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


## 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 eight lemongrass (*Cymbopogon flexuosus*) varieties in an agroforestry system. Growth parameters of *Acacia mangium*trees were assessed, yielding 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 volume of 2.02 $m^3$. It has been observed that Tree 4 exhibited the largest DBH (41.99 cm) and volume (2.84 $m^3$), while Tree 2 had the lowest DBH (29.58 cm) and volume (1.31 $m^3$). The growth performance of the lemongrass varieties showed significant variability among treatments. 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) demonstrated superior growth attributes, while T8 (Kalam) consistently ranked lowest, highlighting the importance of selecting suitable cultivars for agroforestry systems.



**Keywords:**
Agroforestry, *Acacia mangium*, Lemongrass, Growth performance, Biomass accumulation, Sustainable land management.


## 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 (*Cymbopogon flexuosus*) can further enhance productivity. Lemongrass 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). As both a cash crop and a resource for sustainable farming, lemongrass complements agroforestry systems, offering economic and ecological advantages. 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).

**Material and Methods**

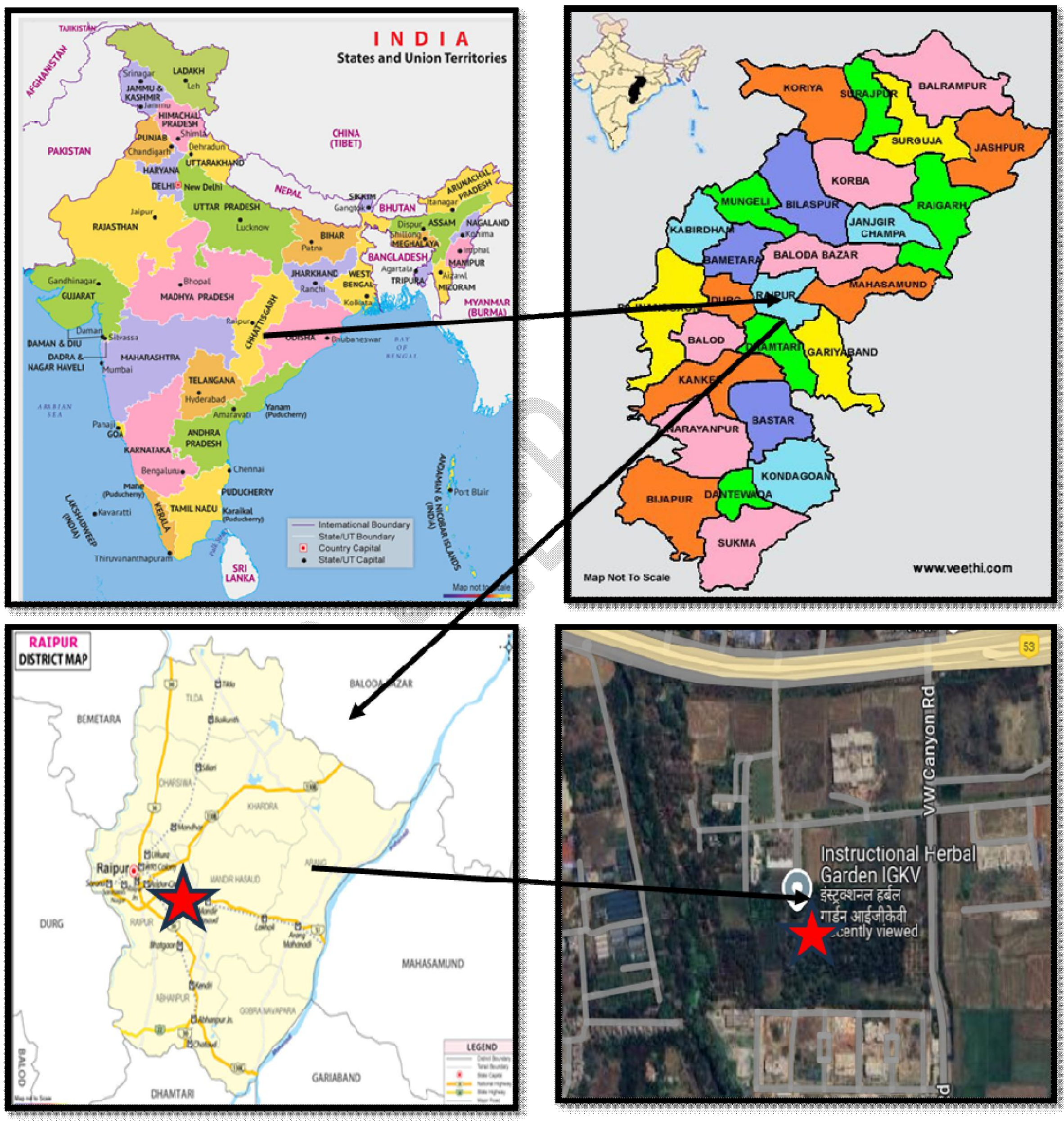
The present investigation was conducted at the Herbal Garden of Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India, in an *Acacia mangium*and lemongrass-based agroforestry system. The study site is located at 21°23'39.77"N latitude and 81°69'44.30"E longitude, at an altitude of 295 meters 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 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, arranged in a Randomized Block Design (RBD), evaluated the growth performance of eight lemongrass varieties, with each variety representing a different treatment: T1 - Krishna, T2 - CG1, T3 - Pragati, T4 - Neema, T5 - Kaveri, T6 - CKP-25, T7 - Praman, and T8 - Kalam. The plot size for each treatment was 2.5 m x 2 m, with plant spacing set at 40 cm x 30 cm. To ensure statistical accuracy, each treatment was replicated three times.

