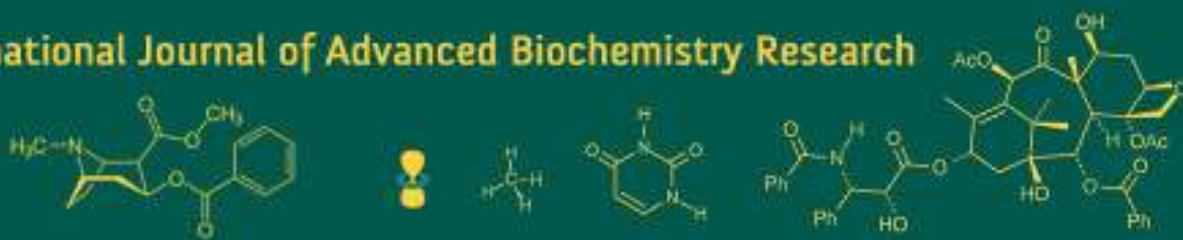


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Characterization of *Butea monosperma* phenotypes in Madhya Pradesh: Implications for forest conservation and breeding programs

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Abstract

Butea monosperma (Lam.) Taub. a multipurpose leguminous tree native to India, exhibits considerable ecological, economic, and medicinal importance. This study aimed to assess the phenotypic variability of morphological and reproductive traits in *B. monosperma* across three districts of Madhya Pradesh; Chhindwara, Mandla, and Balaghat to identify superior trees for conservation and breeding. A total of 30 phenotypically superior trees (10 from each district) were evaluated for five traits: tree height, girth at breast height (GBH), crown spread, flowering intensity, and fruit yield. Descriptive statistical analysis revealed significant variability among regions. Mandla trees exhibited superior growth performance with the highest mean values for tree height (14.1 m), GBH (114.5 cm), and fruit yield (37.3 kg/tree), along with lower coefficients of variation, indicating population uniformity. In contrast, trees from Balaghat showed lower mean values and higher variability, particularly in flowering intensity and fruit yield. The observed trait variation suggests strong genetic diversity and regional adaptation, supporting the potential for region-specific conservation strategies. The results provide a scientific basis for selecting elite trees and establishing breeding programs aimed at genetic improvement and sustainable utilization of *B. monosperma*.

Keywords: *Butea monosperma*, Flame of the Forest, Individual Tree Selection, phenotypic traits, Madhya Pradesh, breeding programs, conservation, seed collection

Introduction

Butea monosperma (Lam.) Taub. also known as the flame of the forest or palash, is a prominent deciduous tree species in the Indian subcontinent. Widely distributed across tropical and subtropical regions of India, Nepal, Sri Lanka, and Bangladesh, it is a crucial part of dry deciduous forests (Burli and Khade, 2007) ^[1]. The tree is particularly valued for its diverse uses, including its vibrant flowers, edible gum, seeds, and durable timber. These components play significant roles in both the local economy and traditional medicine, especially in rural communities (Gupta *et al.*, 2017) ^[3].

The flowers of *B. monosperma* are widely recognized for their medicinal and dyeing properties. The tree's name "flame of the forest" reflects the striking orange-red flowers that are used in traditional medicine for treating wounds and infections (Rizvi *et al.*, 2024). The gum, known as Butea gum, has astringent and antimicrobial properties, making it an essential component in Ayurvedic treatments (Mazumder *et al.*, 2011) ^[4]. Moreover, the seeds produce oil that has culinary and medicinal uses, while the wood is employed in the construction of tools and furniture (Methaniya *et al.*, 2023) ^[5].

Ecologically, *B. monosperma* plays a critical role in maintaining soil health and supporting biodiversity. Its deep root system contributes to soil stabilization, especially in semi-arid and degraded lands, making it a valuable species in afforestation and agroforestry projects (Burli and Khade, 2007) ^[1]. The tree is also a host for the lac insect (*Kerria lacca*), which produces shellac, a valuable resin used in various industries (Mazumder *et al.*, 2011) ^[4].

Despite its wide range of applications, *B. monosperma* faces numerous challenges, particularly related to overexploitation and poor natural regeneration. The increasing demand for its flowers, gum, and wood has led to habitat degradation, while climate change further complicates its regeneration (Rathnaprabha *et al.*, 2017) ^[9]. These pressures underscore the

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importance of developing effective conservation and breeding strategies to safeguard the species' future.

One promising approach to addressing these challenges is the Individual Tree Selection (ITS) method, a technique used in tree breeding and genetic improvement. ITS involves selecting superior trees based on phenotypic traits such as growth rate, flowering intensity, and reproductive potential. These selected trees serve as breeding material for the development of high-yielding and resilient varieties that can better withstand environmental stresses (Zobel and Talbert, 1984) ^[14]. This method holds potential for improving the productivity of *B. monosperma*, ensuring its sustainability for future generations.

