Plant Archives Vol. 25, No. 2, 2025 pp. 744-750 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.2.102

MORPHOLOGICAL EVALUATION OF INDIGENOUS TAMARIND (*TAMARINDUS INDICA* L.) GENOTYPES AT SURGUJA DISTRICT OF CHHATTISGARH, INDIA

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(Date of Receiving-23-05-2025; Date of Acceptance-31-07-2025)

ABSTRACT

Forty-two tamarind genotypes were evaluated at different villages of seven blocks in Surguja district of Chhattisgarh, India, during the years 2022-23 and 2023-24 to find out the variability in growth habit, floral and fruit characteristics of indigenous tamarind genotypes. Among the 42 tamarind genotypes, the growth habit was found upright in 15 genotypes, spreading in 9 genotypes and semi-spreading in 18 genotypes, while the tree foliage was dense in 22 genotypes and sparse in 20 genotypes while new flush colour was reddish green in 31 genotypes and reddish brown in 11 genotypes. Flower pigmentation was observed pale yellow with red veins in 20 genotypes and yellow with red veins in 22 genotypes. Furthermore, the fruit characteristics like mature pod shape was found curved in 12 genotypes, semi curved in 16 genotypes and straight in 14 genotypes, mature fruit colour was brown in 27 genotypes, reddish brown in 1 genotype and grey in 14 genotypes, mature fruit pulp colour was brown in 36 genotypes, light brown in 5 genotypes and reddish brown in 1 genotype while ripening period was early in 11 genotypes, medium in 23 genotypes and late in 8 genotypes under the present investigation.

***Key words*:** Tamarind, evaluation, morphological, variability, genotypes

Introduction

Tamarind (*Tamarindus indica* L.) is a multipurpose perennial tree of the family Fabaceae, highly valued for its ecological adaptability, nutritional richness and economic importance (Morton, 1992). It is believed to have originated in tropical Africa but is now widely distributed across South and Southeast Asia (El-Siddig *et al*., 2006). In India, tamarind is extensively cultivated in traditional agroforestry systems, homesteads and community plantations, where it plays a critical role in rural livelihoods (Kumar *et al.*, 2018). It is tolerant to drought, adaptable to marginal soils and extended life span make it particularly suited to semi-arid and sub-humid tropics (Mahapatra *et al*., 2019). The growth habit of tamarind is predominantly erect, spreading or semi-spreading, with a sturdy central trunk and an irregular, dome-shaped crown (Choudhary *et al.,* 2016). Mature trees reach heights of 12–24 m, developing a broad canopy that provides dense shade (Rao *et al*., 2014). Variation in canopy density is evident across genotypes, some accessions display dense, compact foliage, while others maintain a sparse, open crown structure (Patel *et al*., 2018). New leaf flushes typically emerge in vibrant reddish-green or reddish-brown colour before turning bright green, a colour change largely driven by anthocyanin accumulation during early leaf development (Meena *et al.*, 2021). These flush colour transitions are not only visually striking but also serve as markers of physiological activity and genotypic diversity (Verma and Lakshmanan, 2019).

Tamarind flowers are small, bisexual and borne in loose racemes, each approximately 2–2.5 cm across. Petals are pale yellow or yellow with red streaks, adaptations thought to enhance pollinator attraction (Norton *et al*., 2015). Sepals, often reddish or pink, enclose the developing buds and abscise at anthesis (Khan and Prasad, 2014). Pigmentation results from anthocyanin and carotenoid compounds, with streak intensity varying considerably among genotypes (Gowda *et al*., 2019). Variability in flower colour has been linked to differences in pollinator assemblages and fruit set success (Asha *et al*., 2022). Flowering is largely seasonal, peaking between March and May in most Indian agro-climatic zones, with fruit set depending on phenological synchrony, pollen viability and pollinator activity (Reddy *et al*., 2016). The tamarind fruit is an indehiscent legume, showing wide diversity in size, shape and surface characteristics among genotypes (Mahajan *et al*., 2019). Pods range from straight to curved and may be bulged or flattened depending on seed configuration (Gupta and Singh, 2020). They grow 3–20 cm long and change colour from green during development to mature shades of brown, grey-brown or reddish-brown at full ripeness (Chakraborty *et al*., 2021). As pods dry, their brittle epicarp facilitates easy cracking and pulp extraction. Morphological descriptors such as pod colour have been identified as critical markers in germplasm evaluation (Pooja *et al*., 2018). Within the pods, tamarind pulp is fibrous, sticky and acidulous-sweet, transitioning from green to brown or reddish-brown as ripening progresses (Ahmed *et al*., 2019). Pulp colour and texture vary by genotype and maturity stage, influencing consumer preference and marketability (Chakma *et al*., 2020). Tamarind pulp is a rich source of organic acids, sugars, pectins and polyphenolic compounds, contributing to its wide use in culinary, medicinal and industrial applications (Narayanaswamy *et al*., 2015). Uniformly coloured brown or reddish-brown pulp types are generally preferred for processing and commercial-scale applications (Kannan *et al*., 2017).

