Correlation study among growth, wood density, and seed traits in *Gmelina arborea*: a comprehensive study

Abstract

This study investigates the complex relationships among morphological traits, wood properties, The research, conducted across eight natural and planted populations in Madhya Pradeshaims to provide a holistic understanding of how these traits interrelate, with implications for forest management, conservation, and breeding programs. The results reveal significant positive correlations among several morphological and wood properties, suggesting that traits such as crown width and tree height are interdependent and can influence wood density -a critical factor for timber quality. For instance, crown height shows a notable correlation with total tree height and crown width, implying that trees with larger crowns tend to have increased overall height and density. Similarly, wood density is positively correlated with GBH and branch thickness, indicating that trees with thicker stems and branches tend to produce denser, stronger wood. Seed characteristics were also significantly correlated; for example, larger fruits were linked to heavier seeds, and heavier seeds had higher viability and potential for seedling vigor, which are vital for regeneration and commercial plantations. Additionally, some inverse correlations were observed, such as between crown height and 100-seed weight, suggesting potential trade-offs where trees with taller crowns may yield lighter seeds. This integrated analysis underscores the value of selecting key morphological and wood traits as indicators for superior timber quality and enhanced growth performance, with practical relevance for breeding programs. The study's findings support the use of morphometric and seed traits as selection criteria in *Gmelina arborea* cultivation, thereby promoting sustainable forestry practices and improving productivity in plantation settings.

Introduction

Understanding the complex relationships among morphological, physical, and seed traits of tree species is essential for advancing forest management, conservation, and breeding programs. In the context of tropical forestry, species such as *Gmelina arborea* have garnered significant attention due to their rapid growth, adaptability, and valuable timber properties (Kumar, 2020; Singh & Lal, 2021). Often referred to as "white teak," *Gmelina arborea* is

recognized for its lightweight, durable wood, which is suitable for a variety of applications, including furniture, construction, and pulp production (Moya *et al*., 2004). The correlation analysis of morphological traits, wood properties, and seed characteristics in this species can reveal critical insights into growth performance and wood quality, which are valuable for both natural and plantation forestry.

Morphological traits such as tree height, diameter at breast height (DBH), and canopy spread provide foundational information about growth patterns and biomass accumulation, which are key indicators of ecological fitness and economic viability (Adekunle, 2022). Physical properties of wood, including density, moisture content, and fiber length, influence wood strength, processing efficiency, and end-product quality, directly affecting the economic potential of the species (Zobel &Buijtenen, 2019). Seed traits, including seed weight, size, and viability, are central to understanding the reproductive biology of *Gmelina arborea* and play a crucial role in seedling establishment, survival, and overall forest regeneration (Schmidt, 2018; Garwood & Hartshorn, 2020).

Although several studies have investigated the individual attributes of *Gmelina arborea*, there is limited research exploring the interrelationship among morphological, wood, and seed traits in an integrated framework. Such an approach may reveal underlying trade-offs or synergies among these characteristics, enabling the development of predictive models for growth and wood quality improvement (Sharma *et al*., 2021; Nanda *et al*., 2022). Given the ecological and economic significance of *Gmelina arborea*, this study aims to analyze the correlations among its morphological traits, wood physical properties, and seed characteristics, thereby contributing to a more holistic understanding of the species. This research will not only fill gaps in the existing knowledge but also provide actionable insights for forest management, genetic selection, and breeding programs aimed at enhancing the productivity and sustainability of *Gmelina arborea* plantations.

Materials and methodology

Site Selection and Tree Sampling

Based on an extensive review of the forest flora and vegetation composition of Madhya Pradesh, survey locations were selected, encompassing three natural populations (Mandla, Betul, and Jabalpur) and five planted populations (Barha, Saraswahi, Sonaghati, Badhaura, and Neemkheda).Field reconnaissance was conducted from 2019 to 2021 to identify natural and planted *Gmelina arborea* populations across Madhya Pradesh.A total of 27 trees per

population were selected based on girth at breast height (GBH), which ranged from 50 cm to 125 cm. Trees of similar age were chosen to minimize age-related variation.For natural populations, a minimum spacing of 100 meters between trees was maintained, while for planted populations, 20 meters was maintained to ensure representative sampling.

