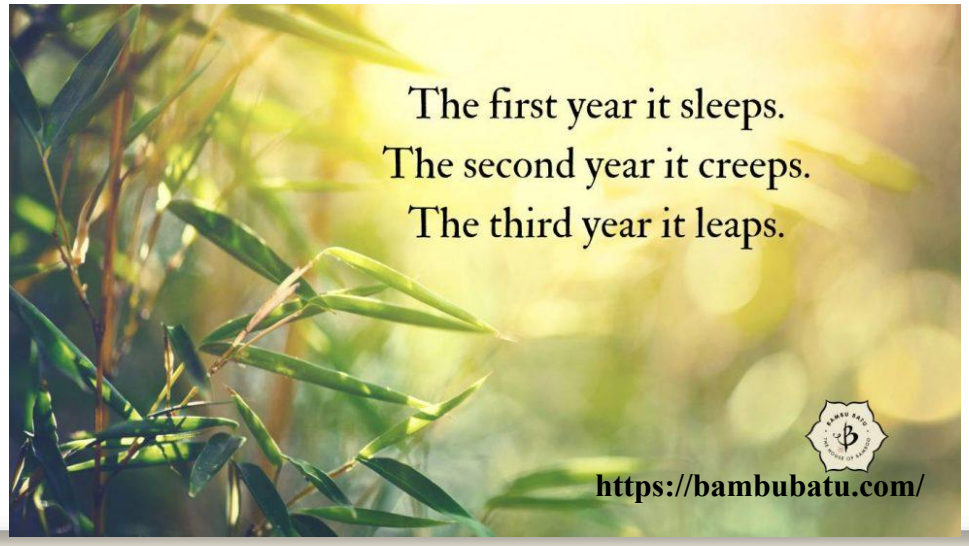
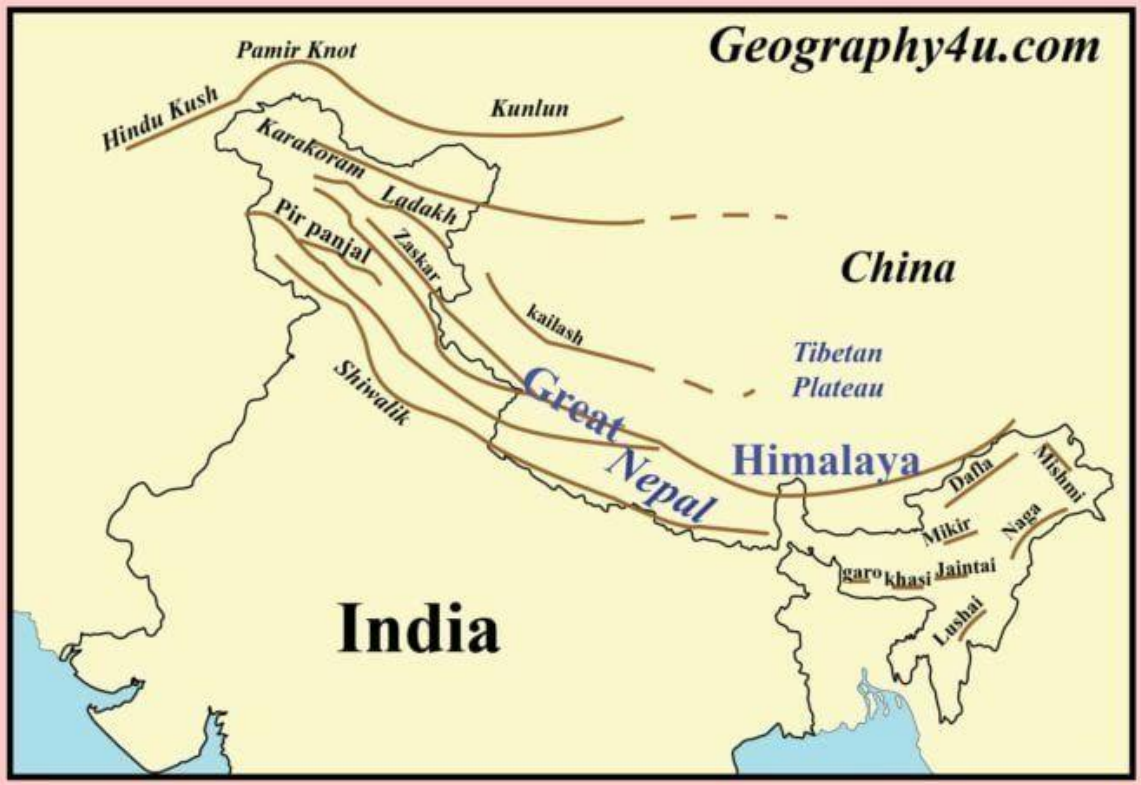


https://bambubatu.com/

Bamboos are astonishing for :

