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Phenotypic characterization and morphological diversity of Tendu (*Diospyros melanoxylon* Roxb.) genotypes from Southern Rajasthan

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Abstract

Tendu (*Diospyros melanoxylon* Roxb.) is an important indigenous multipurpose tree whose natural populations constitute a valuable but comparatively under-characterized genetic resource in southern Rajasthan. The present investigation assessed phenotypic diversity in 30 naturally occurring Tendu genotypes collected from Udaipur, Salumber, Pratapgarh, Banswara and Dungarpur divisions over two consecutive fruiting seasons (2023–24 and 2024–25). Qualitative descriptors and quantitative measurements of leaves and inflorescences were recorded to identify phenotypically contrasting genotypes. Considerable variation was evident in foliage density, mature leaf colour, lamina surface and reproductive traits. Dark green foliage occurred in 20 genotypes (66.66%), whereas 10 genotypes (33.33%) had green leaves. The pooled leaf length-to-width ratio varied from 1.40 to 2.48, with MPUAT-TU1 showing the highest value and MPUAT-TB27 the lowest. Pooled inflorescence diameter ranged from 1.21 to 1.91 cm; MPUAT-TB24 recorded the maximum and MPUAT-TP13 the minimum. Inflorescence length-to-diameter ratio ranged from 1.14 to 2.01, with MPUAT-TP13 and MPUAT-TP19 representing the maximum and minimum, respectively. The persistence of marked phenotypic contrasts across two seasons indicates substantial diversity within the surveyed germplasm, while also highlighting the environmental sensitivity of morphological traits. The characterized genotypes provide useful baseline material for subsequent molecular validation, conservation and systematic utilization of Tendu genetic resources in southern Rajasthan.

Keywords: Tendu, phenotypic diversity, morphological characterization, leaf morphology, inflorescence, germplasm

1. Introduction

Tendu (*Diospyros melanoxylon* Roxb.), a member of Ebenaceae, is an indigenous multipurpose tree species distributed widely across the Indian subcontinent. The species has a diploid chromosome number of $2n = 30$ and occurs under a broad range of environmental conditions (Wallnofer, 2001) ^[14]. Its capacity to persist under dry tropical conditions, together with reported tolerance to drought and frost, contributes to its ecological importance in tropical dry deciduous forests (Hmar *et al.*, 2017) ^[2]. Tendu is also closely associated with the livelihoods of rural and tribal communities. Its leaves are particularly important as a raw material for the bidi industry, while its fruits, wood and other plant parts have food, medicinal and domestic uses (Jamil *et al.*, 2020) ^[4].

Although Tendu has considerable socioeconomic and ecological value, much of its genetic resource base remains represented by naturally occurring forest populations, with comparatively limited systematic domestication and orchard development. Habitat degradation, deforestation and unsustainable exploitation reinforce the need to document, conserve and characterize the available diversity (Kala, 2013) ^[5]. Morphological characterization provides a practical initial approach for identifying phenotypically distinct trees and establishing a foundation for subsequent conservation and utilization programmes (Patel *et al.*, 2021) ^[10].

Morphological traits, however, are not determined exclusively by genotype. Their expression can vary with environmental conditions, making observations across seasons and multiple traits

particularly useful when assessing field populations (Lal *et al.*, 2001) [6]. Southern Rajasthan, encompassing Udaipur, Salumber, Pratapgarh, Banswara and Dungarpur, contains natural Tendu populations distributed across environmentally heterogeneous landscapes (Jain *et al.*, 2005) [3]. Such geographic and environmental variation offers an opportunity to document phenotypic diversity within the species (Malik *et al.*, 2010) [9]. Therefore, the present study was undertaken to characterize morphological variation among Tendu genotypes from southern Rajasthan, with emphasis on leaf and inflorescence descriptors, and to identify contrasting genotypes suitable for further characterization, conservation and utilization.

