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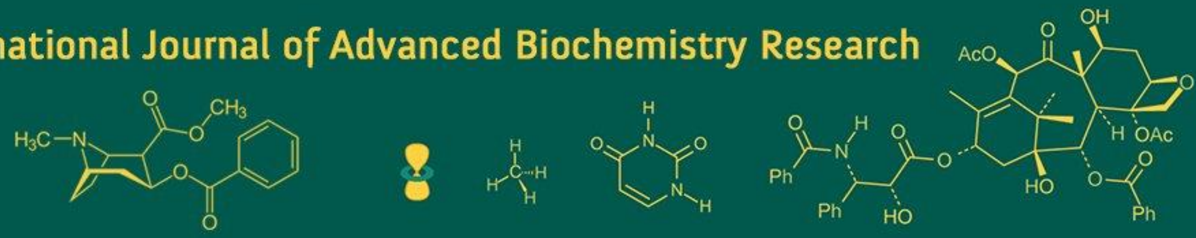

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Growth performance of *Curcuma caesia* on integrated nutrient management under eucalyptus based agroforestry model in Chhattisgarh plain

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Abstract
A field experiment on the effect of organic and inorganic nutrients for the growth of Kaali Haldi (*Curcuma caesia*) under Nilgiri (*Eucalyptus*) based agroforestry system was conducted at the Herbal Garden of Indira Gandhi Agricultural University, Raipur, Chhattisgarh during the year 2024 to 2025. The total number of treatments (T1 100% inorganic, T2 75% inorganic, T3 50% inorganic, T4 25% inorganic, T5 75% inorganic + 25% organic, T6 50% inorganic + 50% organic, T7 25% inorganic + 75% organic, T8 100% organic and T9 Control zero fertilizer) were nine, while Randomized Block Design (RBD) with three replications were used to evaluate the effect of various nutrient combinations under agroforestry model. Results indicated that growth and yield attributes significantly impacts on plant height (101.98 cm), number of leaves (15.01), and tillers (3.46) were recorded with T1 at 120 Days After Planting (DAP) while mother rhizome length (6.95 cm), mother rhizome width (6.03 cm) finger rhizome length (7.67 cm) finger rhizome width (2.37 cm) were observed in T6 whereas lowest was observed in T9.

Keywords: Agroforestry, *Eucalyptus,* Plant, Turmeric, nutrients, Organic

Introduction
The agroforestry model contributes to climate change mitigation through nutrient cycling, erosion control, and atmospheric carbon stabilization (Tripathy et al., 2021, Mankur et al., 2024) [16, 7]. Agroforestry is an ancient land management system where trees and shrubs are integrated with crops and livestock to enhance productivity and sustainability which provides multiple outputs like food, fuel, fodder, timber, fibre, and medicinal products while maintaining ecological balance and soil health. Agroforestry helps in economic, ecological, and social objectives, promoting biodiversity conservation, carbon sequestration, and improved land productivity (Viswanath et al., 2018; Singh et al., 2021) [17, 15].
Among agroforestry, *Eucalyptus tereticornis* (Family: *Myrtaceae*) holds major commercial importance due to its rapid growth, adaptability, and diverse applications in pulp, timber, oil, and medicine. *Eucalyptus tereticornis* and *E. grandis* are particularly valued for high-quality wood and environmental adaptability. Despite concerns regarding allelopathy and water use, eucalyptus supports reforestation, wood supply, soil fertility, and carbon sequestration (Kaur & Monga, 2021 and Mankur et al., 2024) [5, 8]. Its essential oil, rich in 1,8-cineole and γ-terpinene, has antimicrobial, antioxidant, and pesticidal properties, making it valuable for pharmaceuticals, cosmetics, and aromatherapy (Parul et al., 2021; Dixit et al., 2012) [11, 3].
Curcuma caesia Roxb. (Kaali Haldi), a perennial member of the *Zingiberaceae* family, is notable for its bluish-black rhizomes and high medicinal value. Indigenous to North-East and Central India, it is traditionally used to treat ailments such as asthma, cancer, epilepsy, wounds, menstrual disorders, and rheumatic pain (Pandey et al., 2003; Arulmozhi et al., 2006) [10, 2]. The rhizome contains over 30 bioactive compounds including camphor, ar-turmerone, and cineole, responsible for its therapeutic properties (Ratala et al., 2023) [12]. Due to overexploitation, *C. caesia* has been listed among India's critically significant and protected medicinal plants by the National Medicinal Plant Board (Kumar et al., 1998) [6].

