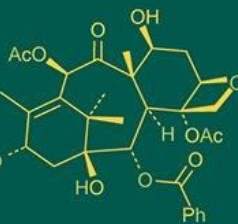
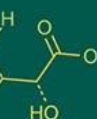
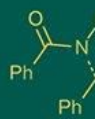
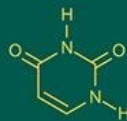
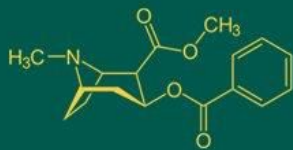


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To estimation biomass and carbon storage capacity of bamboo (*Bambusa arundinacea* and *Dendrocalamus strictus*) in Korba, Bilaspur and Raigarh district of Chhattisgarh

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Abstract

The present experiment entitled “To estimation biomass and carbon storage capacity of Bamboo (*Bambusa arundinacea* and *Dendrocalamus strictus*) in Korba, Bilaspur and Raigarh District of Chhattisgarh” study was conducted in year 2021-22 and 2022-23 at covering site Korba, Bilaspur and Raigarh District of Chhattisgarh under Guru Ghasidas Vishwavidyalaya, Koni, Bilaspur (C.G.). The *Dendrocalamus strictus* and *Bambusa arundinacea* species were selected for the experiment. The results showed that *Bambusa arundinacea* at Bilaspur exhibited the highest number of culms per hectare, followed by *Bambusa arundinacea* at Raigarh and *Dendrocalamus strictus* at Bilaspur. In terms of total soil carbon and carbon stock density, *Bambusa arundinacea* at Korba performed best, followed by Raigarh and Bilaspur sites. The findings suggest that *Bambusa arundinacea* in certain locations has a higher carbon storage potential, making it a valuable species for carbon sequestration and environmental mitigation in tropical regions. This highlights the importance of selecting optimal species and locations for effective carbon management strategies.

Keywords: Carbon storage capacity, *Bambusa arundinacea*, *Dendrocalamus strictus*, carbon sequestration, soil carbon, carbon stock density

1. Introduction

Bamboos are a group of woody perennials, evergreen to deciduous plants that are unique in their distribution, growth, morphogenesis, taxonomy, reproduction, ecology, and diversity. They are members of the grass family Poaceae, subfamily Bambusoideae and tribe Bambuseae (Ramanayake *et al.* 2007) [16].

A total of 1642 species and 115 genera of bamboo have been described from various continents except Europe and Antarctica. The tropics and subtropics are particularly well suited to bamboo growth because it thrives in hot, humid rain forests, but the temperate climates of Japan, China, Chile, and the United States, which include cold resilient forests, are also found to be suitable for some taxa (Grosser and Liese, 1971) [15].

They can withstand and grow in extremely low temperatures (-20 °C) and annual rainfall ranging from 800 mm to 1300 mm. The suitable altitude range for bamboo growth extends from sea level to 4000m. Larger bamboo species are found at lower elevations in the tropics and subtropics, while smaller bamboo species are found in higher elevations or temperate areas (Lee *et al.* 1994) [12]. The Asia-Pacific region has the most major bamboo species, followed by South America, with very few species found on the African continent (Bystriakova *et al.* 2003) [11].

Bamboo's adaptability as a raw material has made it an integral part of human life since time immemorial. Bamboos have had a significant impact on the socioeconomic, cultural, and ecological development of specific regions. Bamboo contributes to the subsistence needs of approximately 2.5 billion people worldwide, the vast majority of whom are tribals, forest dwellers, or communities reliant on forest resources. Approximately 2 million traditional artisans in India rely on the harvesting, processing, value addition, and sale of bamboo products such as baskets, mats, handicrafts, and so on to make a living.

Bamboo is used in a variety of applications, including fodder, pulp, timber, construction, charcoal, edible shoots, and cottage industries.

Bamboos have enormous potential as a substitute. It can be used for decorative and shuttering plywood, a variety of board products such as wafer board, stripboard, laminated boards, roofing sheets; earthquake-resistant and long-lasting conventional housing and buildings, furniture, fuel-wood, charcoal and briquettes, active carbon, matchsticks, agarbattis, toothpicks, skewer sticks, and so on. Bamboos have socio-economic and ecological value, and their management can provide benefits on a local, national, and global scale by providing livelihood, economic, and environmental security to millions of rural people. Bamboos are useful for soil erosion control, stream bank protection, embankment and drainage channel reinforcement, and other applications. Bamboos help to maintain and improve soil physical, chemical, and biological properties due to their high biomass accumulation and abundant litterfall (Christanty *et al.* 1996) [3].