Measurement of morphometric traits

Quantitative growth traits were recorded for each marked tree to assess morphological variation.Total Tree Height was Measured using Ravi's altimeter (Chaturvedi & Khanna, 1984).Clear Bole Height was Measured from the base to the start of major branching using Ravi's altimeter (Chaturvedi & Khanna, 1984).Girth at Breast Height (GBH) was Measured at 1.37 m height using a measuring tape (Chaturvedi & Khanna, 1984).Crown Diameter was Measured by taking the maximum spread of the crown in two directions (East-West and North-South) using a measuring tape, then averaging the measurements to obtain crown diameter (Singh, 2016). Crown Height was recorded as the vertical distance from the top of the crown to halfway between the lowest green branches and the lowest green branch on the bole using a Spiegel Relaskop (Chaturvedi & Khanna, 1984).

Measurement of Fruit and Seed Trait Collection

Fruit Collection:

During the last week of May to the second week of June, approximately 100-150 fruits per tree were collected. Fruits were depulped manually, and seeds were extracted. Fruit length,fruit width, seed length and width: for each tree, the length (longest axis) and width (shortest axis) of 10 fruits and seeds were measured using a Vernier caliper. Measurements were averaged and recorded in millimetres (Mehta, 2019).100-Seed Weight: The weight of 100 seeds from each tree was measured using an electronic balance, with readings recorded to two decimal places (ISTA, 1996).

Measurement of physical properties of wood

Wood Core Sample Collection

Wood core samples were extracted from each tree at breast height using a Haglöf increment borer, ensuring that outer bark and moss were removed at the sampling point (Gerhart & McLauchlan, 2014).Bark Thickness: Measured using a Swedish Bark Gauge. Branch Thickness was Measured with a measuring tape.Heartwood/Sapwood Ratio: Calculated using

measurements taken from the wood core samples with a Vernier caliper. Moisture Content was recorded by taking Freshly extracted wood core samples were weighed, then oven-dried at 105℃ to a constant weight. Moisture content was calculated using the formula.

Data Analysis

All quantitative data collected for morphological, fruit, seed, and wood traits were subjected to correlation analysis to evaluate relationships and patterns among recorded traits.