- **Economic utility** from rural livelihood to industrial applications
- **Ecological role** in soil conservation by checking soil erosion
- Provide **natural or living fence,** retaining wall on steep mountains, along the road sides and riversides
- **Biomass accumulation** and carbon sequestration by removing Co_2 from the environment

The Himalayas are extremely vulnerable to climate change, hence 'Sustaining the Himalayan Ecosysytem' is one of the missions under the National Action Plan on Climate Change



Himalayas Mountain system

Himalayas- 2,500 long & 400 km wide

Includes most of Nepal, Bhutan, South Tibet, north of India up to Pakistan

Shivalik Hills – Mountain range of outer Himalayas starts almost from the Indus and ends close to the Brahamaputra

Carbon sequestration studies on bamboo in the mid Himalayan region of Uttarakhand, India

- **Evaluation of above ground biomass (AGB) produced by *Dendrocalamus asper* on fresh and dry weight basis at two aspects (hill top and river bank) in two year old plantation** (Agarwal & Purwar 2009)

  AGB produced was 17% higher at the hill top as compared to river bank on f/w basis and 19.8% higher on d/w basis

- **Biomass production and carbon sequestration potential of various Bamboo specied in the mid Himalayan region of India** (Agarwal & Purwar 2012)

  Out of five species, highest biomass on f/w basis was found in *D. strictus* (106.49 t/ha but on d/w basis *P. nigra* showed the maximum biomass production (89.76 t/ha). *B. bambos* showed highest biomass on per culm basis (but low culm density)

- Altitudinal variation in carbon sequestration potential of micropropagated *Dendrocalamus asper* in the mid Himalayan region of India (Agarwal & Purwar 2015)

  - Above ground biomass and carbon sequestration in *D. asper* at five various altitudes (900-1400m a.s.l.) varied from 18.55 (1300m a.s.l.)-121.70 (1000m a.s.l.)kg plant^{-1} and 3.70 - 24.34 t ha^{-1}, respectively.

- Growth pattern of Bambusa spp. and carbon estimation of micropropagated *Dendrocalamus asper* in the mid Himalayan region (Agarwal & Purwar 2016)

  - Growth pattern of *Bambusa nutans, B. balcooa, B. bambos* & *B. tulda* along with *Dendrocalamus asper* in the mid Himalayan region of India revealed highest per cent increase in height in *B. balcooa* >*B. bambos* > *B. nutans*. *B. tulda* showed highest number of culms.

- **Carbon sequestration and above ground biomass produced by Bambusa Spp. in the mid Himalayan region of Uttarakhand, India** (Agarwal & Purwar 2017)

  Maximum above ground biomass was reported in *B. balcooa* (53 t ha^{-1}) > *B. nutans* (19.8 t ha^{-1}) > *B. tulda* (4.9 t ha^{-1}) after four years of plantation in the mid Himalayan region. Carbon sequestration potential of *B. balcooa* was estimated more than ten times and *B. nutans* four times as compared to *B. tulda*.

- **Comparative study on growth pattern and above ground biomass produced by *Dendrocalamus asper* and *Bambusa* spp. in the mid Himalayan region of India** (Agarwal & Purwar 2018)

  in 6 years, highest per cent increase in height in *B. bambos* (1075.34) and in number of culms *B. tulda* (742.11). Height and culm production was lowest in *D. asper* as compared to *Bambusa* spp. AGB by *B. bambos* (20.52 t ha^{-1}) & *B. nutans* (20.41 t ha^{-1}) was highest as compared to *D. asper* (12.92 t ha^{-1}). *B. tulda* (9.62 t ha^{-1}) lowest.

