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Phenotypic characterization of *Butea monosperma* in Mandla for breeding potential

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Abstract

This study investigates the phenotypic variability in morphological and reproductive traits of *Butea monosperma* trees in Mandla district of Madhya Pradesh. Ten phenotypically superior trees were selected using the Individual Tree Selection (ITS) method based on tree height, girth at breast height (GBH), crown spread, flowering intensity, and fruit yield. Trees from Mandla demonstrated superior growth and reproductive performance, with a mean tree height of 14.1 m, GBH of 114.5 cm, crown spread of 11.09 m, flowering intensity of 4.7, and fruit yield of 37.3 kg/tree. The low coefficients of variation indicated a uniform population, supporting the region's potential for elite tree selection and breeding programs.

Keywords: *Butea monosperma*, Mandla, phenotypic traits, breeding, conservation

Introduction

Butea monosperma (Lam.) Taub., commonly known as the Flame of the Forest or Palash, is a deciduous tree species native to the tropical and subtropical regions of India. It holds significant ecological, economic, and cultural importance, contributing to soil conservation, biodiversity, and providing valuable timber, gum, fodder, and medicinal products (Mishra, 2016) ^[3]. The species is well adapted to various soil types and climatic conditions, making it particularly suitable for afforestation and agroforestry programs in marginal lands (Tiwari *et al.*, 2021) ^[9]. Its resilience in harsh environmental conditions, especially in dryland ecosystems, further enhances its potential as a multipurpose tree for sustainable rural development.

Phenotypic evaluations have revealed significant variations in the morphological and reproductive traits of *B. monosperma* across different regions in India (Vashishtha *et al.*, 2013) ^[10]. These differences are largely attributed to environmental heterogeneity and underlying genetic diversity. Studies indicate that environmental factors such as rainfall, soil type, and temperature influence the species' expression of traits like tree height, girth, crown spread, flowering, and fruiting (Tiwari *et al.*, 2021) ^[9]. This phenotypic plasticity underscores the need for region-specific evaluations to identify elite genotypes suitable for breeding and conservation. Madhya Pradesh, a central Indian state with diverse agro-climatic conditions, serves as an important habitat for *B. monosperma*. The Mandla district, in particular, offers a unique landscape for studying its performance due to its mix of forested and agricultural zones. Understanding how trees perform under such varied conditions is essential for developing conservation strategies and selecting superior phenotypes for propagation (Tandon *et al.*, 2003) ^[7].

Despite its wide distribution, *B. monosperma* populations are increasingly threatened by habitat degradation, overexploitation, and poor natural regeneration. The lack of systematic conservation and selective breeding efforts has further compounded the decline in population quality and quantity. Recent ecological assessments have documented declining tree densities and reduced reproductive success in several regions, calling for urgent conservation measures (Mishra, 2023) ^[2].

Agroforestry has emerged as a promising strategy for conserving *B. monosperma* while enhancing rural livelihoods. When integrated into farming systems, the tree improves soil fertility, offers economic returns through lac cultivation, and supports ecosystem services such as pollinator habitat (Tiwari *et al.*, 2021) ^[9]. However, optimizing its performance in

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agroforestry systems requires the selection of genetically superior trees with desirable traits like high biomass yield, reproductive success, and resilience to biotic and abiotic stress (Prasad *et al.*, 2024) ^[5]

This study aims to conduct a detailed phenotypic assessment of *Butea monosperma* in the Mandla district of Madhya Pradesh. Specifically, it evaluates traits such as tree height, girth at breast height (GBH), crown spread, flowering intensity, and fruit yield to identify superior individuals for conservation and genetic improvement. The findings will contribute to the development of a core population for future breeding and agroforestry promotion and aid in establishing a scientific basis for region-specific conservation programs.

Methodology

Study Area

The study was conducted in the natural forests of Madhya Pradesh, focusing, Mandla district located in the central part of Madhya Pradesh and are known for their rich forest biodiversity, including significant populations of *Butea monosperma* (Flame of the Forest). The forests in these areas provide an ideal environment for the growth of this species, characterized by a tropical and subtropical climate that supports robust tree growth and reproductive potential.

Sampling and Tree Selection

In total, 10 *Butea monosperma* trees were randomly selected from the natural forests of Mandla,. The trees were chosen using the Individual Tree Selection (ITS) method, which is a common practice in forest tree improvement. This method involves selecting individual trees based on superior phenotypic traits that reflect the genetic potential of the species. The selected trees were mature, aged over 20 years, and displayed phenotypic traits that indicated high productivity and vitality.

Selection Criteria: The selection of superior trees was based on the following phenotypic traits, which are critical for evaluating the overall fitness and potential of the trees:

- 1. Tree Height:** The height of each tree was measured to assess its growth potential. Taller trees are typically indicative of better overall health and vigor.
- 2. Girth at Breast Height (GBH):** The circumference at 1.3 meters above ground level was recorded for each tree to measure its stem diameter. Larger girth values are associated with better growth and reproductive capacity.
- 3. Crown Spread:** The horizontal spread of the tree's crown was measured along both the north-south and east-west axes. A broader crown spread suggests a higher level of

canopy development, which is important for photosynthesis and overall tree productivity.

