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Impact of bamboo-based agroforestry system on yield and quality of Turmeric (*Curcuma longa* L.) Grown in humid tropical soils of Kodagu, Karnataka

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Abstract

A field experiment was conducted to evaluate the effect of different bamboo species on turmeric (*Curcuma longa* L.) yield and quality under a bamboo-based agroforestry system. Nine treatments comprising an open plot (control) and eight bamboo species were evaluated. Significant variation was observed in rhizome yield and curcumin content. The highest fresh rhizome yield was recorded in the open plot (236.80 q ha⁻¹), while among bamboo species, *Bambusa tulda* recorded the highest yield (229.60 q ha⁻¹) with the lowest yield reduction (3.04%). The lowest yield was recorded under *Dendrocalamus stocksii* (189.30 q ha⁻¹), with a 20.06% reduction. In contrast, curcumin content was highest under *Dendrocalamus stocksii* (4.16%), followed by *Dendrocalamus longipathus* (4.08%), compared with 3.48% in the open plot. The results indicate a trade-off between turmeric yield and quality under bamboo canopies. *Bambusa tulda* was most suitable for maintaining higher yield, whereas *Dendrocalamus stocksii* enhanced curcumin content.

Keywords: *Curcuma longa* L., bamboo agroforestry, *Bambusa tulda*, *Dendrocalamus stocksii*, rhizome yield, curcumin

Introduction

Agroforestry has emerged as one of the most sustainable land-use systems capable of simultaneously enhancing agricultural productivity, conserving natural resources, improving biodiversity, and mitigating climate change (Jose, 2009) [7]. By integrating trees with agricultural crops, agroforestry creates a productive ecosystem that efficiently utilizes available land, water, sunlight, and nutrients while providing multiple economic and ecological benefits. Among the various tree components used in agroforestry, bamboo has gained considerable attention owing to its exceptionally rapid growth, high biomass production, extensive root system, and wide range of commercial applications (Shanmughavel & Francis, 2001; Kittur *et al.*, 2015) [12, 9]. Bamboo, popularly known as "Green Gold" or "Poor Man's Timber," belongs to the family Poaceae and subfamily Bambusoideae. Globally, more than 1,600 bamboo species are distributed across tropical, subtropical, and temperate regions. India is the second-largest bamboo-producing country in the world, harboring approximately 135 species under 22 genera distributed over nearly 10.03 million hectares, accounting for about 12.8% of the country's forest area. Integrating bamboo with economically important understory crops presents an attractive opportunity to improve overall farm productivity and profitability while conserving fragile ecosystems.

Turmeric (*Curcuma longa* L.) is a perennial herb belonging to the family Zingiberaceae and is native to South Asia. India is the world's largest producer, consumer, and exporter of turmeric, accounting for nearly 80–90% of global production. Turmeric is classified as a shade-tolerant crop and is traditionally cultivated as an intercrop under coconut, arecanut, coffee, and timber plantations (Nair *et al.*, 1991; Padmapriya *et al.*, 2007) [10, 11].

Partial shading often reduces heat stress, lowers evapotranspiration, maintains soil moisture, and creates a favorable microclimate that enhances secondary metabolite accumulation (Singh & Edison, 2003) [14]. Bamboo canopies provide similar environmental conditions, suggesting that bamboo-based agroforestry systems may offer an ideal production environment for turmeric. However, excessive canopy cover may drastically reduce Photosynthetically Active Radiation

(PAR), thereby limiting photosynthesis and rhizome development (Kittur *et al.*, 2015) ^[9]. Therefore, selecting suitable bamboo species that provide optimum shade without excessively reducing crop productivity becomes essential. Considering the increasing demand for sustainable farming systems, value-added spice production, and climate-resilient agriculture, the present investigation was undertaken to evaluate the effect of different bamboo species on the rhizome yield and curcumin content of turmeric under bamboo-based agroforestry systems in Kodagu, Karnataka.

Materials and Methods

The field experiment was conducted during the *Kharif* season of 2021–22 at a farmer's field in Kodagu district, Karnataka, situated in the humid tropical zone of the Western Ghats. The region receives an average annual rainfall of approximately 2,450 mm, predominantly during the southwest monsoon (June–September), with a mean annual temperature of around 22.4°C and consistently high relative humidity, creating favorable conditions for the cultivation of bamboo and shade-tolerant spice crops such as turmeric. The experimental field comprised deep, well-drained acidic clay loam soils derived from lateritic parent material. Prior to the initiation of the experiment, representative soil samples were collected and analyzed, revealing an initial soil pH of 5.82, organic carbon content of 11.4 g kg⁻¹, and available nitrogen, phosphorus, and potassium contents of 245.20, 18.40, and 285.50 kg ha⁻¹, respectively, indicating moderately acidic soil with high organic matter and medium fertility suitable for turmeric cultivation.

