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Growth Performance of Different Lemongrass (*Cymbopogon flexuosus*) Varieties under an *Acacia mangium*-Based Agroforestry System in the Chhattisgarh Plains

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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

This study was conducted in the year 2023-2024 at the Herbal Garden of Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India, to evaluate the growth performance of *Acacia mangium* trees and different lemongrass (*Cymbopogon flexuosus*) varieties in an agroforestry system. Growth parameters of *Acacia mangium* trees were assessed, an average height of 19.65 meters, a diameter at breast height (DBH) of 35.85 cm, a crown spread of 8.13 meters, and a tree volume of 2.02 m^3. The growth performance of the lemongrass varieties showed significant variability among varieties. T4-Neema recorded the maximum number of tillers (65.53), highest leaf width (2.60 cm), and maximum plant spread (75.52 cm), while T1 Krishna showed the highest plant height (157.20 cm) and leaf length (130.07 cm), while T2 CG-1 showed the maximum leaf area index (40.10). In all treatments, T8-kalam shows the lowest plant height (99.77 cm), number of tillers (31.50), leaf length (87.41 cm), plant spread (47.05 cm), and leaf area index (17.02). The results indicate that genetic selection plays a critical role in optimizing growth performance under agroforestry conditions. Varieties T4-Neema and T7-Praman showed superior growth attributes, while T8-Kalam showed the lowest.

Keywords: Agroforestry; Acacia mangium; lemongrass; growth performance; biomass accumulation; sustainable land management.

1. INTRODUCTION

Agroforestry systems are deliberately designed to maximize the positive interactions between tree and non-tree components, encompassing a wide range of practices (Dutta et al*.,* 2023). The fundamental idea behind the practice of agroforestry is that trees are integral parts of natural ecosystems, providing a range of benefits in the agricultural domain (Dutta et al*.,* 2023, Castle et al*.,* 2022, Murthy et al*.,* 2016).

Acacia mangium, native to Australia, Indonesia, and Papua New Guinea, is a fast-growing, low-elevation tree species commonly found on the margins of rainforests and in disturbed, well-drained acidic soils. Widely used in plantation forestry programs across Asia and the Pacific, it is valued for its ability to fix nitrogen, regenerate rapidly, and tolerate poor soils. This evergreen tree can reach heights of up to 30 meters (100 ft) with a trunk diameter exceeding 60 cm (24 in). It naturally occurs in transitional zones between mangrove stands and inland areas such as forests, rivers, grasslands, and regions disturbed by fire. *Acacia mangium* bark transitions from smooth and greenish in younger trees to rough and fissured in older ones, and its timber is heavy, hard, and strong, making it ideal for furniture and various wood products. As a nitrogen-fixer, it benefits neighboring plants in mixed cultures by enhancing soil fertility and providing shade. Though it can tolerate low-fertility soils, the tree prefers fertile, well-drained conditions, with its growth rate influenced by proximity to the equator. It is widely used for pulp, paper, wood products, and environmental restoration, and its sawdust serves as a high-quality substrate for shiitake mushroom cultivation, making it an invaluable species for both commercial forestry and sustainable land management practices.

In agroforestry systems, the integration of non-tree crops like lemongrass can further enhance productivity. Lemongrass (*Cymbopogon flexuosus*) is a multi-harvest perennial aromatic grass, belonging to the family Poaceae, and is cultivated for its essential oils, including citral (neral and geranial), which are widely used in the perfume and pharmaceutical industries (Meena et al*.*, 2016; Joshi et al*.*, 2016). The essential oil extracted from lemongrass has a characteristic lemon-like aroma, making it a popular ingredient in soaps, detergents, and other commercial products (Mehrotra et al*.*, 2022). Additionally, lemongrass offers medicinal benefits and is used in treatments for conditions like coughs, headaches, and vascular disorders (Shah et al*.* 2011; Saini et al*.* 2018). The global demand for lemongrass oil continues to rise, with projections expecting the market to reach $231.4 million by 2025, driven by an 8% compound annual growth rate (Sharma, 2019).

