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Mother Rhizome Growth of Turmeric Varieties [*Curcuma longa* (L.)] Under Eucalyptus (*Eucalyptus tereticornis*) Based Agroforestry System in Chhattisgarh Plain, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The experiment was carried out during the year 2022-23 and 2023-24 in Kharif seasons at the Herbal Garden of IGKV, Raipur, Chhattisgarh, India. Two production systems were studied: F1 involved sole Turmeric, while F2 involved Eucalyptus intercropped with Turmeric in both the production system used FRBD (Factorial Randomized Block Design). Eight turmeric varieties were used i.e.: T1 - Suranjana, T2 - Selam, T3 – Chhattisgarh Haldi-1, T4 – Chhattisgarh Haldi-2, T5 – Roma, T6- Ranga, T7- NDH-98 and T8- Sonali. From the two year of investigation it's found that mother rhizome length and width (cm) was found maximum in variety Chhattisgarh Haldi-2 and variety NDH-98 under sole turmeric as well as Eucalyptus intercropped with turmeric, while variety Sonali showed the minimum growth of mother rhizome in both the year of investigation and on mean data.

Keywords: Turmeric; eucalyptus; varieties; mother rhizome; production system.

1. INTRODUCTION

Agroforestry is a land use system that combines trees, crops, and animals in a manner that is scientifically sound, ecologically beneficial, practically achievable, and socially acceptable to farmers [1]. With the rising demands due to rapid population growth, urbanization, and industrialization [2] it is crucial to increase the production of food grains and fuel wood for human consumption, along with green and dry fodder for livestock. Agroforestry provides an effective solution for optimizing land use and boosting agricultural productivity in confined spaces. As a result, the multitier 'Agroforestry' system has gained international recognition for maximizing output [3].

Communities in the dry-land regions of India already possess significant knowledge regarding tree management. These knowledge systems are "open," promoting the exchange of information, which can foster innovation more effectively than rigidly combining local knowledge with global scientific approaches. Extension agents encourage local ownership of knowledge by enabling participants to innovate beyond their existing capabilities. This strategy improves program outcomes and fosters long-term farmer and community commitment [4]. In India, eucalyptus is grown for its short-term benefits and diverse uses as a Multipurpose Tree (MPT), providing timber, fuel, essential oils, and pulp. Large-scale eucalyptus plantations are maintained in various sectors, including roadside and canal-side plantings, and farm forestry, to produce bole wood and pulp, while also offering aesthetic benefits. *Eucalyptus tereticornis Sm.*, known for its shorter rotation period, better coppicing ability, and adaptability to different soils and climates, is widely cultivated in India [5].

Agriculture in India significantly influences the country's social, political, and cultural dimensions, and is regarded as one of its major success stories. It has transitioned from being the primary source of livelihood for over two-thirds of the workforce to becoming the foundation of the Indian economy [6]. Despite these advances, the FAO reports that around 820 million people worldwide still suffer from hunger, underscoring the enormous challenge of achieving zero hunger by 2030. This food insecurity forces people to compromise on both the quality and quantity of the food they consume [7].

In India, the production of turmeric is around 11.61 lakh tonnes during year 2022-23. About 3.24 lakh ha of area was covered by turmeric, which is about 6 percent of the total area under spices in India. More than 30 varieties of turmeric are grown in India (over 75% of global turmeric production) (Ministry of Commerce & Industry, 2023).

Because continuous cropping (CC) modifies the microbial micro-ecological environment and soil qualities, it limits the growth of the medicinal plant agriculture sector. It may also result in a decrease in the chemical composition of therapeutic plants. In this study, interplanted ginger or turmeric with continually cropped *Pogostemon cablin* (patchouli). Utilizing high-throughput sequencing, the fungus and bacteria found in soil were examined. Additionally examined were colony differences, structure, diversity, and composition. The relationships between the fungi and bacteria as well as the physical and chemical characteristics of the soil were investigated using a redundancy analysis (RDA) [8].

Typically, a tiny percentage of rhizomes called seed rhizomes—which provide the commercial yield—are used to propagate turmeric [9]. It follows that choosing planting material that is the proper size (length, weight, and number of growing buds per seed) is crucial to the success of turmeric farming. Many researchers have reported that planting larger turmeric seed rhizomes resulted in higher yield compared to smaller seed rhizomes, despite the fact that the scientific package of practices recommends planting rhizomes that weigh 20–30 g. [10]. Additionally, Awasthy & Jessykutty [11] stated that the maximum sprouting % was observed by a turmeric rhizome bit with three nodes and an approximate weight of 7 g.