Tamarind fruits exhibit an extended development cycle, typically requiring 8–10 months from flowering to physiological maturity (Prasad & Menon, 2013; Hussain *et al*., 2019). Ripening period varies widely among genotypes, with accessions classified as early (<255 days), mid-season (255–270 days) or late (>270 days) (Rao and Dey, 2021). Pods often remain attached to trees even after ripening, gradually dehydrating and concentrating sugars, which enhances flavour and shelf life (Roy *et al*., 2022). The ripening period is considered a critical descriptor in germplasm characterization and harvest management (Singh *et al*., 2021).

The variability found in growth habit, foliage density, flower pigmentation, pod morphology, pulp colour and ripening period reflects the broad genetic base of tamarind (Ghosh *et al*., 2015). These characteristics determine agro-ecological adaptability, productivity and market acceptance. Selection and breeding programs prioritize traits such as compact canopy architecture for intensive planting, uniform pulp colour and synchronized ripening to meet industrial requirements (Lakshmanan and Mehta, 2021). Additionally, flower pigmentation and new flush colour are valuable phenotypic markers for genotype identification at early stages (Sharma *et al*., 2017). Despite its high economic and ecological importance, comprehensive characterization of tamarind germplasm remains limited in many regions, particularly central India. Systematic evaluation of morphological traits like flower pigmentation, new flush colour, growth habit, tree foliage type, pod shape and colour, pulp attributes and ripening period is crucial for germplasm conservation, selection and targeted breeding (Singh and Rao, 2020). The present study was therefore designed to document trait variability among a diverse set of tamarind genotypes, identify promising accessions for genetic improvement and provide a descriptive framework to support conservation and utilization of tamarind genetic resources.

Materials and Methods

The present study was carried out using 42 tamarind (*Tamarindus indica* L.) genotypes collected from seven blocks of Surguja district, namely Ambikapur, Batauli, Lakhanpur, Udaipur, Lundra, Mainpat and Sitapur. Surguja is located in the northern part of Chhattisgarh between 22º19’ N to 24º6’N latitude and 81º34’ E to 84º4’ E longitude with an altitude of 623 meters above from mean sea level. These genotypes were selected based on phenotypic variability and fruiting performance and the collected genotypes were evaluated using Randomized Block Design (RBD) with four replications. The morphological characterization of the genotypes was carried out using the Tamarind Descriptor developed by Central Horticulture Experiment Station (CHES), ICAR-IIHR, Godhra (2017). The fruits were randomly collected from each tamarind genotype and further analysis was done at Horticulture Processing Laboratory, Department of Fruit Science, College of Agriculture, IGKV, Raipur, Chhattisgarh.

Result and Discussion

Variability in morphological characteristics

The morphological characteristics of tamarind genotypes were recorded for the following variables *i.e.* growth habit, tree foliage type, new flush colour, flower pigmentation, mature pod shape, mature fruit (pod) colour, mature fruit pulp colour and ripening period respectively, based on tamarind key descriptor, which are presented in Table 1 and graphically depicted from Fig. 1 to 3.

Growth habit

Growth habit for forty-two genotypes of tamarind

Table 1: Variability in morphological characteristics of different tamarind genotypes.