2. MATERIALS AND METHODS

The present investigation was conducted at the Herbal Garden of Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India, in an *Acacia mangium* and lemongrass-based agroforestry system. The study site is located at 21°23'39.77"N latitude and 81°69'44.30"E longitude, at an altitude of 295 meters above sea

level. This region experiences a sub-humid climate with an average annual rainfall ranging from 1200 to 1400 mm and temperature extremes of 10°C in December and 42.5°C in May. The soil was classified as clay loam, with sand (20.87%), silt (27.14%), and clay (51.99%) content. It had an acidic pH of 6.68 and an electrical conductivity of 0.28 dS/m, indicating neutral salinity. The organic carbon content was 0.78%, categorized as high, while the available nitrogen (403 kg/ha), phosphorus (19 kg/ha), and potassium (232 kg/ha) were all in the medium range.

The research was conducted in the years 2023-2024 at the 24-year-old *Acacia mangium* plantation. The plantation is spaced at 5 × 3 meters. The growth parameters evaluated included tree height, diameter at breast height (DBH), crown spread, and tree volume, assessed over the one-year study period. Tree height was measured using a Ravi multimeter, while DBH was calculated at a height of 1.37 meters above ground using a tape measure. Crown spread was determined by averaging the north-south and east-west projections of each tree. Tree volume was estimated using the arithmetic mean of the sample trees. Huber's formula (V = Sm × L), where Sm is the cross-sectional area and L is the tree height, was applied to calculate stem volume.

The experiment, which used a Randomized Block Design (RBD), assessed the growth performance of eight lemongrass varieties, each representing a different treatment: T1 - Krishna, T2 - CG1, T3 - Pragati, T4 - Neema, T5 - Kaveri, T6 - CKP-25, T7 - Praman, and T8 - Kalam. To ensure statistical accuracy, all treatments are replicated three times in the same field conditions during the research work. The plot size for each treatment was 2.5 m × 2 m, with plant spacing set at 40 cm x 30 cm.