2. MATERIALS AND METHODS

The field experiment was conducted at the Herbal Garden of Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.), during the periods of 2022 to 2024. Raipur is situated in the mid-eastern part of Chhattisgarh, at a latitude of 21°16'N, longitude of 81°36'E, and an elevation of 289.56 meters above mean sea level. During the crop growth period, the weekly average maximum temperature 42.34 °C and minimum temperature 8.31 °C observed respectively. The weekly mean relative humidity observed maximum 92.71% and minimum 15.14% recorded respectively. The average weekly maximum rainfall during experiment period was 30.34 mm, while the minimum was 0.16 mm. The experiment followed a Factorial RBD design, with three replications of eight treatment combinations across two production systems applied to eight crop varieties. Each treatment combination was randomly replicated three times. NPK fertilizers were applied at the rate of 120:60:60 kg per hectare using urea, single superphosphate, and muriate of potash. Turmeric rhizomes size was 25-30 g were manually planted following an experimental design in a cropping system with row and plant spacing of 40 cm × 30 cm, involving eight varieties and three replications. Sowing was carried out in 48 plots, each measuring 2.5 m × 2.5 m, using AFS and a monocrop system. Soil type in experimental field was sandy to loam soil. Main tree component was *Eucalyptus tereticornis* Sm. Under agroforestry system. Yield parameters of mother rhizome like length and width plant^{-1} was measured respectively during season 2022-2023 and 2023 to 2024 in Kharif.

3. RESULTS AND DISCUSSION

Yield attributes of turmeric i.e. size of mother rhizome length (cm) at harvest of turmeric is very essential parameter for yield estimation of turmeric. The data regarding size of mother rhizome length (cm) of rhizome has been presented in Table 1 and Fig. 1 & Fig. 2.

Table 1. Mother Rhizome length plant^{-1} (cm) as affected by production system and turmeric varieties under Eucalyptus-based agroforestry system

Treatments	Size of mother rhizome length (cm)		
	2022-23	2023-24	Pooled
Factor A (Production system)			
F_1- Sole turmeric	9.44	9.77	9.60
F_2- Eucalyptus+turmeric	9.20	9.51	9.36
SEm±	0.076	0.074	0.075
CD @ 5%	0.154	0.15	0.152
Factor B (Crop varieties)			
T_1 –Suranjana	7.11	7.45	7.28
T_2 –Selam	8.65	8.96	8.80
T_3 -Chhattisgarh Haldi-1	7.48	7.82	7.65
T_4 -Chhattisgarh Haldi-2	9.39	9.70	9.54
T_5 –Roma	7.25	7.55	7.40
T_6 –Ranga	7.38	7.71	7.54
T_7 -NDH-98	20.74	21.02	20.88
T_8 –Sonali	6.58	6.91	6.75
SEm±	0.152	0.148	0.149
CD @ 5%	0.309	0.301	0.304