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.

Fig 1- location of experimental site

**Plate 1: A view of field area during experimental period**

## Result 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).

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** |

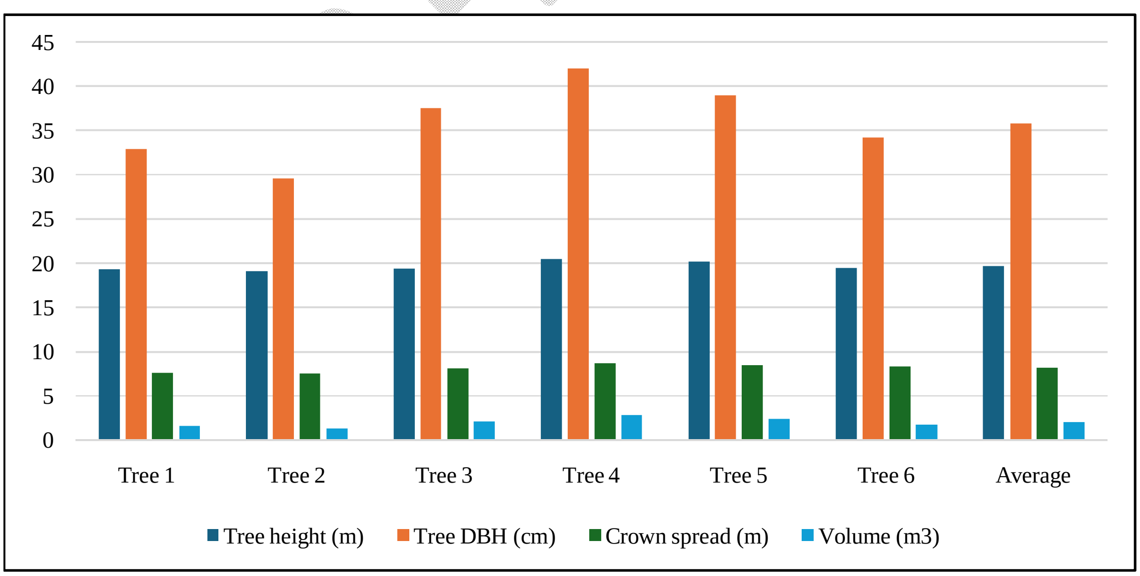



Fig 2- Growth parameters of Acacia mangium tree

Patil *et al.* (2012) demonstrated that wider spacing (5m x 4m) in Melia azedarach agroforestry systems significantly enhanced DBH compared to narrower spacing, emphasizing the importance of spacing in promoting radial growth. Singh and Hymavathi (2012) also found increased height and collar diameter in Dalbergia sissoo intercropped with maize, particularly at larger spacings (6m x 6m). Nayak *et al.* (2014) noted that *Acacia mangium*intercropped with pineapple resulted in the highest volume increment, showcasing the benefits of integrating fast-growing tree species with suitable crops. Rajalingam *et al.* (2015) reported the highest tree height and DBH in Ailanthus excelsa intercropped with palak, further underscoring the roleof appropriatecrop-tree combinations in enhancing growth. Sereke*et al.* (2015) demonstrated that tree-based intercropping systems improve overall productivity by optimizing resource use (water, nutrients, and sunlight). Das *et al.* (2017) confirmed that agri-horticultural systems, such as mango intercropped with paddy and filler plants, promote enhanced growth. 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.Finally, Flumignan*et al.* (2023) emphasized the role of rainfall in enhancing eucalyptus diameter growth, particularly in agroforestry systems, while temperature had minimal effect. Collectively, these studies underline that species selection, spacing, and complementary intercrops are crucial for optimizing tree growth in agroforestry systems.

