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Evaluating phenotypic traits of *Butea monosperma* for conservation and improvement in chhindwara

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Abstract
This study aimed to evaluate the phenotypic variability of *Butea monosperma* trees in Chhindwara district, Madhya Pradesh, to identify superior genotypes for breeding and conservation programs. A total of 10 mature trees were selected based on their phenotypic traits, including tree height, girth at breast height (GBH), crown spread, flowering intensity, and fruit yield. Descriptive statistical analysis revealed moderate variation in tree height (12.73±0.79 m) and GBH (105.4±3.72 cm), indicating genetic stability in these traits. However, crown spread (9.37±0.34 m), flowering intensity (mean score of 3.3), and fruit yield (27.1±2.96 kg/tree) exhibited higher variability, suggesting potential for selection in breeding programs aimed at improving reproductive traits. The findings highlight the importance of phenotypic variability in selecting superior genotypes for improving *Butea monosperma* productivity and its ecological role in agroforestry systems. Future research should expand the sampling size and include additional traits, such as wood quality and pest resistance, to enhance the effectiveness of breeding and conservation efforts.

Keywords: *Butea monosperma*, GBH, Chhindwara, phenotypic variability, conservation, tree improvement

Introduction

Butea monosperma (Lam.) Taub, commonly known as the flame of the forest, is a deciduous tree species native to the Indian subcontinent. It is a member of the Fabaceae family and is widely distributed in tropical and subtropical regions, particularly in dry forests of central India. This species thrives in varying environmental conditions, ranging from arid landscapes to more humid subtropical climates,its distribution is heavily concentrated in the states of Madhya Pradesh, Rajasthan, Maharashtra, and Uttar Pradesh, where it plays a crucial role in local ecosystems and provides significant economic value to communities (Kumar *et al.*, 2010) [12].

Ecologically, *B. monosperma* is vital for soil conservation, habitat restoration, and enhancing biodiversity in degraded landscapes. The species is well-adapted to low-moisture environments and is often used in agroforestry systems due to its drought resistance and rapid growth rate. Its leaves, bark, and flowers are also used in traditional medicine, and its wood is employed for making various artifacts, furniture, and fuelwood, contributing to local economies (Neupane and Aryal, 2022) [15]. *B. monosperma* is especially recognized for its vibrant orange-red flowers, which bloom in the spring, attracting various pollinators and playing a role in the pollination networks of forest ecosystems (Sindhia and Bairwa, 2010) [18].

The genetic diversity of *B. monosperma* is an important factor in its ability to adapt to diverse climatic and environmental conditions. While several studies have highlighted the species' ecological roles and potential economic benefits, research on its genetic variability and phenotypic traits remains scarce. Understanding the variability in its morphological and reproductive traits across different ecological zones is crucial for effective conservation and breeding programs (Mishra, 2023) [13]. Such programs can help identify superior genotypes that exhibit desirable traits like fast growth, high fruit yield, resistance to pests, and better adaptability to environmental stressors (Zobel and Talbert, 1984) [22].

Phenotypic traits, such as tree height, girth at breast height (GBH), crown spread, and reproductive characteristics like flowering intensity and fruit yield, directly affect the productivity and ecological resilience of *B. monosperma*.

These traits play a pivotal role in determining the species' regenerative capacity, reproductive success, and ability to thrive under varying environmental conditions (Das *et al.*, 2012) [4]. The tree height and GBH are strong indicators of overall tree health, with taller trees and larger diameters often associated with better growth rates and increased timber production (Zobel and Talbert, 1984) [22]. In central India, particularly in the state of Madhya Pradesh, *B. monosperma* is a dominant species in many forest ecosystems. The region's dry deciduous forests provide a favorable environment for this tree species, with seasonal rainfall patterns that contribute to the species' growth cycles. The variability in rainfall, temperature, and soil types across different districts of Madhya Pradesh influences the phenotypic traits of *B. monosperma*, making the region a key area for studying this species' adaptability and productivity. Local variations in tree morphology, fruit yield, and flowering intensity could offer insights into the genetic potential of *B. monosperma* populations in this region (Kasture *et al.* 2002) [11].

In Madhya Pradesh, *B. monosperma* plays an essential role in agroforestry systems. The species is often intercropped with other crops, such as pulses, vegetables, and cereals, due to its compatibility with agricultural practices. Moreover, its ability to withstand droughts and harsh climatic conditions makes it an ideal species for soil conservation in degraded or marginal lands. The fruit yield of *B. monosperma* is of particular importance, as it provides a valuable source of food for local wildlife and a potential income source through its medicinal and nutritional properties (Sahu and Padhy 2013) [17]. While the ecological and economic importance of *B. monosperma* is well-documented, there is a notable gap in knowledge regarding its phenotypic variability across different ecological zones. As the pressure on forest resources increases due to climate change and land-use changes, it becomes imperative to assess the morphological and reproductive traits of *B. monosperma* populations in different regions (Firdaus and Mazumder 2012) [7]. Such assessments can guide the selection of superior genotypes for conservation and breeding programs, ensuring that the species remains resilient in the face of environmental changes.