2. Materials and Methods

2.1 Study period and survey area

The investigation was conducted during two consecutive fruiting seasons, 2023-24 and 2024-25. Field observations were made in Udaipur, Salumber, Pratapgarh, Banswara and Dungarpur districts of southern Rajasthan. The surveyed sites extended approximately from 23.48690 to 24.898640° N latitude and 73.4295820 to 74.78180° E longitude, with elevations ranging from 222 to 736 m above mean sea level. The study area represented the Humid Southern Plains and the Sub-humid Southern Plains and Aravalli Hills agro-climatic regions.

2.2 Genotype identification and field observations

Thirty naturally occurring Tendu genotypes were identified and assigned the codes MPUAT-TU1 to MPUAT-TU6, MPUAT-TS7 to MPUAT-TS10, MPUAT-TP11 to MPUAT-TP23, MPUAT-TB24 to MPUAT-TB27 and MPUAT-TD28 to MPUAT-TD30. Representative trees were selected in their natural habitats according to predefined field selection criteria. Observations were recorded during the flowering-to-fruiting period from April to July in each year.

2.3 Morphological descriptors and measurements

Qualitative characterization included foliage density, mature leaf colour, leaf lamina surface and pedicel attachment. Foliage density was visually categorized as sparse or dense. Mature leaf colour was assessed under natural daylight according to predominant pigmentation, while lamina surface was assessed visually and by gentle tactile observation and classified as smooth or glabrous. Leaf and inflorescence measurements were obtained from representative samples of each genotype.

Leaf length-to-width ratio was calculated using the corresponding mean leaf length and mean leaf width. Inflorescence diameter was measured at the widest point with a digital Vernier caliper, and the inflorescence length-to-diameter ratio was calculated from the corresponding mean measurements. Five mature leaves or representative inflorescences were used for the relevant measurements in each replication. Genotype-wise observations were recorded for both seasons, and pooled values were used to summarize the two-season observations.

3. Results

3.1 Qualitative phenotypic variation

The surveyed Tendu germplasm exhibited clear qualitative differences among genotypes. Both sparse and dense foliage types were observed. Mature leaf colour varied between green and dark green, while smooth and glabrous lamina surfaces were recorded. Among the 30 genotypes, 20 (66.66%) possessed dark green leaves and 10 (33.33%) possessed green leaves. Calyx-lobe type pedicel attachment was recorded for all genotypes. These descriptors provided readily observable characters for

preliminary discrimination of the surveyed material.

Table 1: Qualitative morphological variation among the 30 Tendu genotypes

Trait	Observed categories / distribution
Tree foliage type	Sparse and dense foliage were observed among the genotypes.
Mature leaf colour	Green (10 genotypes; 33.33%) and dark green (20 genotypes; 66.66%).
Leaf lamina surface	Smooth and glabrous surfaces were recorded.
Pedicel attachment	Calyx-lobe type was recorded for all 30 genotypes in the source dataset.

3.2 Quantitative variation in leaf and inflorescence traits

Marked genotype-to-genotype variation was observed for all three quantitative descriptors. Leaf length-to-width ratio ranged from 1.40 to 2.50 during 2023–24 and from 1.40 to 2.46 during 2024–25; the pooled range was 1.40–2.48. The pooled mean was 1.88. MPUAT-TU1 recorded the highest pooled ratio (2.48), followed by MPUAT-TP21 (2.34) and MPUAT-TU5 (2.32), whereas MPUAT-TB27 had the lowest value (1.40). The pooled S.E.m. was 0.08, C.D. at P=0.05 was 0.24 and the coefficient of variation was 7.80%.

Inflorescence diameter ranged from 1.18 to 1.92 cm in 2023–24 and from 1.18 to 1.90 cm in 2024–25, with a pooled range of 1.21–1.91 cm and a pooled mean of 1.54 cm. MPUAT-TB24 showed the maximum pooled diameter (1.91 cm), followed by MPUAT-TB26 (1.86 cm) and MPUAT-TP22 (1.83 cm), whereas MPUAT-TP13 recorded the minimum (1.21 cm). The pooled S.E.m. was 0.07, C.D. at p=0.05 was 0.20 and the coefficient of variation was 8.11%.