Bamboo has a high carbon sequestration capacity due to its rapid biomass accumulation and effective fixation of solar energy and carbon dioxide. Bamboo is estimated to account for one-quarter of the biomass in tropical regions and one-fifth in subtropical regions. Bamboo can absorb up to 40 tonnes of CO₂ per acre. It is estimated that a 1,000 sq. ft. bamboo living green home contains more than 15 tonnes of CO₂ locked up (sequestered) within its fibres. Because of its numerous essential uses, it has earned the moniker “Green Gold,” “Poor Man's Timber,” “Bamboo, Friend of the People,” and “Cradle to Coffin Timber” (Tewari *et al.* 2019) [24].

2. Materials and Methods

The study employed a comparative analysis to estimate the carbon storage capacity of two bamboo species, *Bambusa arundinacea* and *Dendrocalamus strictus*, across different locations (Bilaspur, Raigarh, and Korba) over the years 2021-22 and 2022-23. Field data were collected on various parameters, including the number of culms per hectare, total carbon in soil (inorganic), and total carbon stock density. Biomass data were recorded for different components such as culms, branches, and leaves at two distinct clump ages, 5 and 20 years old plant. Linear regression equations were developed to estimate dry biomass from fresh biomass, providing a framework for rapid carbon stock estimation in bamboo stands. Statistical tools like RBD (Randomized Block Design) and paired t-tests were used to validate the accuracy of the regression models, ensuring that the observed and estimated dry biomass values were closely aligned.

The methodology involved detailed sampling and data collection from each bamboo plantation site, with three repetitions for each observation to ensure accuracy. Biomass was calculated for both fresh and dry weights of bamboo components, and the differences across clump ages were analyzed. The data from both species and locations were compiled to compare the carbon storage capacity, revealing trends in biomass accumulation and carbon stock density over time. The study's results were presented in tables that summarize the differences between the species, locations, and years, highlighting the role of bamboo age in carbon storage.

3. Result

The data regarding to estimate biomass and carbon storage capacity of Bamboo species viz., (*Bambusa arundinacea* and *Dendrocalamus strictus*) was presented in Table 1, Table 2, Table 3, Table 4 and Table 5.

3.1 To estimation biomass and carbon storage capacity of C (Number of culms ha⁻¹) in bamboo plantation.

Among the table 1, The C (number of culms ha⁻¹) was found significantly highest in the *Bambusa arundinacea* at Bilaspur (1570), which was followed by the *Bambusa arundinacea* at Raigarh (1324) and *Dendrocalamus strictus* at Bilaspur (1250). The significantly lowest C (number of culms ha⁻¹) in the *Dendrocalamus strictus* at Raigarh (895) in the year 2021-22. The C (number of culms ha⁻¹) was found significantly highest in the *Bambusa arundinacea* at Bilaspur (1607), which was followed by the *Bambusa arundinacea* at Raigarh (1361) and *Dendrocalamus strictus* at Bilaspur (1287). The significantly lowest C (number of culms ha⁻¹) in the *Dendrocalamus strictus* at Raigarh (932) in the year 2022-23. The C (number of culms ha⁻¹) was found significantly highest in the *Bambusa arundinacea* at Bilaspur (1588.50), which was followed by the *Bambusa arundinacea* at Raigarh (1342.50) and *Dendrocalamus strictus* at Bilaspur (1288.50). The significantly lowest C (number of culms ha⁻¹) in the *Dendrocalamus strictus* at Raigarh (913.50) in the pooled mean. The results obtained in the present study is in accordance with the results of Sharma, R., Pradhan, L., Kumari, M., & Bhattacharya, P. (2020) [21].