This study aims to evaluate the phenotypic variability of *B. monosperma* trees in the Chhindwara district of Madhya Pradesh. By analyzing traits such as tree height, girth at breast height, crown spread, flowering intensity, and fruit yield, we seek to identify superior genotypes that exhibit desirable characteristics for future breeding programs. The findings from this research will contribute to the development of strategies for improving the productivity, sustainability, and ecological resilience of *B. monosperma* in Madhya Pradesh.

Methodology

Study Area

The study was conducted in the natural forests of Madhya Pradesh, focusing on Chhindwara, 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 Chhindwara, district. 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) [3]:

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 axe.
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
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.

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 for morphological and reproductive traits of *Butea monosperma* from Chhindwara are presented in Table 1. The sample of ten mature trees exhibited low variation in structural attributes but greater variability in reproductive traits, a pattern consistent with other widely distributed tropical tree species.

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

	Tree Height (m)	GBH (cm)	Crown Spread (m)	Flowering Intensity (1-5)	Fruit Yield (kg/tree)
N	10	10	10	10	10
Min	11.5	100	8.9	3	22
Max	14.2	111	10	4	32
Sum	127.3	1054	93.7	33	271
Mean	12.73	105.4	9.37	3.3	27.1
Std. error	0.2512414	1.175679	0.1075484	0.1527525	0.9363048
Variance	0.6312222	13.82222	0.1156667	0.2333333	8.766667
Stand. dev	0.7944949	3.717825	0.340098	0.4830459	2.960856
Median	12.75	105.5	9.35	3	27.5
25 prcntil	12.075	101.75	9.075	3	24.75
75 prcntil	13.275	108.5	9.625	4	29.25
Skewness	0.3260865	0.0272434	0.4270679	1.035098	-0.1213553
Kurtosis	-0.04492783	-1.087884	-0.3231486	-1.22449	-0.2177276
Geom. mean	12.70786	105.341	9.364485	3.270415	26.95192
Coeff. var	6.241123	3.527348	3.629648	14.63775	10.92567

Morphological Traits

Tree height ranged from 11.5 m to 14.2 m (mean = 12.73 m±0.25 SE), while GBH varied from 100 cm to 111 cm (mean = 105.4 cm±1.18 SE). Crown spread ranged from 8.9 m to 10.0 m (mean = 9.37 m±0.11 SE). All three structural traits displayed low coefficients of variation (height = 6.24%, GBH = 3.53%, crown spread = 3.63%), indicating morphological uniformity among individuals. Similar stability in size traits has been reported in other native tree species, including *Madhuca indica*, where most mature trees exhibit consistent GBH above 100 cm within populations (Prasad, 1993) [16]. In Sapotaceae member *Argania spinosa*, Bani-Aameur and Ferradous (2001) [2] also observed low variance due to strong adaptive plasticity, enabling morphological stability despite environmental differences. The relatively symmetrical skewness values in this study further suggest absence of extreme outliers, implying that the sampled trees represent a fairly homogeneous age and growth class.

Reproductive Traits

Flowering intensity, rated on a 1-5 scale, ranged from 3 to 4 (mean = 3.3±0.15 SE) with a CV of 14.64%, while fruit yield per tree varied from 22 to 32 kg (mean = 27.1±0.94 SE; CV = 10.93%). These higher CV values relative to morphological traits reflect greater variability in reproductive performance, a trend also reported for *M. indica* in central India, where crown size and local conditions strongly influence flower and seed yields (Prasad, 1993) [16]. Larger crowns typically enhance floral production (Kadam, 1994) [10], and similar relationships between canopy size and yield have been observed in other NTFP species. Significant variation in reproductive output between populations, but relative stability within populations, has been documented for *Argania spinosa* (Aabd *et al.,* 2015) [1], *Vitellaria paradoxa* (Djekota *et al.,* 2014) [5], and *Rhizophora mangle* (Dominguez *et al.,* 1998) [6]. These patterns suggest that while environmental factors (e.g., microclimate, soil fertility) may drive site-level differences, reproductive traits within a given locality are often moderated by shared growing conditions and similar genetic backgrounds.

The observed pattern, low variation in structural traits and higher variation in reproductive traits is characteristic of tree species with wide ecological amplitude, where morphology is under stabilizing selection to ensure survival, while reproductive traits remain plastic to exploit favorable conditions (Hamrick *et al.,* 1994; Young *et al.,* 1996) [9, 21]. In *Butea monosperma*, flowering and fruiting are known to be sensitive to temperature, photoperiod, and rainfall patterns, leading to annual and inter-individual differences even under broadly similar conditions. Environmental influences on reproductive yield, as noted for *M. indica* by Munasinghe and Wansapala (2015) [14] and for *A. spinosa* by Haloui *et al.* (2017) [8], likely also apply to *B. monosperma*. Nevertheless, the low within-population variability for morphological traits in this study indicates that the Chhindwara population is relatively uniform in its growth form, possibly due to common origin or similar management history.

Conclusion

Butea monosperma trees from Chhindwara exhibited low variation in structural traits, indicating morphological stability, and higher variation in reproductive traits, reflecting environmental and genotypic influences. The uniformity in growth form makes this population suitable for consistent planting material, while the variability in reproductive performance offers scope for selecting superior genotypes for yield improvement. These results highlight the importance of integrating phenotypic and molecular approaches for the sustainable utilization and genetic improvement of this key multipurpose species.

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