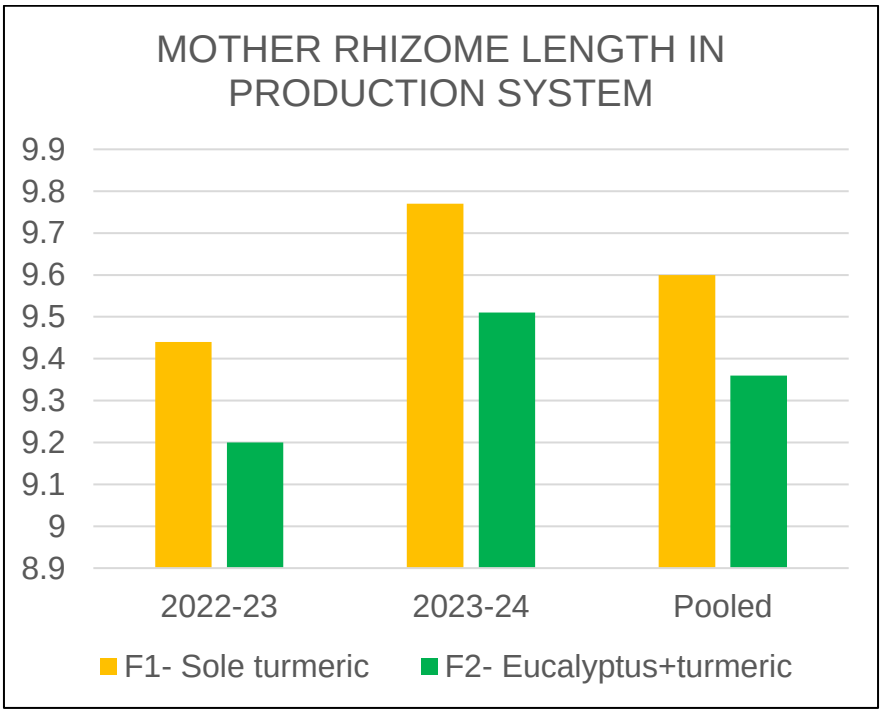

Fig. 1. Mother Rhizome length (cm) at harvesting stage of Turmeric as influenced by control farming and Eucalyptus tereticornis based agroforestry system in production system

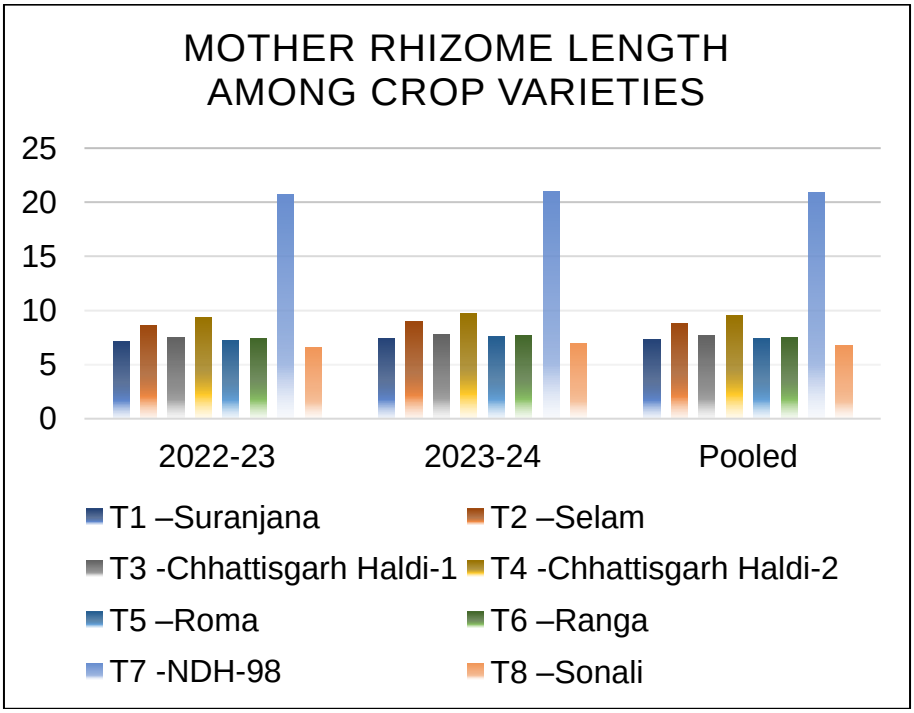

Fig. 2. Mother Rhizome length (cm) at harvesting stage of Turmeric as influenced by control farming and Eucalyptus tereticornis based agroforestry system among crop varieties

The results of the size of mother rhizome length (cm) for the different treatments during the 2022-23 and 2023-24 growing seasons, as well as the Pooled Mean. The production system had a significant effect on the size of mother rhizome length (cm), with the sole turmeric system (F1)

producing significantly maximum size of mother rhizome length (cm) than the eucalyptus + turmeric system (F2). The mean size of mother rhizome length (cm) was 9.6 cm for F1 (Sole turmeric) and 9.36 cm for F2 (Eucalyptus intercropping with turmeric).

Among the crop varieties also had a significant effect on the size of mother rhizome length (cm). NDH-98 (T7) produced the maximum size of mother rhizome length (cm), with a mean of 20.88 cm, followed by Chhattisgarh Haldi-2 (T7) with a mean of 9.54 cm whereas Sonali (T8) produced the minimum size of mother rhizome length (cm), with a mean of 6.75 cm.