The inflorescence length-to-diameter ratio varied from 1.14 to 2.01 on a pooled basis. MPUAT-TP13 recorded the highest value (2.01), followed by MPUAT-TS7 (1.92) and MPUAT-TU4 (1.76), whereas MPUAT-TP19 recorded the lowest value (1.14). The pooled S.E.m. was 0.08, C.D. at p=0.05 was 0.23 and the coefficient of variation was 10.05%. The genotype-wise values for both seasons and pooled observations are presented in Table 2.

4. Discussion

The observed qualitative and quantitative differences confirm appreciable phenotypic heterogeneity within the surveyed Tendu germplasm. Variation in leaf colour, lamina characteristics and foliage density offers practical descriptors for preliminary field-level discrimination. The predominance of dark green foliage, recorded in two-thirds of the genotypes, may reflect differences in pigment-associated phenotypes; however, leaf pigmentation can also respond to environmental variables such as light, temperature, nutrient availability and developmental stage (Taiz *et al.*, 2015; Li *et al.*, 2023) [12, 8].

Variation in leaf dimensions was reflected in the leaf length-to-width ratio, which extended from 1.40 to 2.48 on a pooled basis. MPUAT-TU1 displayed the most elongated leaf proportion, whereas MPUAT-TB27 exhibited the lowest ratio. Similar variability in Tendu leaf morphology has been reported previously (Toppo *et al.*, 2020) [13]. Leaf form is influenced by both genetic constitution and environmental factors, including light regime, temperature, water availability and nutrient status (Lambers *et al.*, 2008; Ren *et al.*, 2020) [7, 11]. Consequently, the repeated observation of contrasting phenotypes over two seasons supports their usefulness as preliminary descriptors, although evaluation under a common environment would be required to

strengthen conclusions concerning genetic control.

Reproductive morphology also differed substantially among the genotypes. Pooled inflorescence diameter ranged from 1.21 to 1.91 cm, while the length-to-diameter ratio ranged from 1.14 to 2.01. MPUAT-TB24 was characterized by the largest pooled inflorescence diameter, whereas MPUAT-TP13 combined the smallest diameter with the highest length-to-diameter ratio. Such contrasting combinations suggest differences in reproductive architecture among the surveyed trees. At the same time, flowering and inflorescence development can be modified by genotype, temperature, light, moisture, nutrient availability and genotype $\times$ environment interaction (Taiz *et al.*, 2015) [12].

Morphological characterization should therefore be viewed as an

initial layer of germplasm assessment rather than definitive evidence of genetic relatedness. Integrating field descriptors with molecular approaches can improve the resolution of diversity analysis. Morphological descriptors are accessible for preliminary classification, whereas molecular markers can provide complementary evidence of genetic relationships because they are less directly influenced by the immediate environment. SSR and other PCR-based marker systems have been used effectively for diversity assessment in *Diospyros* and other fruit crops (Gajera *et al.*, 2018) [1]. The contrasting genotypes identified in the present investigation can consequently serve as candidate material for subsequent molecular characterization and conservation-oriented studies.

Table 2: Leaf length-to-width ratio, inflorescence diameter and inflorescence length-to-diameter ratio of 30 Tendu genotypes across two seasons