3.2 Total carbon of soil (inorganic) (t/ha)

The data display in table 2, Total carbon of soil (inorganic) (t/ha) was found significantly highest in the *Bambusa arundinacea* at Korba (12.54 t/ha), which was at par with the *Bambusa arundinacea* at Raigarh (11.36 t/ha) and *Bambusa arundinacea* at Bilaspur (11.54 t/ha). The significantly lowest Total carbon of soil (inorganic) (t/ha) at *Dendrocalamus strictus* at Raigarh (7.97 t/ha) in the year 2021-22. The data display that Total carbon of soil (inorganic) (t/ha) was found significantly highest in the *Bambusa arundinacea* at Korba (16.45 t/ha), which was followed by the *Bambusa arundinacea* at Raigarh (11.87 t/ha) and *Bambusa arundinacea* at Bilaspur (11.98 t/ha). The significantly lowest Total carbon of soil (inorganic) (t/ha) at *Dendrocalamus strictus* at Bilaspur (10.25 t/ha) in the year 2022-23. The data display that Total carbon of soil (inorganic) (t/ha) was found significantly highest in the *Bambusa arundinacea* at Korba (14.50 t/ha), which was followed by the *Bambusa arundinacea* at Raigarh (11.62 t/ha) and *Bambusa arundinacea* at Bilaspur (11.76 t/ha). The significantly lowest Total carbon of soil (inorganic) (t/ha) at *Dendrocalamus strictus* at Raigarh (9.59 t/ha) in the pooled mean. The results obtained in the present study are supported by the works of Yen, T. M., & Lee, J. S. (2011) [23].

3.3 Total carbon Stock Density (t/ha)

According to the data table 3, Total Carbon Stock Density (t/ha) was found significantly highest in the *Bambusa arundinacea* at Korba (43.33 t/ha), which was at par with the *Bambusa arundinacea* at Raigarh (41.86 t/ha) and *Dendrocalamus strictus* at Raigarh (38.28 t/ha). The significantly lowest Total Carbon Stock Density (t/ha) at

Dendrocalamus strictus at Bilaspur (34.92 t/ha) in the year 2021-22. According to the data, Total Carbon Stock Density (t/ha) was found significantly highest in the *Bambusa arundinacea* at Korba (46.70 t/ha), which was at par with the *Bambusa arundinacea* at Raigarh (42.12 t/ha) and *Bambusa arundinacea* at Bilaspur (40.82 t/ha). The significantly lowest Total Carbon Stock Density (t/ha) at *Dendrocalamus strictus* at Bilaspur (36.73 t/ha) in the year 2022-23. According to the data, Total Carbon Stock Density (t/ha) was found significantly highest in the *Bambusa arundinacea* at Korba (45.02 t/ha), which was followed by the *Bambusa arundinacea* at Raigarh (41.99 t/ha) and *Bambusa arundinacea* at Bilaspur (39.18 t/ha). The significantly lowest Total Carbon Stock Density (t/ha) at *Dendrocalamus strictus* at Bilaspur (35.82 t/ha) in the pooled mean. The results obtained in the present study are supported by the works of Jose Hermis P. Patricio and Scarlet Wine L. Dumago (2014) [15].

3.4 Biomass stock (t ha⁻¹) in different culm components of *Dendrocalamus strictus* and *Bambusa arundinacea* plantation

Among the table 4, The pooled mean data for biomass stock in *Dendrocalamus strictus* and *Bambusa arundinacea* plantations for 2021-22 and 2022-23 reveals a significant increase in biomass with clump age. For 5-year-old clumps, the fresh weight biomass is 24.13±1.31 t ha⁻¹ for culms and 16.96±0.92 t ha⁻¹ for branches and leaves, totaling 41.09±2.23 t ha⁻¹, while the dry biomass is 17.83±0.97 t ha⁻¹ for culms and 14.81±0.80 t ha⁻¹ for branches and leaves, amounting to 32.64±1.77 t ha⁻¹. In contrast, 20-year-old clumps show a notable increase with fresh weight biomass of 84.74±3.21 t ha⁻¹ for culms and 26.44±1.00 t ha⁻¹ for branches and leaves, totaling 111.17±4.21 t ha⁻¹. The dry biomass at this age is 33.52±1.27 t ha⁻¹ for culms and 8.97±0.34 t ha⁻¹ for branches and leaves, summing to 42.49±1.61 t ha⁻¹. These results underline the considerable growth in both fresh and dry biomass as clump age increases, with a marked accumulation in culms. The pooled

mean data for 2021-22 and 2022-23 on equations and validation statistics for estimating dry biomass (kg culm⁻¹) of different components of *Dendrocalamus strictus* and *Bambusa arundinacea*. Linear regression equations of the form, $Y = a + bX$ were fitted, where Y is the dry biomass and X is the fresh biomass. The R-square values ranged from 0.013 to 0.24 indicating a good fit of the linear regression models. The observed and estimated mean dry biomass values were very close for different components as evident from the non-significant p-values in paired t-test. The study thus developed and validated linear regression models that can be effectively used to estimate dry biomass from fresh biomass measurements for different culm components of *D. strictus* and *B. arundinacea* bamboo. This will help in rapid estimation of carbon stocks in bamboo stands. This study is in accordance with the results of Zemek, O. J. (2009) [25] and Kumar, B. M., Rajesh, G., & Sudheesh, K. G. (2006) [11].