- 4. Flowering Intensity:** The flowering intensity was visually assessed on a scale of 1 to 5, with 1 representing minimal flowering and 5 representing abundant flowering. Strong flowering intensity is crucial for seed production and reproductive success.
- 5. Fruit Yield:** The quantity and weight of fruit produced by each tree were recorded. Higher fruit yield is indicative of the tree's reproductive fitness and potential for seed collection.

Data Collection

Data was collected during the flowering and fruiting seasons to capture the full spectrum of phenotypic traits. The following methods were employed to measure the traits (Chaturvedi and Khanna, 1994) ^[1].

- 1. Tree Height Measurement:** The height of each selected tree was measured using a Ravi multimeter to ensure accurate measurements
- 2. GBH Measurement:** The girth at breast height was measured using a standard measuring tape at 1.37 meters from the ground
- 3. Crown Spread Measurement:** The crown spread was measured by calculating the distance between the furthest branches along the north-south and east-west axis.
- 4. Flowering Intensity Rating:** Flowering intensity was rated on a scale of 1 to 5 based on visual observation, with higher scores assigned to trees with more abundant and vibrant flowers Olubode *et al.* (2015) ^[4].
- 5. Fruit Yield Estimation:** The number of pods and the total weight of fruits from each tree were recorded during the peak fruiting season to estimate the overall fruit yield (Shukla *et al.* 2014) ^[6].

Statistical Analysis

The collected data was analyzed using descriptive statistics and trees exhibiting superior phenotypic traits, such as taller height, larger GBH, more extensive crown spread, stronger flowering intensity, and higher fruit yield, were identified as candidates for future breeding programs. These superior trees will be used for seed collection and genetic improvement efforts aimed at enhancing the productivity and resilience of *Butea monosperma* in the region.

Results

The descriptive statistics of the measured traits for *Butea monosperma* trees from Mandla are presented in Table 1.

Table 1: Descriptive Statistics of Morphological and Reproductive Traits in *Butea monosperma* Trees from Mandla

	Tree Height (m)	GBH (cm)	Crown Spread (m)	Flowering Intensity (1-5)	Fruit Yield (kg/tree)
N	10	10	10	10	10
Min	13.5	110	10.5	4	34
Max	15	119	12	5	40
Sum	141	1145	110.9	47	373
Mean	14.1	114.5	11.09	4.7	37.3
Std. error	0.136626	0.9574271	0.1401983	0.1527525	0.6506407
Variance	0.1866667	9.166667	0.1965556	0.2333333	4.233333
Stand. dev	0.4320494	3.02765	0.4433459	0.4830459	2.057507
Median	14.05	114.5	11.05	5	37.5
25 prcntil	13.775	111.75	10.75	4	35.75
75 prcntil	14.35	117.25	11.35	5	39.25
Skewness	0.8369579	0	0.7619739	-1.035098	-0.1205496
Kurtosis	0.9748087	-1.2	0.7640387	-1.22449	-1.082522
Geom. mean	14.09412	114.464	11.08214	4.676242	37.24865
Coeff. var	3.06418	2.644236	3.997708	10.27757	5.516103

The selected trees exhibited superior morphological and reproductive performance, with mean values of: tree height = 14.1 m, GBH = 114.5 cm, crown spread = 11.09 m, flowering intensity = 4.7, and fruit yield = 37.3 kg/tree. Among these, flowering intensity displayed the highest relative variability (CV = 10.28%), while GBH showed the lowest (CV = 2.64%), indicating stable bole growth across the sampled population. Fruit yield exhibited moderate variability (CV = 5.52%), suggesting potential for selection of high-yielding individuals within this population.

Compared to previous reports on regional performance of *B. monosperma*, the Mandla population demonstrated superior growth metrics. This is consistent with observations by Tewari (1995)^[8] and Vashishtha *et al.* (2013)^[10], who identified central India particularly Madhya Pradesh as an ecologically favorable region for *B. monosperma*, supporting vigorous growth and high reproductive output. Similar to findings by Mishra (2023)^[2], the enhanced performance in Mandla may be attributed to favorable edaphic conditions, optimal microclimate, and reduced anthropogenic disturbance. The narrow variation observed in GBH and crown spread (CV < 5%) suggests a relatively uniform genetic background, which is advantageous for clonal propagation and targeted breeding programs. The combination of stable morphology and high fruit yield enhances the utility of this population for seed-based propagation, commercial exploitation of reproductive products, and genetic improvement initiatives. These results support the inclusion of Mandla germplasm in future breeding, conservation, and restoration programs, with the dual aim of preserving genetic resources and improving productivity.

Conclusion

The evaluation of *Butea monosperma* trees from Mandla revealed a combination of vigorous growth and high reproductive performance, with mean tree height, GBH, and crown spread exceeding many previously reported regional averages. The low variability in key structural traits, particularly GBH and crown spread, reflects a stable and uniform population well suited for clonal multiplication, while the moderate variability in fruit yield offers scope for selecting superior seed-producing individuals. The consistently high flowering intensity and yield highlight the suitability of Mandla's edaphic and climatic conditions for supporting productive populations. These findings underscore the potential of Mandla germplasm as a priority resource for breeding, conservation, and sustainable utilization programs aimed at enhancing productivity and genetic quality in *B. monosperma*.

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