Material and Methods

To develop Linear regression equation and estimation of above ground biomass

Duration of the study: 2010-2023

Location: Agriculture Research Station, Majhera, Nainital (Uttarakhand) India

Altitude: 905m (a.s.l.)
Latitude: 29°30.137'North
Longitude: 79°28.784'East

Planting material: *Bambusa balcooa* plants (50-100cm)
Spacing: 5 X 5 m on a hill slope
Replications: 9 (one plant as one replication)
Sampling: November 2014, three culms from three clumps

Data recorded: Length, girth of culms at 1.0m & 1.5m, fresh and dry weight Dry weight: By shade drying

contd……

WBC
TAIWAN

Latitude: 29.504156
Longitude: 79.478404
Elevation: 932.94±6 m
Accuracy: 7.8 m
Time: 12-03-2024 14:42
Note: Bamboo plantation
Powered by NoteCam

Latitude: 29.504178
Longitude: 79.478397
Elevation: 933.93±10 m
Accuracy: 9.9 m
Time: 12-03-2024 14:47
Note: Bamboo plantation
Powered by NoteCam

Bamboo Plantation at hill slope at ARS, Majhera

For non-destructive estimation of AGB on dry weight basis:

- Length and girth of culms at 1.0m and 1.5m along with total number of culms was recorded in the years 2017, 2020 and 2023.
- Data of three culms in each clump was used for AGB estimation (kg Pole^{-1})
- Biomass accumulation per clump was extrapolated to per ha basis by multiplying with 400 with a spacing of 5 X 5 m.
- Carbon content estimation was done on the basis of 50 per cent of the total above ground biomass produced (Scurlock *et al*., 2000).

Results and Discussion

AGB of *B. balcooa* was estimated at three year interval in the year

- **2017**
- **2020**
- **2023**

On the basis of Regression model

S. No.	Biomass (kg culm^{-1}) y	Intercept (a)	Slope (x_1)	Slope (x_2)	Slope (x_3)	R^2
1.	Fresh weight	-20.44	0.50	510.90	-304.61	0.99
2.	Dry weight	-13.38	0.26	328.62	-194.23	0.98

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 *B. balcooa*

According to this, AGB of *B. balcooa* depended on: length of culm, girth to height at 1.0m & 1.5m by 99 on fresh weight and 98 per cent on dry weight basis.

And length of culm was directly proportional to the above ground biomass (kg pole^{-1}) on fresh and dry weight basis

Agarwal & Purwar (2009) have also reported similar results in case of *Dendrocalamus asper*.

This equation also explains:

That with one unit increase in girth at 1.5m, the above ground biomass of *B. balcooa* decreased by 304.61 per cent on fresh and 194.23 per cent on dry weight basis.

As per previous reports:

Agarwal and Purwar, 2012: girth at 1.5m has been reported as the major deciding independent variable for biomass estimation in bamboos

Riano et al., 2002: In *Guadua angustifolia,* 45 per cent of the whole fresh weight can be explained by the variation of DBH

Nath & Das, 2011: A regression model for carbon stock estimation in *B. vulgaris, B. balcooa and B. cacharensis* was also developed with DBH as an independent variable

Estimation of above ground biomass of *B. balcooa* on fresh and dry weight basis at three year interval after the plantation

Above ground biomass	2014		2017		2020		2023	
	FW	DW	FW	DW	FW	DW	FW	DW
Biomass (kg culm^{-1})	4.45	2.40	17.12	10.45	35.36	21.95	39.22	24.48
Biomass (kg clump^{-1})	31.15	16.80	158.14	96.64	406.19	252.46	891.98	557.50
Biomass (t ha^{-1})	12.46	6.72	63.26	38.66	162.48	100.98	356.66	223.00

2014: AGB is as per actual (Average of three culms from each clump after harvesting)

2017
2020 &
2023
AGB estimated through non-destructive method through regression by measuring length and girth of culms

From the year 2020 (35.36 kg) to 2023 (39.22 kg) biomass per culm was almost at par (10.91 % increase) but per clump gain was much more i.e. 119.60 % on fresh weight basis

So increase in biomass was due to more number of culms not much increase in size of culms after 10 years of plantation

Per cent increase in above ground biomass of *B. balcooa* on fresh and dry weight basis in subsequent years after the plantation

Year	Per cent increase			
	Per culm		Per clump	
	FW	DW	FW	DW
2017	284.72	334.42	407.67	475.24
2020	106.54	110.05	156.85	161.24
2023	10.91	11.52	119.60	120.82