Its extensive ethnomedicinal applications and pharmacological potential highlight the importance of integrating *Curcuma caesia* under sustainable agroforestry systems, such as eucalyptus-based models, to ensure both conservation and enhanced economic returns for farming communities.

Materials and Methods

The experiment was conducted at the Herbal Garden under Department of Silviculture & Agroforestry, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). Geographically, the site lies at 21°23′39.77″ N latitude and 81°.69"44.30″ E longitude, with an elevation of about 295 meters above mean sea level. The soil of the experimental field was clay to loam soil. Experimental period (June 2024 to March 2025), the mean monthly maximum temperature for the crop growing period was 38.96°C, while the minimum temperature dropped from 38.96°C to 27.68°C. The single rhizome used for planting of Kaali Haldi (*Curcuma caesia*) under Nilgiri (*Eucalyptus*) based agroforestry system. The field was prepared by three ploughings, manual cleaning, and incorporation of farmyard manure (10 t ha^{-1}). Fertilizers were applied at 150:125:150 kg ha^{-1} N:P: K using urea, SSP, and MOP. Turmeric (*Curcuma caesia*) rhizomes were planted manually on 18 June 2024 at 30 × 15 cm spacing. Irrigation was provided immediately after sowing and subsequently at 20 days intervals based on soil moisture. Monthly weeding and removal of *Eucalyptus* leaf litter were carried out.

Growth parameter viz., plant height, number of tillers, and number of leaves were recorded from five randomly selected plants per plot at 30, 60, 90, and 120 DAP & yield parameters viz., mother rhizome length & width (cm) and finger rhizome length & width (cm) were recorded from five randomly selected plants per replication. The crop was harvested on 7 March 2025 at physiological maturity & yield per hectare was estimated. Observation on growth & yield parameters were recorded from five plants in each replication & the mean were used for statistical analysis.

Results and Discussion

The important growth parameters like plant height, number of leaves and number of tillers influence the growth and productivity of the crop (Table 1). From the Table 1, it is revealed that the treatment T_1 (100% inorganic) has the significant influence on plant growth in comparison to T_2 (75% inorganic), T3 (50% inorganic), T4 (25% inorganic), T5 (75% inorganic + 25% organic), T6 (50% inorganic + 50% organic), T7 (25% inorganic + 75% organic), T8 (100% organic) and T9 (Control zero fertilizer). The maximum plant height of Kaali Haldi (33.80 cm, 61.52 cm, 80.36 cm & 101.98 cm) at 30 DAP, 60 DAP, 90 DAP & 120 DAP was recorded in T_1 (100% inorganic) followed by T_2 (75% inorganic). However, the minimum plant height of Kaali Haldi (21.94 cm, 49.49 cm, 70.35 cm, & 90.81 cm) at 30 DAP, 60 DAP, 90 DAP & 120 DAP was recorded under T_9 (Control zero fertilizer). Similar finding was also reported by Padmapriya and Chezhiyan (2007) that height of turmeric crop under the shade was higher than open system. Singh, H.P. (2016) [14] also reported that the height of turmeric crop under agroforestry was higher than open farming due to less population of weed and less competition for nutrient under agroforestry system as compared to open farming system between turmeric crop and weed.

The maximum number of leaves per plant (6.14, 9.31, 13.22 & 15.01) respectively at 30 DAP, 60 DAP, 90 DAP & 120 DAP was recorded in T1 (100% inorganic) followed by T_2 (75% inorganic) & minimum number of leaves per plant (3.65, 4.43, 6.76, 10.27) at 30 DAP, 60 DAP, 90 DAP & 120 DAP was recorded in T_9 (Control zero fertilizer). Consequently, the maximum number of tillers per plant (3.04, 3.46, 3.46, 3.46) at 30 DAP, 60 DAP, 90 DAP & 120 DAP was recorded in T_1 (100% inorganic) followed by T_2 (75% inorganic) & the minimum number of tillers per plant (1.00, 1.37, 1.37, 1.37) at 30 DAP, 60 DAP, 90 DAP & 120 DAP was recorded in T_9 (Control zero fertilizer). Similar result was also reported by Amin *et al*., (2010) [1] studied the positive impact of shade on numbers of tillers per plant, Kandiannan *et al.*, (1999) [4] who recorded insignificant variation in No. of tiller bed when ginger crop grown pure and with maize.