3.5 Biomass stock (t ha⁻¹) in different culm components of *Dendrocalamus strictus* and *Bambusa arundinacea* plantation

The table 5 shows the pooled mean data for biomass stock (tonnes per hectare) in different culm components of *Dendrocalamus strictus* and *Bambusa arundinacea* plantation at two clump ages - 5 years and 20 years. At 5 years, the fresh weight and dry biomass of culm, branch and leaf, and total was higher for both species. At 20 years, the fresh weight and dry biomass of culm increased significantly due to the increase in number and thickness of culms with age. However, the fresh weight and dry biomass of branch and leaf decreased at 20 years compared to 5 years, which could be due to senescence and shedding of branches and leaves as the culms become older and thicker. The results obtained in the present study is in accordance with the results of Zemek, O. J. (2009) [25] and Lasco, R. D., Pulhin, F. B., Visco, R. G., Racelis, D. A., Guillermo, I. Q., & Sales, R. F. (2000, February).

Table 1: To estimation biomass and carbon storage capacity of C (Number of culms ha⁻¹) in bamboo plantation.

S. N	Study Area	Plot No.	Species Name	C (Number of culms ha ⁻¹)		
				2021-22	2022-23	Pooled Mean
1	Korba	1	<i>Dendrocalamus strictus</i>	906	943	924.50
		2	<i>Bambusa arundinacea</i>	1025	1062	1043.50
2	Bilaspur	1	<i>Dendrocalamus strictus</i>	1250	1287	1268.50
		2	<i>Bambusa arundinacea</i>	1570	1607	1588.50
3	Raigarh	1	<i>Dendrocalamus strictus</i>	895	932	913.50
		2	<i>Bambusa arundinacea</i>	1324	1361	1342.50
SEm (±)				63.25	63.25	44.72
CD (0.05%)				199.29	199.29	140.92
CV (%)				9.43	9.14	6.56

Table 2: Organic carbon content (t/ha) in above and below-ground biomass in the soil component over the different bamboo spp at different location.

S. N	Study Area	Plot no.	Species name	Total carbon of soil (inorganic) (t/ha)		
				2021-22	2022-23	Pooled Mean
1	Korba	1	<i>Dendrocalamus strictus</i>	8.74	11.78	10.26
		2	<i>Bambusa arundinacea</i>	12.54	16.45	14.50
2	Bilaspur	1	<i>Dendrocalamus strictus</i>	9.58	10.25	9.92
		2	<i>Bambusa arundinacea</i>	11.54	11.98	11.76
3	Raigarh	1	<i>Dendrocalamus strictus</i>	7.97	11.20	9.59
		2	<i>Bambusa arundinacea</i>	11.36	11.87	11.62
	SEm ±			0.57	0.84	0.41
	CD (0.05%)			1.81	2.66	1.31
	CV			9.66	11.94	6.37

Table 3: Total Carbon Stock Density (t/ha) in above and below-ground biomass in the soil component over the different bamboo spp at different location.

S. N	Study Area	Plot no.	Species name	Total Carbon Stock Density (t/ha)		
				2021-22	2022-23	Pooled Mean
1	Korba	1	<i>Dendrocalamus strictus</i>	37.03	40.13	38.58
		2	<i>Bambusa arundinacea</i>	43.33	46.70	45.02
2	Bilaspur	1	<i>Dendrocalamus strictus</i>	34.92	36.73	35.82
		2	<i>Bambusa arundinacea</i>	35.12	40.82	37.97
3	Raigarh	1	<i>Dendrocalamus strictus</i>	38.28	40.09	39.18
		2	<i>Bambusa arundinacea</i>	41.86	42.12	41.99
	SEm $\pm$			1.87	1.81	1.25
	CD (0.05%)			5.88	5.71	3.93
	CV			8.41	7.63	5.43

Table 4: 2021-22 and 2022-23 pooled mean data basis of equations and validation statistic for estimating dry biomass (kg culm^{-1}) of *Dendrocalamus strictus* and *Bambusa arundinacea*.