The interaction effect of production system and crop varieties on size of mother rhizome length (cm) of crop recorded significant effect in both year and their mean data.

The observed differences in the size of mother rhizome length (cm) among the treatments can be attributed to the different production systems and crop varieties used in the experiment. The sole turmeric production system (F1) may have provided a more favorable environment for rhizome growth and development, resulting in maximum size of mother rhizome length (cm) compared to the Eucalyptus + turmeric (F2). The different crop varieties used may have also had varying size of mother rhizome length (cm), with some varieties producing maximum size of mother rhizome length (cm) due to genetic traits such as rhizome size and weight. The size of mother rhizome length (cm) per plant serves as an indicator of the suitability of the various production systems and crop varieties for supporting turmeric yield formation. Maximum size of mother rhizome length (cm) point to treatments that conditioned the plant growth environment in a way that promoted higher mother rhizome length. Other factors such as soil fertility, water availability, and pest and disease pressure may have also influenced the size of mother rhizome length (cm) of plant. Similar result was also found by Painkra et al*.* [12] and Sahu et al*.* [13].

The data regarding size of mother rhizome width (cm) of rhizome has been presented in Table 2 and Fig. 3 & Fig. 4.

The results of the size of mother rhizome width (cm) for the different treatments during the 2022-23 and 2023-24 growing seasons, as well as the Pooled Mean.

The production system had a significantly not affect the size of mother rhizome width (cm), with the sole turmeric production system (F2) producing minimum size of mother rhizome width (cm) than the Eucalyptus + turmeric system (F1). The mean size of mother rhizome width (cm) was 6.68 cm for F1 (sole turmeric) and 6.59 cm for F2 (Eucalyptus intercropped with turmeric).

Table 2. Mother Rhizome width plant^{-1} (cm)as affected by production system and turmeric varieties under Eucalyptus-based agroforestry system

Treatments	Size of mother rhizome width (cm)		
	2022-23	2023-24	Pooled
Factor A (Production system)			
F_1- Sole turmeric	6.51	6.84	6.68
F_2- Eucalyptus+turmeric	6.43	6.75	6.59
Sem±	0.071	0.073	0.071
CD @ 5%	NS	NS	NS
Factor B (Crop varieties)			
T_1 –Suranjana	6.28	6.61	6.44
T_2 –Selam	6.33	6.68	6.50
T_3 -Chhattisgarh Haldi-1	6.37	6.69	6.53
T_4 -Chhattisgarh Haldi-2	7.28	7.58	7.43
T_5 –Roma	6.32	6.63	6.48
T_6 –Ranga	6.33	6.64	6.49
T_7 -NDH-98	6.95	7.25	7.10
T_8 –Sonali	5.90	6.28	6.09
Sem±	0.143	0.147	0.143
CD @ 5%	0.291	0.299	0.291