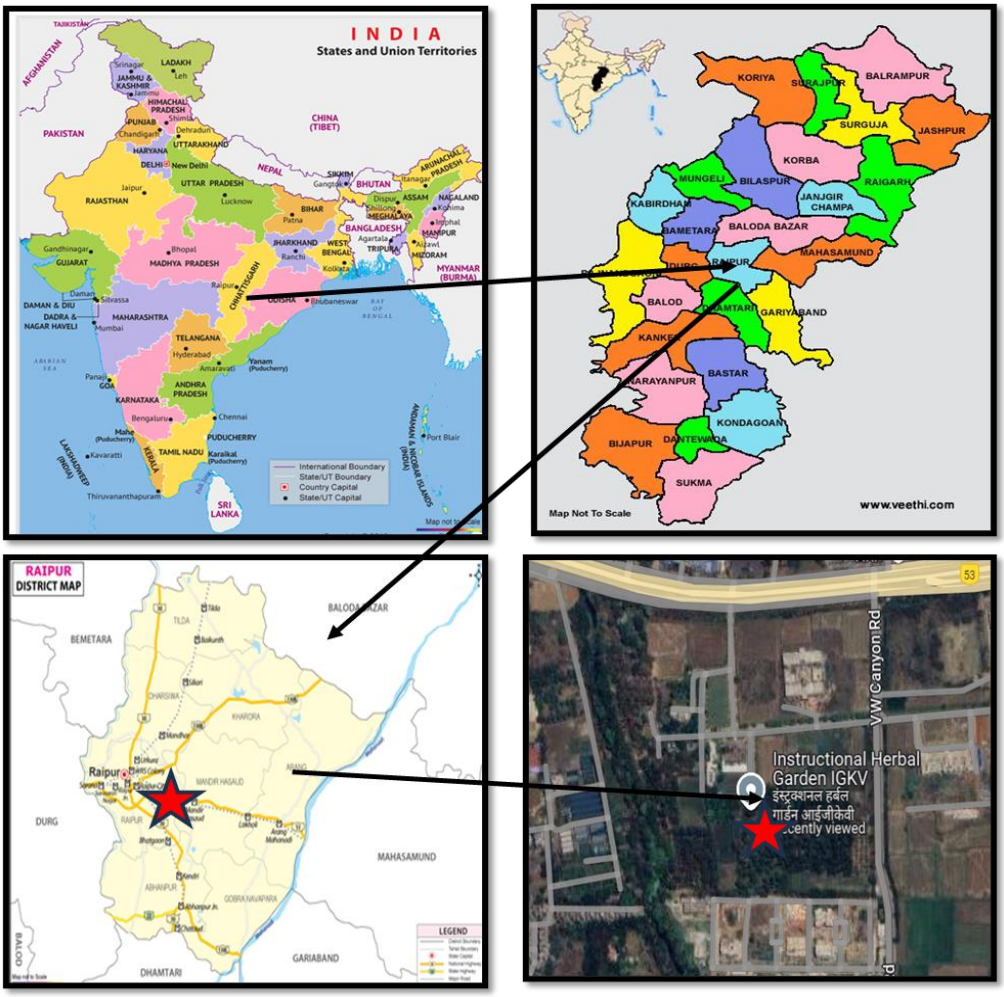


Fig. 1. Location of experimental site

Plate 1. A view of field area during experimental period

The growth parameters measured in the experiment included plant height, number of tillers per plant, leaf length, leaf width, plant spread (E-W and N-S), and leaf area index. Plant height was recorded by measuring five randomly selected plants from the soil surface to the upper tip of the leaf, and the average height was calculated. The number of tillers per plant was counted for the same five plants, and their average was noted. Leaf length was measured from the leaf blade joint to the tip along the midrib, while leaf width was measured at the widest point of the leaf lamina for three well-developed leaves per plant, with averages calculated for both. Plant spread was recorded in the East-West and North-South directions for five selected plants, and the average was calculated. For leaf area index, leaf length and width were used to compute the leaf area by multiplying the two with a conversion factor (1.9) and then multiplying the result by the total number of leaves per clump. The leaf area index was calculated by dividing the total leaf area by the plant spacing.

3. RESULTS AND DISCUSSION

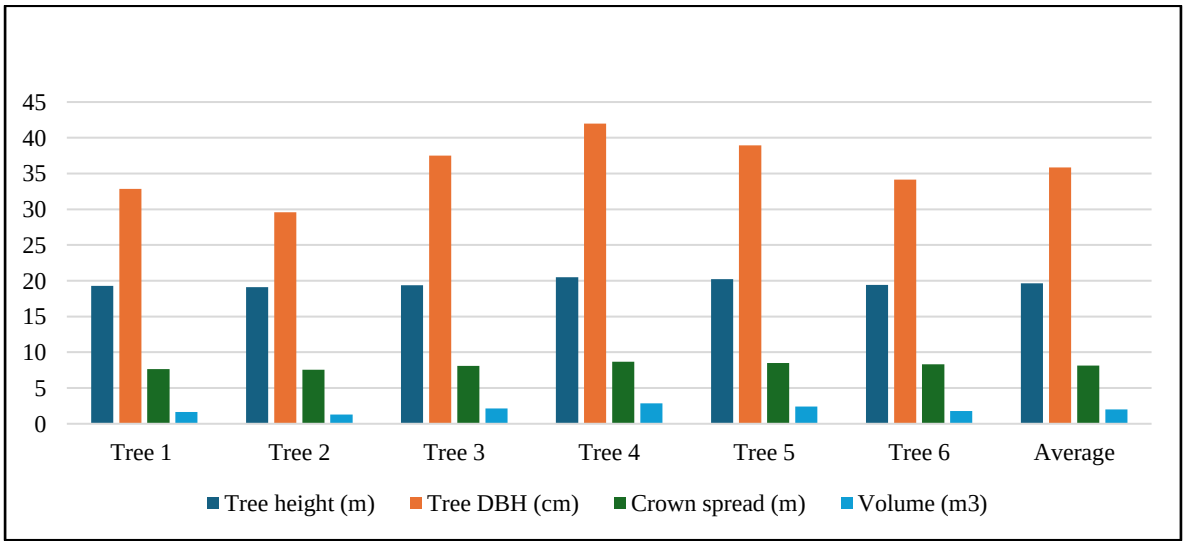
The tree growth parameters, including tree height, diameter at breast height (DBH), crown spread, and volume, were recorded for six trees. The average tree height was 19.65 meters, with individual tree heights ranging from 19.12 to 20.48 meters. The average DBH was 35.85 cm, with the smallest DBH recorded at 29.58 cm (Tree 2) and the largest at 41.99 cm (Tree 4). The average crown spread was 8.13 meters, with values ranging from 7.55 to 8.67 meters. The average tree volume was 2.02 m^3, with the lowest recorded volume at 1.31 m^3 (Tree 2) and the highest at 2.84 m^3 (Tree 4).