Biomass component	Parameter estimate (standard error)		R-square	Observed mean	Estimated mean	Paired t-test	
	a (SEm)	b (SEd)				t-statistic	P(T<=t) two-tail
Fresh culm (kg culm^{-1})	0.177	0.25	0.14	3.59	3.52	-2.46	0.033
Fresh branch and leaf (kg culm^{-1})	0.046	0.07	0.013	1.12	1.11	-7.24	2.77
Total fresh (kg culm^{-1})	0.22	0.31	0.24	4.72	4.63	-1.93	0.081
Dry culm (kg culm^{-1})	0.058	0.08	0.023	1.42	1.43	-5.82	0.01
Dry branch and leaf (kg culm^{-1})	0.015	0.02	0.0016	0.38	0.37	-21.45	0.001
Total dry (kg culm^{-1})	0.070	0.10	0.04	1.81	1.80	-4.61	0.001

Table 5: 2021-22 and 2022-23 pooled mean data basis of biomass stock (t ha^{-1}) in different culm components of *Dendrocalamus strictus* and *Bambusa arundinacea* plantation.

Clump age (culm age)/Biomass component	Fresh weight (t ha^{-1})			Dry Biomass (t ha^{-1})		
	Culm	Branch and Leaf	Total	Culm	Branch and Leaf	Total
5	24.13 $\pm$ 1.31	16.96 $\pm$ 0.92	41.09 $\pm$ 2.23	17.83 $\pm$ 0.97	14.81 $\pm$ 0.80	32.64 $\pm$ 1.77
20	84.74 $\pm$ 3.21	26.44 $\pm$ 1.00	111.17 $\pm$ 4.21	33.52 $\pm$ 1.27	8.97 $\pm$ 0.34	42.49 $\pm$ 1.61

4. Conclusion

In conclusion, the comparative analysis of carbon storage capacity in *Bambusa arundinacea* and *Dendrocalamus strictus* reveals significant differences across various locations and years. The study of biomass and carbon storage capacity of Bamboo species in Korba, Bilaspur and Raigarh District of Chhattisgarh, revealed significant differences in carbon sequestration potential between species and locations. *Bambusa arundinacea* at Bilaspur exhibited the highest number of culms per hectare, highlighting its superior carbon storage capacity compared to *Dendrocalamus strictus*. Additionally, *Bambusa arundinacea* at Korba showed the highest total soil carbon and carbon stock density, suggesting that this species, particularly in Korba and Raigarh, is more effective in enhancing carbon storage. These findings underscore the role of bamboo, especially *Bambusa arundinacea*, in mitigating climate change by serving as an efficient carbon sink in tropical ecosystems. Continued research is essential to optimize management practices for bamboo plantations.

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and friends for their unwavering encouragement during the research period.

6. Future Study

- The potential to expand the scope by examining other bamboo species with high carbon sequestration potential in additional climatic zones.
- A detailed study of the carbon storage capacity of bamboo at different stages of maturity, particularly for bamboo plantations older than 20 years.
- Analysis of the long-term effects of environmental factors such as temperature, rainfall, and soil type on the carbon storage dynamics of bamboo species.
- Study of the economic benefits of bamboo in terms of carbon credits and its role in sustainable development initiatives.
- Investigation into the role of bamboo in mitigating soil erosion and enhancing soil fertility over time.
- A comparative analysis of bamboo's carbon sequestration potential against other fast-growing plants and trees in tropical and subtropical ecosystems.

7. Scope of the study

- Contributes to the understanding of bamboo's role in carbon sequestration, which can be instrumental in combating climate change.
- Provides insights into the most suitable bamboo species and locations for enhancing carbon storage capacity in tropical and subtropical regions.

- Can be used by policymakers and environmentalists in planning large-scale bamboo afforestation and reforestation projects aimed at carbon offsetting.
- Supports future research into bamboo management practices for maximizing biomass production and carbon storage.
- Facilitates the development of predictive models for estimating carbon stock in bamboo plantations, aiding quick assessment methods for forest managers and conservationists.

8. Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this research. All procedures, data analysis, and findings were conducted impartially and without bias.

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