Table 1: Growth attributes of Kaali Haldi (*Curcuma caesia*) at 30, 60, 90 and 120 DAP under Eucalyptus based AFS

Treatments	Plant height (cm)				No. of Leaves (cm)				Number of Tillers per plant			
	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP	30 DAP	60 DAP	90 DAP	120 DAP
T1	33.80	61.52	80.36	101.98	6.14	9.31	13.22	15.01	3.04	3.46	3.46	3.46
T2	29.17	58.42	78.49	99.16	6.05	8.17	12.09	13.83	2.56	2.72	2.72	2.72
T3	27.51	57.95	77.34	97.78	5.23	7.29	11.16	13.04	2.56	2.71	2.71	2.71
T4	25.08	55.28	73.45	94.22	4.20	5.82	8.42	11.01	1.33	2.00	2.00	2.00
T5	28.51	58.54	78.09	98.31	5.75	8.55	12.49	14.02	2.87	2.92	2.92	2.92
T6	28.11	57.70	77.15	97.42	4.52	7.43	11.25	13.05	2.33	2.59	2.59	2.59
T7	28.28	56.69	78.28	96.76	5.08	7.15	10.03	12.98	2.33	2.59	2.59	2.59
T8	28.26	55.28	80.98	96.11	4.94	6.46	9.86	12.01	1.33	2.00	2.00	2.00
T9	21.94	49.49	70.35	90.81	3.65	4.43	6.76	10.27	1.00	1.37	1.37	1.37
CD@ (P=0.05)	5.17	6.01	6.08	5.44	1.62	1.48	1.63	1.69	0.96	1.00	1.00	1.00
CV%	10.73	6.11	4.55	3.24	18.33	11.91	8.92	7.64	11.03	10.41	10.41	10.41

Table 1: Yield growth attributes of Kaali Haldi (*Curcuma caesia*) at harvest under Eucalyptus based AFS

Treatments	Mother rhizome length (cm)	Mother rhizome width (cm)	Finger rhizome length (cm)	Finger rhizome width (cm)
T1: 100% inorganic	6.02	5.02	7.04	1.57
T2:75% inorganic	6.23	5.07	6.62	1.43
T3: 50% inorganic	5.37	4.98	5.86	1.35
T4: 25% inorganic	5.31	4.46	5.73	1.30
T5:75% inorganic + 25% FYM	6.52	5.89	6.98	2.03

T6: 50% inorganic + 50%FYM	6.95	6.03	7.67	2.37
T7: 25% inorganic + 75%FYM	5.22	5.24	7.04	1.57
T8: 100% FYM	6.37	5.84	6.62	1.43
T9: control zero fertilizer	4.70	3.73	5.86	1.35
CD @ (P=0.05)	1.13	1.23	1.15	0.58
CV%	13.93	13.93	10.16	19.99

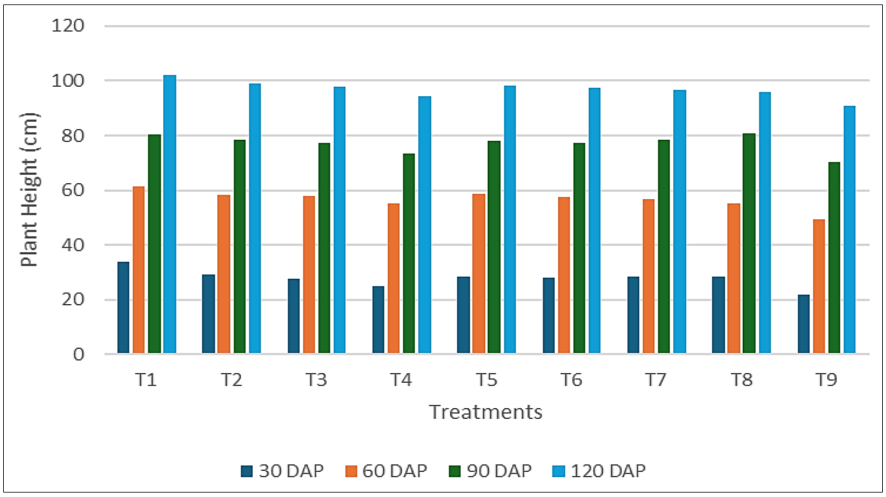

Fig 1: Effect of organic & inorganic nutrients on plant height (cm) of kaali Haldi (*Curcuma caesia)* under Nilgiri (*Eucalyptus)* based agroforestry system