Sr. No.	Genotypes	Growth Habit	Tree foliage type	New flush colour	Flower pigmentation	Mature pod shape	Mature fruit (pod) colour	Mature fruit pulp colour	Ripening period
1	STAM-1	Semi spreading	Dense	Reddish green	Pale yellow with red veins	Semi curved	Brown	Brown	Mid
2	STAM-2	Upright	Sparse	Reddish green	Pale yellow with red veins	Semi curved	Brown	Brown	Late
3	STAM-3	Semi spreading	Dense	Reddish green	Pale yellow with red veins	Semi curved	Grey	Brown	Mid
4	STAM-4	Semi spreading	Sparse	Reddish green	Yellow with red veins	Curved	Brown	Brown	Mid
5	STAM-5	Spreading	Sparse	Reddish green	Pale yellow with red veins	Straight	Brown	Light brown	Late
6	STAM-6	Upright	Sparse	Reddish brown	Yellow with red veins	Semi curved	Grey	Brown	Late
7	STAM-7	Upright	Sparse	Reddish green	Yellow with red veins	Straight	Brown	Brown	Early
8	STAM-8	Upright	Dense	Reddish green	Yellow with red veins	Straight	Grey	Brown	Early
9	STAM-9	Semi spreading	Dense	Reddish green	Yellow with red veins	Semi curved	Grey	Brown	Mid
10	STAM-10	Semi spreading	Dense	Reddish green	Pale yellow with red veins	Straight	Brown	Brown	Mid
11	STAM-11	Spreading	Sparse	Reddish green	Yellow with red veins	Semi curved	Brown	Light brown	Mid
12	STAM-12	Upright	Sparse	Reddish brown	Pale yellow with red veins	Semi curved	Brown	Brown	Late
13	STAM-13	Semi spreading	Dense	Reddish brown	Pale yellow with red veins	Semi curved	Brown	Brown	Mid
14	STAM-14	Semi spreading	Dense	Reddish brown	Yellow with red veins	Straight	Reddish brown	Reddish brown	Mid
15	STAM-15	Semi spreading	Dense	Reddish green	Pale yellow with red veins	Semi curved	Brown	Brown	Late
16	STAM-16	Spreading	Dense	Reddish green	Pale yellow with red veins	Straight	Brown	Light brown	Early
17	STAM-17	Spreading	Sparse	Reddish green	Pale yellow with red veins	Straight	Brown	Light brown	Mid
18	STAM-18	Upright	Sparse	Reddish green	Yellow with red veins	Semi curved	Grey	Brown	Mid
19	STAM-19	Spreading	Sparse	Reddish brown	Pale yellow with red veins	Semi curved	Brown	Brown	Early
20	STAM-20	Upright	Dense	Reddish green	Yellow with red veins	Straight	Grey	Brown	Mid
21	STAM-21	Semi spreading	Sparse	Reddish green	Yellow with red veins	Curved	Brown	Brown	Mid
22	STAM-22	Spreading	Dense	Reddish green	Yellow with red veins	Curved	Brown	Brown	Mid
23	STAM-23	Semi spreading	Sparse	Reddish green	Yellow with red veins	Curved	Brown	Brown	Early
24	STAM-24	Upright	Dense	Reddish brown	Pale yellow with red veins	Curved	Grey	Brown	Mid

Continue ...1

25	STAM-25	Upright	Sparse	Reddish green	Yellow with red veins	Semi curved	Grey	Brown	Early
26	STAM-26	Semi spreading	Sparse	Reddish green	Yellow with red veins	Straight	Grey	Brown	Late
27	STAM-27	Upright	Sparse	Reddish brown	Pale yellow with red veins	Semi curved	Grey	Brown	Mid
28	STAM-28	Spreading	Sparse	Reddish green	Yellow with red veins	Semi curved	Brown	Brown	Early
29	STAM-29	Upright	Dense	Reddish green	Yellow with red veins	Curved	Brown	Light brown	Mid
30	STAM-30	Semi spreading	Dense	Reddish brown	Pale yellow with red veins	Straight	Brown	Brown	Mid
31	STAM-31	Semi spreading	Dense	Reddish green	Pale yellow with red veins	Curved	Brown	Brown	Early
32	STAM-32	Spreading	Sparse	Reddish green	Pale yellow with red veins	Straight	Brown	Brown	Late
33	STAM-33	Semi spreading	Dense	Reddish green	Pale yellow with red veins	Curved	Grey	Brown	Mid
34	STAM-34	Spreading	Dense	Reddish green	Yellow with red veins	Curved	Brown	Brown	Mid
35	STAM-35	Upright	Sparse	Reddish brown	Pale yellow with red veins	Curved	Brown	Brown	Early
36	STAM-36	Semi spreading	Dense	Reddish brown	Yellow with red veins	Straight	Brown	Brown	Mid
37	STAM-37	Semi spreading	Dense	Reddish green	Yellow with red veins	Curved	Brown	Brown	Mid
38	STAM-38	Semi spreading	Dense	Reddish green	Yellow with red veins	Straight	Brown	Brown	Early
39	STAM-39	Upright	Dense	Reddish green	Semi curved	Straight	Grey	Brown	Mid
40	STAM-40	Semi spreading	Dense	Reddish brown	Yellow with red veins	Semi curved	Grey	Brown	Mid
41	STAM-41	Upright	Sparse	Reddish green	Pale yellow with red veins	Semi curved	Grey	Brown	Early
42	STAM-42	Upright	Sparse	Reddish green	Pale yellow with red veins	Curved	Brown	Brown	Late