Nayak et al. (2014) noted that *Acacia mangium* intercropped with pineapple resulted in the highest volume increment, showing the benefits of integrating fast-growing tree species with suitable crops. Sereke et al. (2015) demonstrated that tree-based intercropping systems improve overall productivity by optimizing resource use (water, nutrients, and sunlight). Singh and Oraon (2017) found that *Leucaena leucocephala* in agri-silviculture systems produced the highest wood volume, indicating that tree species with high biomass potential thrive in agroforestry setups.

The growth performance of various lemongrass varieties under a Mangium-based agroforestry system revealed notable differences in several key parameters. The maximum plat height was observed in T1-Krishna (157.20 cm), followed by T7-Praman (156.06 cm), while T8-Kalam had the minimum plant height (99.77 cm). Number of tillers was found to be maximum in T4-Neema (65.53), with T8-Kalam having recorded the minimum number of tillers (31.50). In leaf length, T1-Krishna exhibited the longest leaves (130.07 cm), and T8-Kalam had the shortest (87.41 cm). Leaf width was widest in T4-Neema (2.60 cm), while T6-CKP-25 had the narrowest leaves (1.18 cm). The plant spread was observed to be maximum in T4-Neema (75.52 cm), whereas the smallest was in T8-Kalam (47.05 cm). In the leaf area index (LAI), T2-CG-1 achieved the highest leaf area index (40.10), indicating greater leaf surface area, while T8-Kalam had the lowest LAI (17.02). Overall, T4-Neema and T7-Praman showed superior growth in several parameters, while T8-Kalam consistently showed the lowest performance in this agroforestry system.

Table 1. Growth parameters of Acacia mangium tree

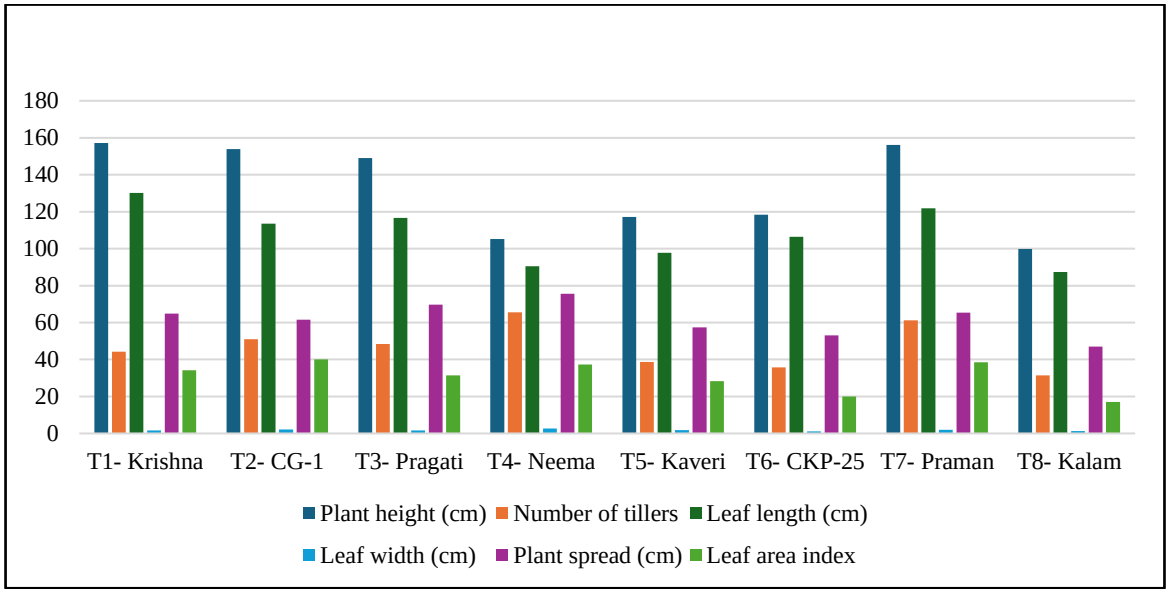
Trees	Tree height (m)	Tree DBH (cm)	Crown spread (m)	Volume (m^3)
Tree 1	19.30	32.87	7.64	1.64
Tree 2	19.12	29.58	7.55	1.31
Tree 3	19.37	37.51	8.10	2.14
Tree 4	20.48	41.99	8.67	2.84
Tree 5	20.21	38.95	8.51	2.41
Tree 6	19.43	34.17	8.31	1.78
Average	19.65	35.85	8.13	2.02