The experiment was laid out in a Randomized Block Design (RBD) consisting of nine treatments and three replications:

- **T₁:** Open plot (Sole turmeric control)
- **T₂:** *Bambusa vulgaris*
- **T₃:** *Dendrocalamus longipathus*
- **T₄:** *Bambusa tulda*
- **T₅:** *Bambusa cacherensis*
- **T₆:** *Dendrocalamus stocksii*
- **T₇:** *Bambusa polymorpha*
- **T₈:** *Bambusa balcooa*
- **T₉:** *Dendrocalamus strictus*

Four-year-old bamboo plantations established at a spacing of 7 m × 2 m served as the overstory component, while healthy turmeric seed rhizomes were planted between the bamboo rows following standard agronomic practices. Uniform crop management practices were followed throughout the experimental period,

including the application of the recommended fertilizer dose of 120:60:60 kg N:P₂O₅:K₂O ha⁻¹ in split doses, along with regular weeding, irrigation during dry spells, and plant protection measures as per standard recommendations. At harvest, fresh rhizome yield was recorded and expressed in quintals per hectare (q ha⁻¹). Representative rhizome samples were cured, dried, powdered, and analyzed for curcumin content using the ASTA spectrophotometric method (ASTA, 1997) ^[2]. The recorded data were subjected to Analysis of Variance (ANOVA) following the procedures of Gomez and Gomez (1984) ^[6], and treatment means were compared using the Critical Difference (CD) test at the 5% level of significance ($P = 0.05$).

Results and Discussion

The influence of different bamboo species on fresh rhizome yield, yield reduction and curcumin content of turmeric is presented in Table 1. Significant differences were observed among treatments. The highest fresh rhizome yield was recorded in the open plot (T₁) (236.80 q ha⁻¹), followed by *Bambusa tulda* (T₄) (229.60 q ha⁻¹), which was statistically at par with *Bambusa balcooa* (T₈) (223.75 q ha⁻¹) and *Bambusa vulgaris* (T₂) (218.95 q ha⁻¹). Their corresponding yield reductions were only 3.04%, 5.51% and 7.54%, respectively. Bhardwaj *et al.* (2020) ^[3] similarly reported reduced turmeric productivity under bamboo-based systems compared with open cultivation. The lowest rhizome yield was recorded under *Dendrocalamus stocksii* (T₆) (189.30 q ha⁻¹), followed by *Dendrocalamus longipathus* (T₃) (196.40 q ha⁻¹) and *Bambusa cacherensis* (T₅) (198.10 q ha⁻¹), with yield reductions of 20.06%, 17.06% and 16.34%, respectively. The reduction may be attributed to competition for light, moisture and nutrients. Alam *et al.* (2020) ^[1] reported that shade intensity significantly influenced turmeric growth and yield. In contrast, curcumin content was highest under *Dendrocalamus stocksii* (T₆) (4.16%), followed by *Dendrocalamus longipathus* (T₃) (4.08%) and *Bambusa cacherensis* (T₅) (4.03%), while the lowest was recorded in the open plot (T₁) (3.48%). *Bambusa vulgaris* (T₂) recorded the lowest curcumin content among bamboo treatments (3.72%), but it remained higher than the control. Dhale *et al.* (2024) ^[5] and Bijakal *et al.* (2020) ^[4] also reported enhanced curcumin content under agroforestry conditions, suggesting that moderate shade can favour curcumin accumulation. Overall, the results indicate a trade-off between turmeric yield and quality under bamboo-based agroforestry. *Bambusa tulda* was most suitable for maintaining higher rhizome yield with minimum reduction, whereas *Dendrocalamus stocksii* favoured maximum curcumin content despite the highest yield reduction.

Table 1: Effect of bamboo-based agroforestry systems on fresh rhizome yield and curcumin content of turmeric

Treatment	Bamboo Species	Fresh Rhizome Yield (q ha ⁻¹)	Yield Reduction (%)	Curcumin (%)
T ₁	Open plot (Control)	236.8	—	3.48
T ₂	<i>Bambusa vulgaris</i>	218.95	7.54	3.72
T ₃	<i>Dendrocalamus longipathus</i>	196.4	17.06	4.08
T ₄	<i>Bambusa tulda</i>	229.6	3.04	3.84
T ₅	<i>Bambusa cacherensis</i>	198.1	16.34	4.03
T ₆	<i>Dendrocalamus stocksii</i>	189.3	20.06	4.16
T ₇	<i>Bambusa polymorpha</i>	204.8	13.51	3.88
T ₈	<i>Bambusa balcooa</i>	223.75	5.51	3.77
T ₉	<i>Dendrocalamus strictus</i>	209.2	11.66	3.94
S.Em. ±	—	1.72	—	0.05
C.D. (P = 0.05)	—	5.14	—	0.14

Conclusion

The study demonstrated that bamboo-based agroforestry systems significantly influence the yield and quality of turmeric under the

humid tropical conditions of Kodagu, Karnataka. While sole turmeric cultivation produced the highest rhizome yield, *Bambusa tulda* and *Bambusa balcooa* maintained comparable

yields with minimal reductions, making them highly suitable overstory species. *Dendrocalamus stocksii* recorded the highest curcumin content, confirming that moderate shade enhances spice quality. Overall, integrating turmeric with suitable bamboo species provides a sustainable agroforestry model that improves land-use efficiency, enhances spice quality, and diversifies farm income.

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