The growth performance of various lemongrass varieties under a Mangium-based agroforestry system revealed notable differences in several key parameters. T1 (Krishna) recorded the tallest plant height at 157.20 cm, followed closely by T7 (Praman) at 156.06 cm, while T8 (Kalam) had the shortest plants at 99.77 cm. T4 (Neema) produced the highest number of tillers (65.53), significantly outperforming the other varieties, with T8 (Kalam) recording the fewest tillers (31.50). In terms of leaf length, T1 (Krishna) exhibited the longest leaves at 130.07 cm, and T8 (Kalam) had the shortest at 87.41 cm. Leaf width was widest in T4 (Neema) at 2.60 cm, while T6 (CKP-25) had the narrowest leaves at 1.18 cm. The largest plant spread was observed in T4 (Neema) at 75.52 cm, whereas the smallest was in T8 (Kalam) at 47.05 cm. T2 (CG-1) achieved the highest leaf area index (LAI) at 40.10, indicating greater leaf surface area, while T8 (Kalam) had the lowest LAI at 17.02. Overall, T4 (Neema) and T7 (Praman) demonstrated superior growth in several parameters, while T8 (Kalam) consistently ranked the lowest, indicating poorer performance in this 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. Studies by Gupta et al. (2013) and Pandey et al. (2019) similarly reported notable differences in plant height among lemongrass varieties, highlighting the role of genetic traits in determining growth potential across diverse

| 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 |

agroforestry conditions. Selecting varieties suited to specific environments is, therefore, crucial for optimizing growth

Table 2-Average Growth Performance of Different Lemongrass Varieties under Mangium-Based Agroforestry System

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.

| | | | | | | |
|---|---|---|---|---|---|---|
| **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 |

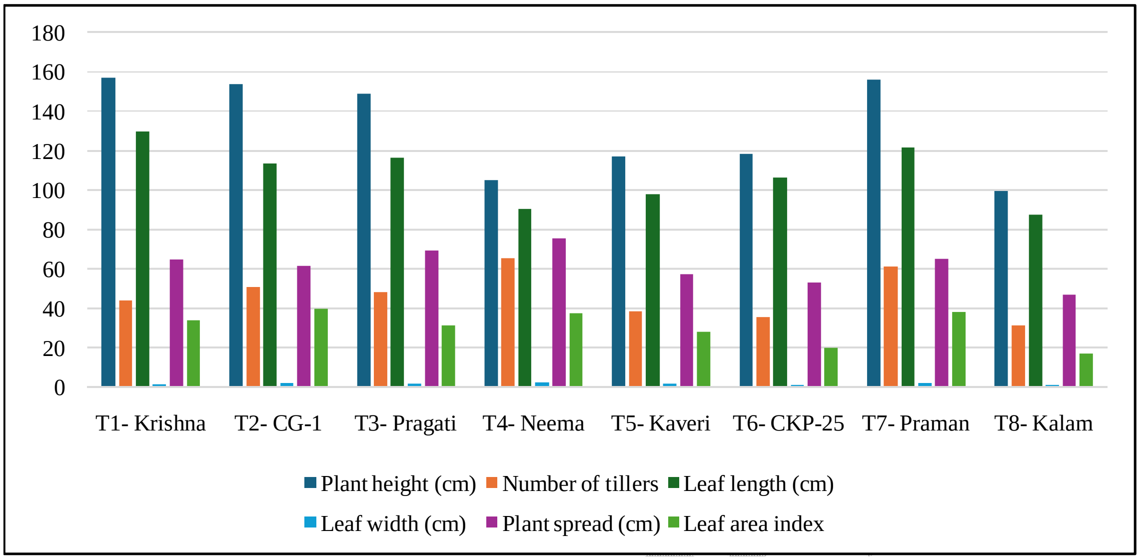



Fig 3-Growth Performance of Different Lemongrass Varieties under Acacia mangium-Based Agroforestry System

The study also found that T4 (Neema) outperformed other varieties in key growth parameters such as tiller production, leaf area, and plant spread, suggesting that genetic adaptation plays a role in enhancing performance under agroforestry conditions. The higher tiller count in T4 supports the findings of 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. This finding aligns with the research of Singh et al. (2004) and Nair et al. (1984), who linked leaf width to essential oil yield. Furthermore, the superior plant spread observed in T4 aligns with studies by Patil et al. (2012) and Vidya et al. (2013), which emphasized the importance of genetic diversity in promoting growth under agroforestry conditions. 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.

## 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, and how these varieties perform across different environmental conditions within similar agroforestry systems.



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