Genotype	Leaf length: width	Leaf length: width	Leaf length: width	Inflorescence diameter (cm)	Inflorescence diameter (cm)	Inflorescence diameter (cm)	Inflorescence length: diameter	Inflorescence length: diameter	Inflorescence length: diameter
Genotype	2023–24	2024–25	Pooled	2023–24	2024–25	Pooled	2023–24	2024–25	Pooled
MPUAT-TU1	2.50	2.46	2.48	1.42	1.52	1.47	1.55	1.49	1.52
MPUAT-TU2	2.11	2.06	2.08	1.40	1.61	1.51	1.36	1.26	1.31
MPUAT-TU3	1.86	1.79	1.83	1.33	1.38	1.36	1.35	1.36	1.35
MPUAT-TU4	2.05	1.98	2.02	1.30	1.36	1.33	1.82	1.70	1.76
MPUAT-TU5	2.33	2.31	2.32	1.47	1.62	1.54	1.52	1.36	1.44
MPUAT-TU6	1.83	1.87	1.85	1.56	1.40	1.48	1.34	1.43	1.38
MPUAT-TS7	2.30	2.12	2.21	1.27	1.33	1.30	1.96	1.87	1.92
MPUAT-TS8	1.90	1.63	1.77	1.30	1.40	1.35	1.79	1.62	1.71
MPUAT-TS9	2.09	1.78	1.93	1.42	1.57	1.49	1.55	1.45	1.50
MPUAT-TS10	2.14	1.77	1.95	1.76	1.78	1.77	1.23	1.28	1.26
MPUAT-TP11	1.94	1.84	1.89	1.50	1.68	1.59	1.37	1.29	1.33
MPUAT-TP12	1.50	1.60	1.55	1.56	1.65	1.60	1.46	1.35	1.41
MPUAT-TP13	1.97	1.98	1.97	1.23	1.18	1.21	1.96	2.06	2.01
MPUAT-TP14	1.85	1.88	1.87	1.43	1.48	1.45	1.48	1.47	1.47
MPUAT-TP15	1.57	1.60	1.58	1.71	1.65	1.68	1.35	1.40	1.37
MPUAT-TP16	2.19	1.86	2.03	1.42	1.54	1.48	1.56	1.32	1.44
MPUAT-TP17	1.57	1.55	1.56	1.18	1.33	1.26	1.93	1.48	1.70
MPUAT-TP18	1.79	1.71	1.75	1.53	1.71	1.62	1.33	1.26	1.30
MPUAT-TP19	1.75	1.82	1.79	1.67	1.76	1.71	1.17	1.12	1.14
MPUAT-TP20	1.67	1.61	1.64	1.31	1.46	1.39	1.61	1.57	1.59
MPUAT-TP21	2.28	2.39	2.34	1.40	1.58	1.49	1.65	1.43	1.54
MPUAT-TP22	2.19	2.04	2.11	1.82	1.84	1.83	1.19	1.18	1.18
MPUAT-TP23	1.77	1.77	1.77	1.63	1.72	1.68	1.45	1.34	1.39
MPUAT-TB24	1.87	1.89	1.88	1.92	1.90	1.91	1.18	1.19	1.19
MPUAT-TB25	2.00	1.86	1.93	1.52	1.66	1.59	1.47	1.36	1.42
MPUAT-TB26	1.77	1.78	1.78	1.85	1.87	1.86	1.19	1.18	1.19
MPUAT-TB27	1.40	1.40	1.40	1.47	1.57	1.52	1.44	1.47	1.45
MPUAT-TD28	1.56	1.56	1.56	1.33	1.67	1.50	1.53	1.26	1.39
MPUAT-TD29	1.88	1.90	1.89	1.74	1.37	1.56	1.07	1.41	1.24
MPUAT-TD30	1.79	1.81	1.80	1.56	1.66	1.61	1.29	1.19	1.24

5. Conclusion

The 30 naturally occurring Tendu genotypes surveyed across southern Rajasthan showed substantial qualitative and quantitative phenotypic diversity. Differences were evident in foliage density, mature leaf colour, lamina surface, leaf proportions and inflorescence architecture. On a pooled basis, leaf length-to-width ratio ranged from 1.40 to 2.48, inflorescence diameter from 1.21 to 1.91 cm and inflorescence length-to-diameter ratio from 1.14 to 2.01. MPUAT-TU1, MPUAT-TB27, MPUAT-TB24, MPUAT-TP13 and MPUAT-TP19 represented particularly contrasting phenotypes for the major descriptors. The study establishes a useful baseline for morphological characterization of Tendu germplasm in southern Rajasthan and identifies material suitable for further molecular validation, conservation and utilization. Because quantitative morphological

traits may respond to environmental conditions, controlled or replicated common-environment evaluation should precede definitive breeding or domestication selections.

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