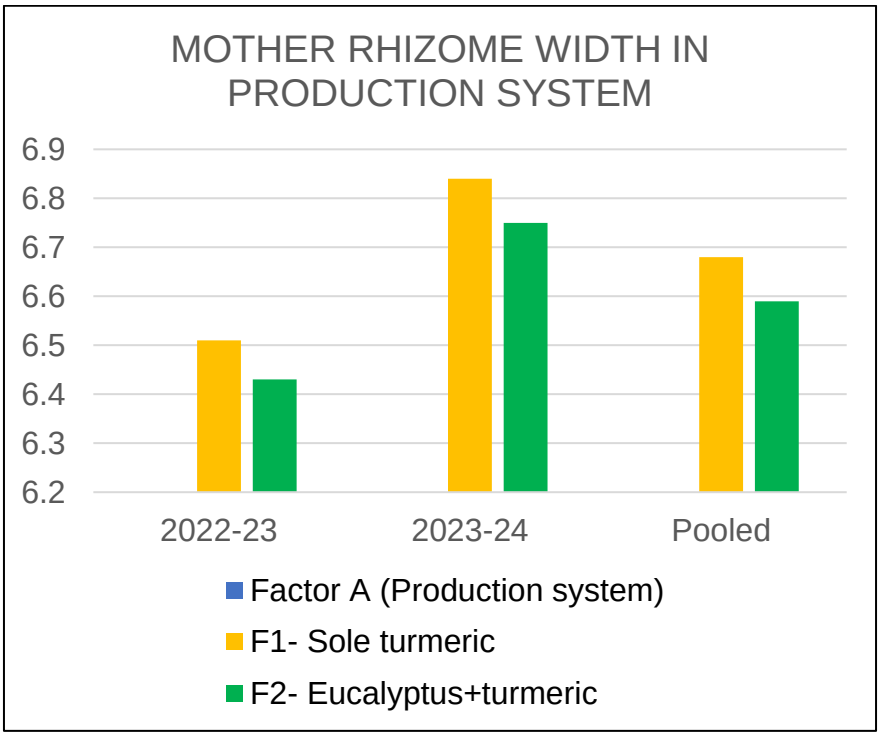

Fig. 3. Mother Rhizome width (cm) at harvesting stage of Turmeric as influenced by control farming and Eucalyptus tereticornis based agroforestry system in production system

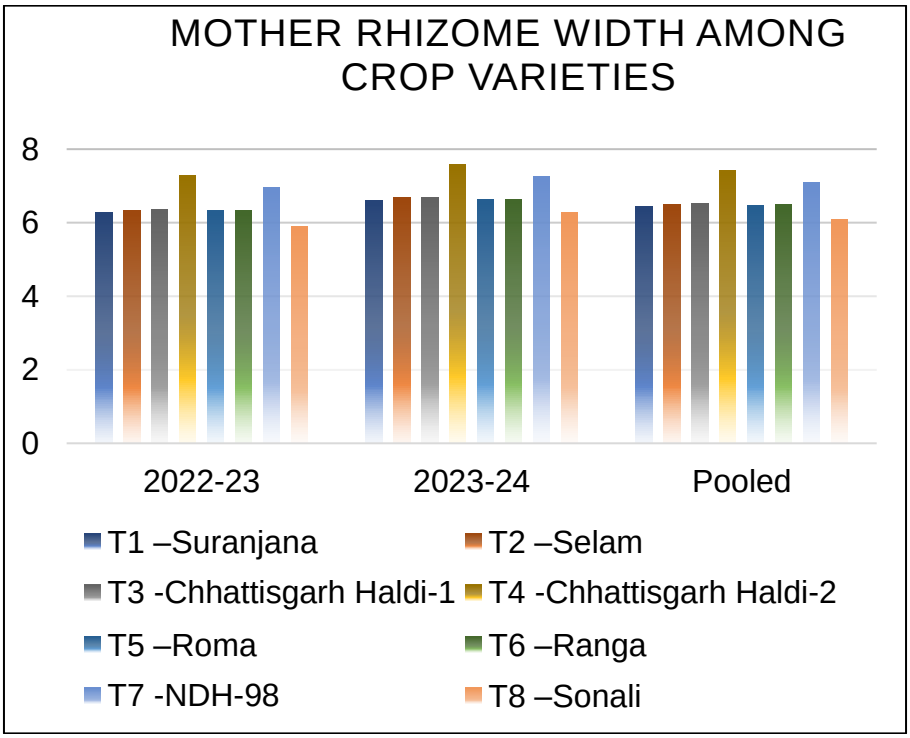

Fig. 4. Mother Rhizome width (cm) at harvesting stage of Turmeric as influenced by control farming and Eucalyptus tereticornis based agroforestry system among crop varieties

The crop variety also had a significant effect on the size of mother rhizome width (cm). Chhattisgarh Haldi-2 (T4) produced the maximum mother rhizome width (cm), with a

mean of 7.43 cm, followed by NDH-98 (T7) with a mean of 7.10 cm whereas Sonali (T8) produced the minimum size of mother rhizome width (cm), with a mean of 6.09 cm.

The interaction effect of production system and crop varieties on size of mother rhizome width (cm) of crop recorded significant effect in both year and their mean data.

The observed differences in the size of mother rhizome width (cm) among the treatments can be attributed to the different production systems and crop varieties used in the experiment. The sole turmeric production system (F1) may have provided a more favourable environment for rhizome growth and development, resulting in maximum size of mother rhizome width (cm) compared to the Eucalyptus + turmeric (F2). The different crop varieties used may have also had varying size of mother rhizome width (cm), with some varieties producing maximum size of mother rhizome width (cm) due to genetic traits such as rhizome size and weight. The size of mother rhizome width (cm) per plant serves as an indicator of the suitability of the various production systems and crop varieties for supporting turmeric yield formation. Maximum size of mother rhizome width (cm) point to treatments that conditioned the plant growth environment in a way that promoted higher mother rhizome width. Other factors such as soil fertility, water availability, and pest and disease pressure may have also influenced the size of mother rhizome width (cm) of plant. Similar result was also found by Painkra et al. [12] and Sahu et al. [13].