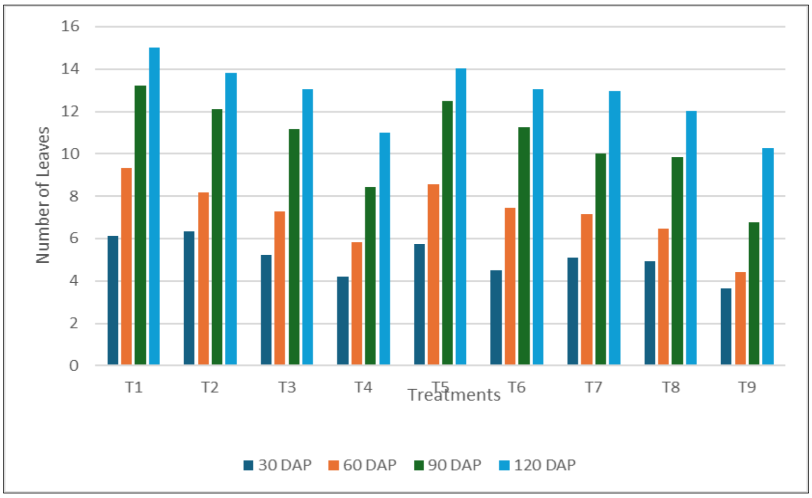

Fig 2: Effect of organic & inorganic nutrients on number of leaves of kaali Haldi (*Curcuma caesia)* under Nilgiri (*Eucalyptus)* based agroforestry system

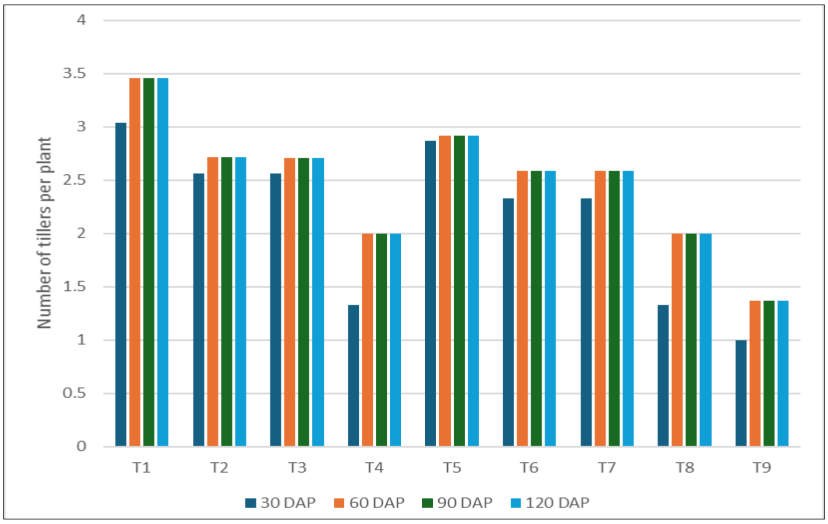

Fig 3: Effect of organic & inorganic nutrients on number of tillers per plant of kaali Haldi (*Curcuma caesia)* under Nilgiri (*Eucalyptus)* based agroforestry system

The data for yield of Kaali Haldi are presented in Table 2. The maximum length of mother rhizome was recorded under T_6: 50% inorganic + 50% FYM (6.95 cm) treatment whereas minimum in T_9: Control zero fertilizer (4.70 cm) treatment.

The maximum width of mother rhizome was recorded under T_6: 50% inorganic + 50% FYM (6.03 cm) treatment whereas minimum in T_9: Control zero fertilizer (3.73 cm) treatment. Finger rhizome length (cm) was highest under T_6: 50% inorganic + 50% FYM (7.67 cm) treatment whereas lowest under T_9: Control zero fertilizer (5.86 cm) treatment. The maximum width of finger rhizome was recorded under T_6: 50% inorganic + 50% FYM (2.37 cm) treatment whereas minimum in T_9: Control zero fertilizer (1.35 cm) treatment. Similar result was also found by Sil, A., and Hore, J.K. (2024) [13] reported the growth and yield of black turmeric, when subjected to different combinations of inorganic fertilizers, organic manures and biofertilizers.