Results

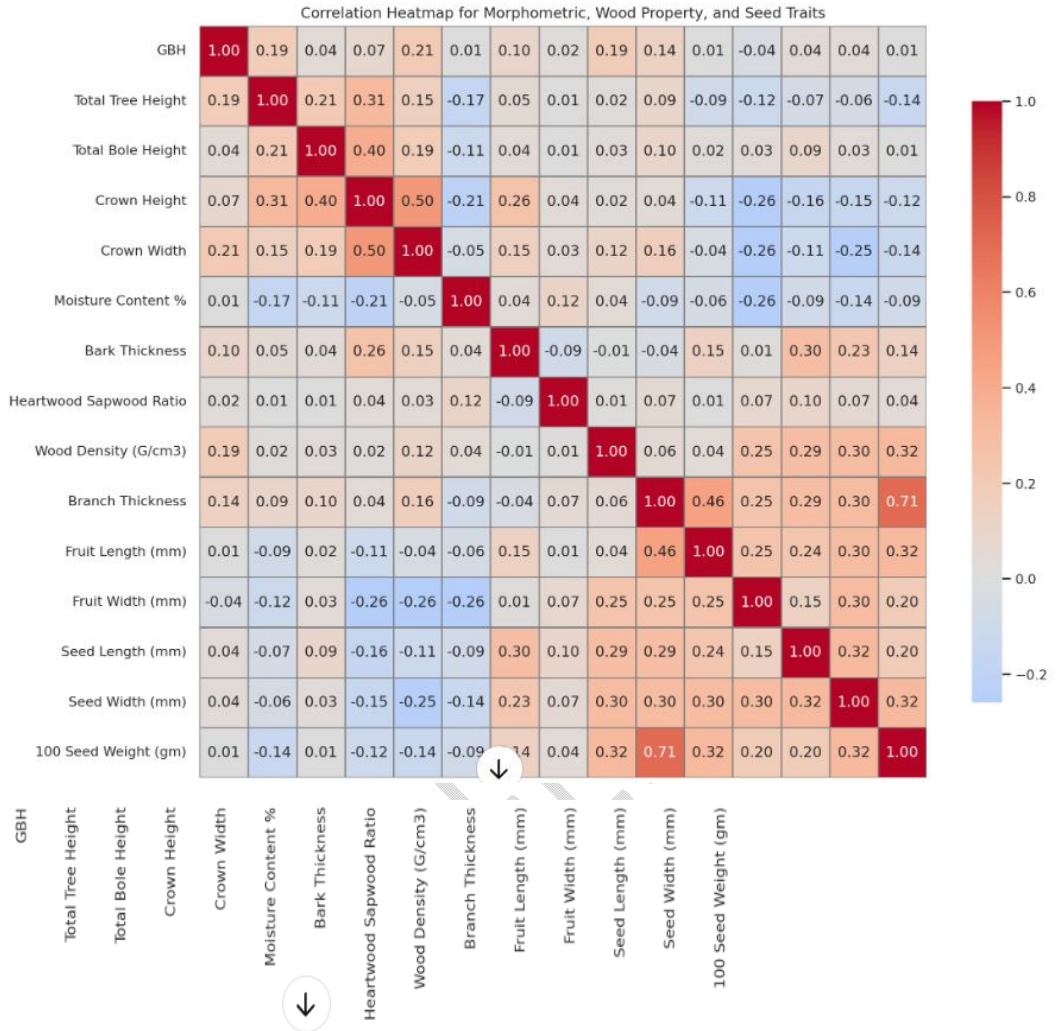
Morphometric Traits Correlation

Total Tree Height shows a significant positive correlation with GBH (0.187**) and Crown Height (0.312**), suggesting that trees with greater girth at breast height (GBH) and higher crown height also tends to have increased overall height. Crown Height shows strong positive correlations with Total Tree Height (0.312**), Total Bole Height (0.395**), and Crown Width (0.500**), indicating that trees with taller bole heights and wider crowns also have higher crown heights. Crown Width has a strong positive correlation with Crown Height (0.500**), implying that a wider crown is associated with an increased height of the crown, which is expected in trees with balanced, extensive crown structures.

Wood Property Traits Correlation

Wood Density shows a significant positive correlation with GBH (0.194**) and Branch Thickness (0.164*). This suggests that trees with greater girth and thicker branches tend to have denser wood. Branch Thickness is positively correlated with Total Tree Height (0.090NS) and Wood Density (0.164*), indicating that thicker branches may be associated with both taller trees and denser wood, although the relationship with tree height is not statistically significant. Moisture Content shows no significant correlations with most traits, indicating it is relatively independent of the measured morphometric and wood property traits.

Figure 1: Pearson correlation matrix for morphometric traits, fruits and seed traits of *Gmelina arborea*



correlated with each other (0.301**), which is expected as larger seeds in one dimension are generally larger in the other.100 Seed Weight has significant positive correlations with Fruit Length (0.320**), Seed Length (0.301**), and Seed Width (0.197*), suggesting that heavier seeds tend to come from larger fruits and have greater length and width.

Interrelations Between Morphometric, Wood, and Fruit/Seed Traits

GBH shows a mild positive correlation with Wood Density (0.194**), Branch Thickness (0.139*), and Seed Width (0.036NS), suggesting a complex relationship between tree girth, wood structure, and seed characteristics.Crown Width is positively correlated with Wood Density (0.108NS) and Branch Thickness (0.090NS), suggesting that trees with broader crowns may also tend to have denser wood and thicker branches.Total Bole Height shows a

mild, inverse correlation with 100 Seed Weight (-0.142*), indicating that trees with longer boles may have seeds with slightly lower weights.Crown Height shows a significant inverse relationship with 100 Seed Weight (-0.221**), suggesting that trees with higher crowns may tend to produce lighter seeds.