This study aims to identify superior *B. monosperma* trees in Madhya Pradesh, focusing on three districts; Chhindwara, Mandla, and Balaghat. By evaluating the phenotypic characteristics of trees in these regions, we aim to select superior genotypes for breeding programs that can enhance the species' productivity, resilience, and overall sustainability. This study aims to identify and select superior *Butea monosperma* trees from Madhya Pradesh, India, for breeding and conservation efforts. A total of 10 trees will be selected based on their outstanding phenotypic characteristics, which will serve as the foundation for future breeding programs and sustainable management of the species.

Methodology

Study Area

The study was conducted in the natural forests of Madhya Pradesh, focusing on three key districts: Chhindwara, Mandla, and Balaghat. These regions are 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, 30 *Butea monosperma* trees were randomly selected from the natural forests of Chhindwara, Mandla, and Balaghat, with 10 trees selected from each 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) ^[12]:

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) ^[6].
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) ^[11].

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 morphological and reproductive traits of *Butea monosperma* trees exhibited noticeable variation across the three districts of Madhya Pradesh; Chhindwara, Mandla, and Balaghat as presented in Tables 1, 2, and 3.

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
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
Coeff. var	6.241123	3.527348	3.629648	14.63775	10.92567

Table 2: 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
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
Coeff. var	3.06418	2.644236	3.997708	10.27757	5.516103

Table 3: Descriptive Statistics of Morphological and Reproductive Traits in *Butea monosperma* Trees from Balaghat

	Tree Height (m)	GBH (cm)	Crown Spread (m)	Flowering Intensity (1-5)	Fruit Yield (kg/tree)
N	10	10	10	10	10
Mean	12.2	99.8	8.36	2.6	24.5
Std. error	0.2043961	1.083205	0.09092121	0.1632993	0.9574271
Variance	0.4177778	11.73333	0.08266667	0.2666667	9.166667
Stand. dev	0.6463573	3.425395	0.2875181	0.5163978	3.02765
Coeff. var	5.298011	3.43226	3.439212	19.86145	12.35776

In Chhindwara, mean tree height was 12.73 m (CV = 6.24%), indicating moderate uniformity. GBH averaged 105.4 cm with low variability (CV = 3.53%), while crown spread averaged 9.37 m (CV = 3.63%). Flowering intensity averaged 3.3 (scale 1-5) with moderate variability (CV = 14.64%), and fruit yield averaged 27.1 kg/tree (CV = 10.93%). In Mandla, trees demonstrated the most vigorous growth and reproductive performance. Mean height was 14.1 m (CV = 3.06%), GBH was 114.5 cm (CV = 2.64%), and crown spread reached 11.09 m (CV = 4.00%). Flowering intensity was high at 4.7 (CV = 10.28%), and fruit yield was the highest among the districts at 37.3 kg/tree (CV = 5.52%). In Balaghat, trees recorded the lowest mean values for all traits. Mean height was 12.2 m (CV = 5.30%), GBH averaged 99.8 cm (CV = 3.43%), and crown spread was narrowest at 8.36 m (CV = 3.44%). Flowering intensity was the lowest at 2.6 (CV = 19.86%), indicating considerable variation, while fruit yield was also lowest at 24.5 kg/tree with high variability (CV = 12.36%).

Overall, Mandla trees combined superior growth (taller stature, greater girth, and wider crowns) with high reproductive output and relatively low variability in most traits, making this population both productive and uniform. Chhindwara showed intermediate performance in all traits, while Balaghat had the smallest trees and lowest reproductive output, coupled with greater variability in flowering and yield.

These trends align with Vashishtha *et al.* (2013) [13], who reported substantial genetic diversity and population differentiation in *B. monosperma* across India, indicating that local environmental conditions such as Mandla's favorable soils and microclimate may enhance both vegetative growth and reproductive success. The high flowering and fruit yield in Mandla also align with the species' mixed mating system and propensity for geitonogamy noted by Tandon *et al.* (2003) [12], suggesting

that higher pollinator activity or greater genetic compatibility may be contributing factors.

The variation observed among districts likely reflects a combination of genetic differences and localized environmental influences. Limited gene flow, as documented in *B. monosperma* (Vashishtha *et al.*, 2013) [13], can lead to population-specific adaptations and trait divergence.

From a management perspective, Mandla populations offer valuable germplasm for seed collection, propagation, and breeding programs, while Balaghat populations may warrant targeted conservation efforts to preserve unique local genotypes adapted to less favorable conditions.

Conclusion

The comparative evaluation of *Butea monosperma* across Chhindwara, Mandla, and Balaghat districts revealed clear population-level differences in both morphological and reproductive traits. Mandla emerged as the most productive population, with superior tree height, GBH, crown spread, flowering intensity, and fruit yield, coupled with relatively low variability, making it an ideal source for seed collection, clonal propagation, and breeding programs. Chhindwara populations displayed intermediate performance, while Balaghat populations though lower in overall growth and reproductive output, may harbor unique genotypes adapted to local conditions that merit conservation attention. These findings highlight the combined influence of genetic makeup and local environmental factors on population performance in *B. monosperma*. Targeted utilization of high-performing populations, alongside conservation of genetically distinct but less productive ones, can support sustainable management, genetic improvement, and long-term conservation of this ecologically and economically valuable species.

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