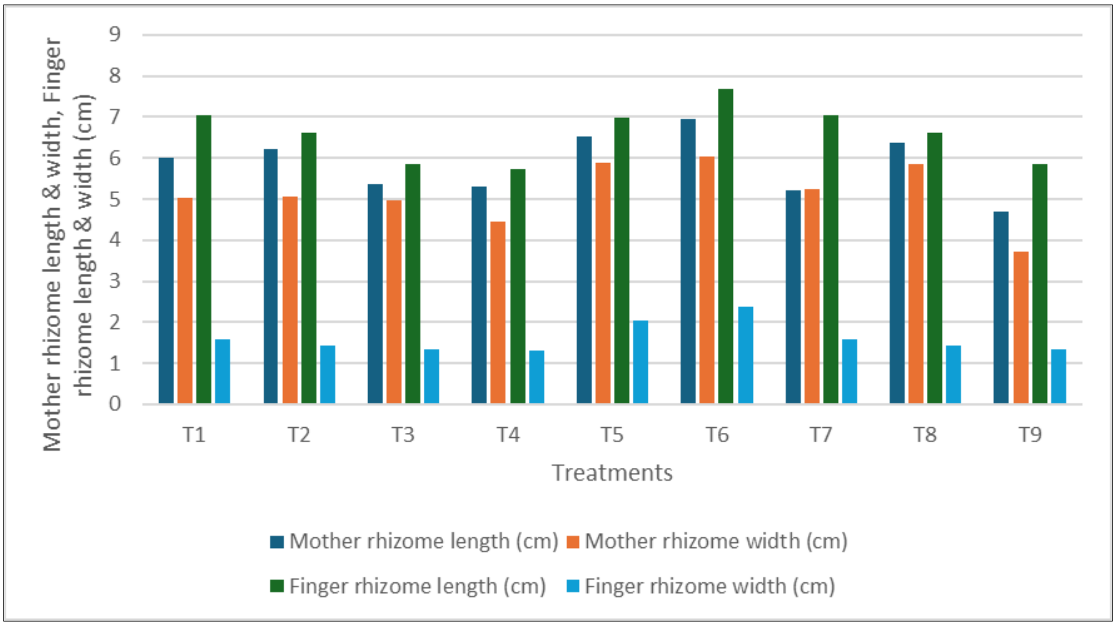

Fig 4: Effect of organic & inorganic nutrients on mother rhizome length & width, finger rhizome length & width (cm) of kaali Haldi (*Curcuma caesia)* under Nilgiri (*Eucalyptus)* based agroforestry system

Conclusion

The study revealed that integrated nutrient management significantly affects the growth and yield of *Curcuma caesia* cultivated under a Eucalyptus-based agroforestry system. Among the nutrient treatments, 100% inorganic fertilizer (T1) resulted in the greatest plant height, number of leaves, and tillers at all growth stages, demonstrating that readily available nutrients strongly promote vegetative growth. In contrast, the control treatment (T9) exhibited the lowest growth, highlighting the importance of external nutrient application for optimal crop performance in tree-based systems. Yield parameters, including mother rhizome length and width as well as finger rhizome length and width, were highest under 50% inorganic + 50% FYM (T6), indicating that a balanced combination of chemical fertilizers and organic manure more effectively enhances rhizome development than inorganic fertilizer alone. This underscores the beneficial role of organic inputs in improving soil structure, nutrient availability, and moisture retention under agroforestry conditions.

Overall, while T1 favors vegetative growth, the integrated nutrient management approach (T6) is superior for maximizing rhizome yield. Therefore, the application of 50% inorganic fertilizer combined with 50% FYM is recommended as an efficient and sustainable strategy for enhancing *Curcuma caesia* productivity in Eucalyptus-based agroforestry systems. This approach not only improves yield but also contributes to long-term soil health and sustainability in spice cultivation under agroforestry.

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Competing Interests

Authors have declared that no competing interests exist.

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