Graph 1. Growth parameters of acacia mangium tree

Table 2. Average growth performance of different lemongrass varieties under mangium-based agroforestry system

Treatments	Plant height (cm)	Number of tillers	Leaf length (cm)	Leaf width (cm)	Plant spread (cm)	Leaf area index
T1- Krishna	157.20	44.21	130.07	1.66	64.84	34.20
T2- CG-1	153.88	50.92	113.46	2.23	61.51	40.10
T3- Pragati	149.02	48.45	116.60	1.70	69.70	31.43
T4- Neema	105.12	65.53	90.55	2.60	75.52	37.38
T5- Kaveri	117.12	38.72	97.83	1.82	57.42	28.33
T6- CKP-25	118.40	35.73	106.47	1.18	53.13	20.06
T7- Praman	156.06	61.25	121.81	1.99	65.34	38.47
T8- Kalam	99.77	31.50	87.41	1.23	47.05	17.02
CD@ 5%	4.73	5.98	5.00	0.043	3.374	1.598
SE(m)	1.56	1.97	1.65	0.01	1.11	0.53



Graph 2. Growth performance of different lemongrass varieties under acacia mangium-based agroforestry system

The varietal differences observed in the growth performance of lemongrass varieties under a Mangium-based agroforestry system underscore the significant influence of genetic factors on plant development. similarly reported by Gupta et al. (2013) and Pandey et al. (2019) notable differences in plant height among lemongrass varieties, highlighting the role of genetic traits in determining growth potential across diverse agroforestry conditions. Selecting varieties suited to specific environments is, therefore, crucial for optimizing growth and yield. However, contrasting findings from Ali et al. (2011) and Nagarajaiah et al. (2012) suggest that agroforestry systems may sometimes reduce plant height in certain medicinal plants, likely due to factors such as shading and resource competition. This emphasizes the complexity of tree-crop interactions, where the microclimate created by trees can either benefit or hinder plant growth based on the variety and environmental context. Syakir & Gusmaini (2015), who noted that genetic factors significantly influence tiller production, impacting biomass and oil yield in lemongrass. Additionally, leaf width, a critical determinant of photosynthesis and herb yield, was greater in varieties like T4 and T2, contributing to a higher leaf area index. Chairudin et al. (2015) also highlighted that varieties adapted to low-light environments can increase leaf area and chlorophyll content to optimize light absorption, a key trait for success in shaded agroforestry systems.

4. CONCLUSION

In conclusion, the experiment conducted to assess the growth performance of eight lemongrass varieties (Krishna, CG1, Pragati, Neema, Kaveri, CKP-25, Praman, and Kalam) under an *Acacia mangium*-based agroforestry system in the Chhattisgarh plains has provided valuable insights into varietal differences and their adaptation to the agroforestry environment. The Randomized Block Design (RBD) allowed for a robust comparison between varieties, and the findings indicate that factors such as genotype variation, plant spacing, and environmental conditions significantly influence growth performance.

The study's results can help identify the most suitable varieties for agroforestry systems, maximizing both lemongrass yield and essential oil production while ensuring sustainable land use. Future research could further explore long-term growth trends, oil content stability, oil composition and how these varieties perform across different environmental conditions within similar agroforestry systems.

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 writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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