2014 to 2017: highest per cent increase in biomass per culm (284.72) and per clump (407.70) was observed, indicates faster growth in the initial years i.e. 6 years after plantation

Agarwal & Purwar 2017, 2018: AGB produced by *B. tulda* in four years was 4.9 t ha^{-1} on dry weight basis. An increase in AGB of 100 per cent was observed in two years by *B. tulda*

Carbon sequestered by *B. balcooa* was 19.33t ha^{-1} in the year 2017 (Seven years after plantation) , which is 475.3 per cent higher than the year 2014

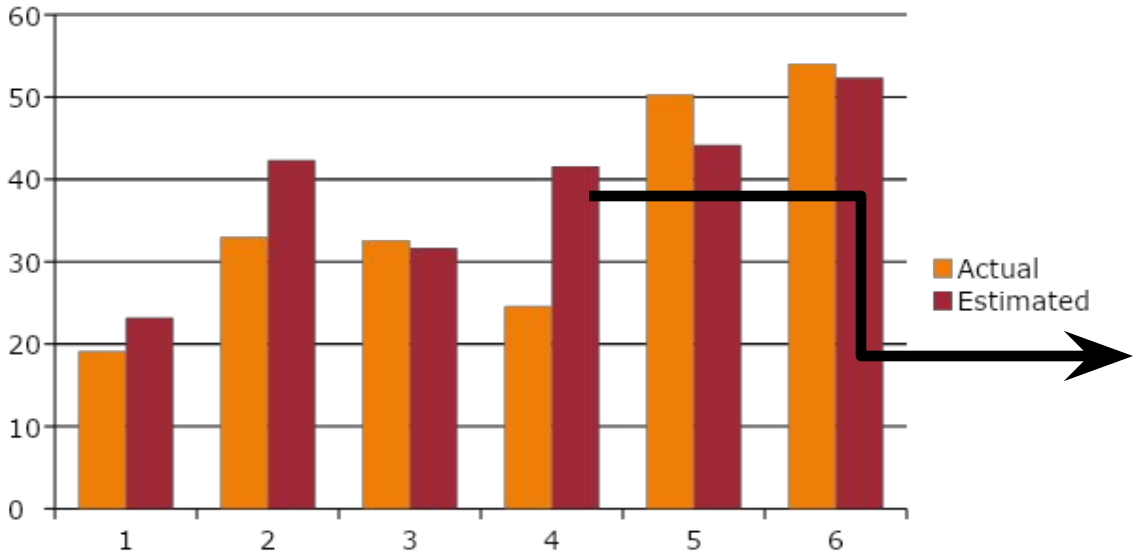
Year	Carbon sequestered (t ha^{-1})	Per cent increment
2014	3.36	-
2017	19.33	475.24
2020	50.49	161.24
2023	111.50	120.82

Choudhury et al. 2015: Reported 88.95 t ha^{-1} through above ground biomass and 96.46 t ha^{-1} through total biomass carbon sequestration by *B. nutans* in four years in Assam, North-East region of India

Choudhury et al. 2015: also reported similar findings in *B. balcooa* at 5th year 101.49 t ha^{-1} carbon in AGB in Assam India

Actual vs. Estimated

Validation of regression by taking the actual fresh weight and estimating through regression



Estimated weight is 69% more than the actual weight ; the variation may be due to number of branches, twigs and leaves because weight of culms for developing regression was recorded of the whole culm.

This comparison suggests that to develop regression for culm biomass estimation, only the weight of culms should be recorded excluding the branches and leaves.

However, the average of 6 culms show the difference of only 10% (35.6 kg pole^{-1} actual & 39.2 35.6 kg pole^{-1} estimated)