Discussion

The findings of the correlation analysis between morphometric traits, wood properties, fruit, and seed traits in *Gmelina arborea* highlight significant interactions that are consistent with previous studies on various tree species, supporting the practical relevance of these traits in breeding programs and conservation efforts.

Research shows that morphological characteristics such as height, diameter, and crown spread in *Gmelina arborea* have a direct impact on wood density, an essential factor for wood quality (Olajuyigbe&Adegeye, 2022). These traits influence the mechanical properties of the wood, which are vital for timber use, especially in construction and furniture making. High-density wood correlates positively with mechanical strength, a relationship found in other studies on tropical tree species (Azad *et al*., 2014). This finding aligns with the work of Rawat (2022) on *Grewia optiva*, where variations in seed morphology were linked to seedling vigor and, consequently, wood density in mature trees.

Seed traits also play a significant role in determining germination rates and seedling growth in *Gmelina arborea*. Seed size, weight, and viability are positively correlated with germination success and early seedling growth, which is crucial for reforestation and commercial plantation programs. Studies by Topwal*et al*. (2024) on *Cedrus deodara* have shown that larger seeds tend to produce more vigorous seedlings, a trait that translates into better growth performance in field conditions. Similar results were observed in *Tamarindus indica*, where larger, more robust seeds led to higher germination rates and stronger seedlings, suggesting that seed morphology can be an indicator of plant vigor (Azad *et al*., 2014).

Moreover, geographical provenance has been found to affect morphometric and wood traits significantly, which is also observed in *Gmelina arborea*. Variations in seed and fruit traits based on geographic sources were documented in Dhaka *et al*. (2017) with *Tectona grandis*, suggesting that local environmental conditions may drive genetic divergence, influencing phenotypic traits. This finding is crucial for conservation strategies, where matching provenances to specific environmental conditions may optimize survival and growth rates.

The relationship between fruit traits and seed quality in *Gmelina arborea* underscores the importance of selecting fruit traits as indirect markers for seed quality, especially in breeding programs. Studies by Azad *et al*. (2014) demonstrate that seed viability and size positively correlate with wood density, hinting that these traits could serve as proxies in selecting high-quality genotypes. Olajuyigbe and Adegeye (2022) further emphasize that selecting morphometric traits, which exhibit strong correlations with wood properties, can be instrumental in breeding programs aimed at enhancing wood quality and yield.

In conclusion, this study reinforces the importance of morphometric, wood property, fruit, and seed traits as interconnected parameters that influence the overall growth, quality, and productivity of *Gmelina arborea*. These findings align with previous research on various tropical and subtropical trees, validating the use of such traits in selective breeding and forest management strategies. Understanding these correlations provides a foundation for optimizing timber production and ensures the sustainable use of *Gmelina arborea* resources in forestry applications.

Implications and Significance

- The significant positive correlations among certain morphometric traits (e.g., Total Tree Height, Crown Height, and Crown Width) imply that these dimensions are interdependent and likely related to overall tree growth patterns.
- The correlation of wood density with GBH and Branch Thickness suggests a possible link between growth form and wood strength, as trees with larger girths and branch thicknesses tend to have denser wood.
- The associations between fruit and seed dimensions and seed weight imply that larger fruits generally produce larger and heavier seeds, which could impact seed dispersal and germination success.

Conclusion

The correlation matrix reveals significant relationships among several morphometric, wood, and reproductive traits of *Gmelina arborea*, indicating interdependent growth patterns. These relationships can help in understanding the ecological adaptations of the species and in selecting traits for tree breeding and conservation efforts. The statistically significant correlations, particularly at the 0.01 and 0.05 levels, provide reliable insights that can inform further research and applications in forestry management.

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