Mother rhizome length and width are higher in open conditions because to increased sunshine exposure, allowing for more efficient photosynthesis. In agroforestry environments, trees provide shade and compete for soil minerals and moisture, restricting turmeric's access to essential resources. Open fields also allow for improved air circulation, which reduces disease risk and makes weeding and irrigation easier to maintain. Open systems have higher yields than agroforestry setups since there is no competition and the growing conditions are higher.

From the present study it was found that NDH-98 turmeric variety length was found maximum as compare to other turmeric variety it was due to the genetic trait of the crop. Variation in Mother Rhizome length plant^{-1} among crop varieties found significantly difference under both the production system it may be due to the plant available nutrients, soil fertility and pest disease pressure/management. It also effect the total fresh and dry weight production. From the economical point of view agroforestry system will be better as compare to sole cropping system.

Kaur et al. [14] found that growing turmeric beneath six-year-old poplar trees spaced at a distance of 6 × 3.5 m resulted in a 55% drop in production. According to Gill et al. [15] as poplar ages, its fresh rhizome production decreases. Turmeric's fresh rhizome output when interplanted with poplar plantations was 40.6% lower than when it was grown as a single crop [16]. Dhillon et al. [17] observed physiological alterations in colocasia and turmeric, two rhizomatous crops. Changes in the microclimate beneath tree canopy impacted crop productivity. According to Sreekala and Jayachandran [18] crop growth rate and ginger production declined at high shade levels (60 and 80%). The overall decrease in intercrop yield caused by tree presence may be ascribed to variable canopy spread patterns that cause variations in light interception, intense competition amongst tree roots for nutrients and moisture, and shading impacts (Alam et al., 2014). Under regimes of partial shade, they found that turmeric had improved physiological efficiency from 33 to 50%. At each stage of crop growth, there are ideal temperature and moisture/relative humidity needs that affect the physiological and developmental processes. The variation in tree phenology had little impact on turmeric crop yield. According to Kumar et al. (2014), a 50% shade level is optimal for turmeric cultivation. The check varieties performed similarly, with varieties SD-3 and PH-24 showing significantly higher rhizome weights. In contrast, varieties PH-8 and PH-21 had significantly lower rhizome weights, while the remaining varieties were comparable to the check varieties [19,20].

The Sonali turmeric variety is not recommended for agroforestry-based intercropping because to low mother rhizome length and width which will be the responsible for the poor yield in the Central Plain zone of Chhattisgarh [21].

4. CONCLUSION

Both production systems were statistically analyzed, revealing significant differences among crop varieties. Notably, variations in mother rhizome length and width were observed in both

systems, which could influence the total fresh and dry weight of the crops at later stage. These rhizome characteristics may play a crucial role in nutrient storage and plant vigor, ultimately affecting the overall yield of the varietal crops.

Turmeric cultivation in Agroforestry Systems can thrive with compatible tree species, improved soil health, and effective water management. Key yield parameters include the size of mother rhizomes which include mother rhizome length and width, soil quality, nutrient management, proper irrigation, pest control, and timely harvesting. Larger mother rhizomes significantly enhance yield.

FUTURE SCOPE

The following relevant suggestions are recommended to highlight the future scope of the problem:

1. Similar research should be conducted in different tree species for AFS.
2. The Sonali turmeric variety is not recommended for agroforestry-based intercropping because to low tuber yield and quality in the Central Plain zone of Chhattisgarh.
3. Integrating eucalyptus with turmeric in Agroforestry Systems can increase in rhizome yield. Financial incentives arise from dual income streams, efficient resource use, and market diversification, encouraging farmers to adopt this intercropping system for increased revenue, capital and stability.
4. Financial incentives might encourage farmers to adopt the eucalyptus + turmeric agroforestry system, leading to increased revenue and better resource utilization.
5. Optimize plant shape and spacing for eucalyptus trees and turmeric crops to enhance productivity and profitability.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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