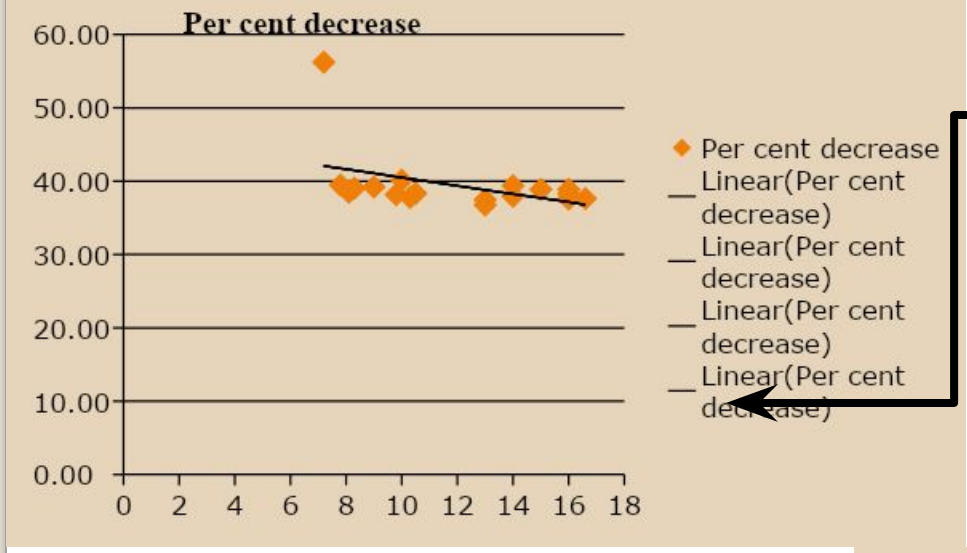
Correlation matrix of the biometric parameters and above ground biomass accumulation in *B. balcooa*

	Length	Girth1 m	Girth 1.5m	FW	DW
Length	1				
Girth1 m	0.742813	1			
Girth 1.5m	0.746892	0.995970	1		
FW	0.785311	0.989861	0.975902	1	
DW	0.775121	0.990970	0.976836	0.999864	1

Estimation of above ground biomass showed significant ($p < 0.05$) correlation with culm height, girth at 1.0 & 1.5m both on fresh & dry weight basis .

Singh & Rai (2012): have also reported significant ($p < 0.01$) positive correlation with culm height, rind thickness, leaf length and number of internodes/culm.

There was a negative correlation between culm height and girth at 1.5m with decrease in dry weight over fresh weight

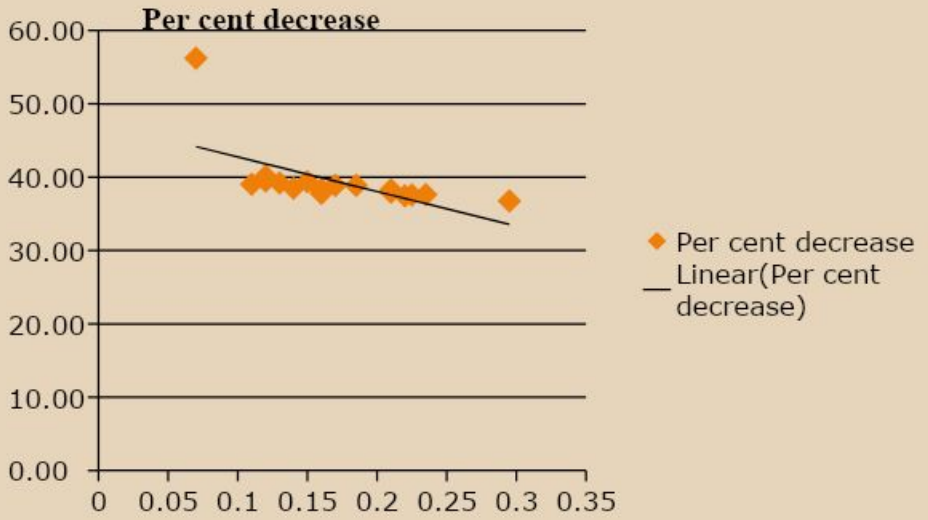


Relationship between length of culm with per cent decrease in dry weight over fresh weight

18.3 per cent variation for culm length

Relationship between girth (at 1.5m) of culm with per cent decrease in dry weight over fresh weight

36 per cent for girth at 1.5m



Conclusion

- The present study indicated that *B. balcooa* has vast potential for carbon sequestration in the mid Himalayan region as long as the poles are used in construction or making the furniture etc.
- Previous reports of other species like *B. bambos* and *B. nutans* almost at par estimated 20.52 and 20.41 t ha^{-1} above ground biomass produced in six years of the same geographical location.
- In *B. tulda* lowest AGB was observed in (9.62 t ha^{-1}) among all the four species (Agarwal & Purwar 2018).
- Whereas, *B. balcooa* produced almost double (38.66 t ha^{-1}) in the same time period.

Thanks

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- Department of Scienece & Technology, Govt. of India
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- Audiences