Note: STAM stand for Surguja Tamarind

evaluated at Surguja district of Chhattisgarh was classified into three categories *viz*. spreading, semi spreading and upright (Table 1). Among them, 9 genotypes were recorded with spreading type of growth habit (STAM-05, STAM-11, STAM-16, STAM-17, STAM-19, STAM-22, STAM-28, STAM-32, STAM-34) while 18 genotypes were recorded with semi spreading type of growth habit (STAM-01, STAM-03, STAM-04, STAM-09, STAM-10, STAM-13, STAM-14, STAM-15, STAM-21, STAM-23, STAM-26, STAM-30, STAM-31, STAM-31, STAM-33, STAM-36, STAM-37, STAM-38, STAM-40) and remaining 15 genotypes were recorded with upright type of growth habit (STAM-02, STAM-06, STAM-07, STAM-08, STAM-12, STAM-18, STAM-20, STAM-24, STAM-25, STAM-27, STAM-29, STAM-35, STAM-39, STAM-41, STAM-42). Among all the genotype studied, the highest proportion of tree growth habit was observed in the semi spreading type (43%), followed by upright type (36%). The remaining 21% exhibited semi spreading growth habit (Fig. 1).

Tree foliage type

Tree foliage type for forty-two genotypes studied was

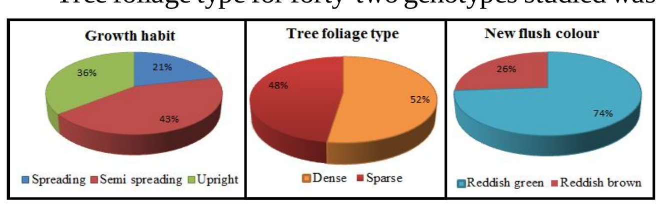

Fig. 1: Percentage of growth habit, tree foliage type and new flush colour of tamarind genotypes.

classified into two categories *viz.*, sparse and dense (Table 1). Among them, 20 genotypes were recorded with sparse type of tree foliage (STAM-02, STAM-04, STAM-05, STAM-06, STAM-07, STAM-11, STAM-12, STAM-17, STAM-18, STAM-19, STAM-21, STAM-23, STAM-25, STAM-26, STAM-27, STAM-28, STAM-32, STAM-35, STAM-41, STAM-42) and remaining 22 genotypes were recorded with dense tree foliage (STAM-01, STAM-03, SATAM-08, STAM-09, STAM-10, STAM-13, STAM-14, STAM-15, STAM-16, STAM-20, STAM-22, STAM-24, STAM-29, STAM-30, STAM-30, STAM-31, STAM-33, STAM-34, STAM-36, STAM-37, STAM-38, STAM-39, STAM-40). Among all the genotypes studied, 52% displayed dense foliage, where as 48% exhibited a sparse foliage type (Fig. 1).

New flush colour

New flush colour for forty-two tamarind genotypes studied and classified into two categories *viz.*, reddish green and reddish brown (Table 1). Among all genotypes, 31 genotypes were recorded with reddish green colour of new flush, (STAM-1, STAM-2, STAM-3, STAM-4 STAM-5, STAM-7, STAM-8, STAM-9, STAM-10, STAM-11, STAM-15, STAM-16, STAM-17, STAM-18, STAM-20, STAM-21, STAM-22, STAM-23, STAM-25, STAM-26, STAM-28, STAM-29, STAM-31, STAM-32, STAM-33 STAM-34, STAM-37, STAM-38, STAM-39, STAM-41, STAM-42) while, 11 genotypes were recorded with reddish brown colour of new flush, (STAM-6, STAM-12, STAM-13, STAM-14, STAM-19, STAM-24, STAM-27, STAM-30, STAM-35, STAM-36, STAM-40). Among all the genotypes studied, 74% exhibited reddish green new flush colour and reddish brown colour of new flush was observed in 26% of tamarind genotypes (Fig. 1).

Flower pigmentation

Flower pigmentation for forty-two genotypes studied was classified into two categories *viz.*, pale yellow with red veins and yellow with red veins (Table 1). Among all genotypes, 20 genotypes were recorded with pale yellow with red veins flower (STAM-01, STAM-02, STAM-03, STAM-05, STAM-10, STAM-12, STAM-13, STAM-15, STAM-16, STAM-17, STAM-19, STAM-19, STAM-24, STAM-27, STAM-30, STAM-31, STAM-32, STAM-33, STAM-35, STAM-41, STAM-42) whereas, 22 genotypes were recorded with yellow with red veins flower (STAM-04, STAM-06, STAM-07, STAM-08, STAM-09, STAM-11, STAM-14, STAM-18, STAM-20, STAM-21, STAM-22, STAM-23, STAM-25, STAM-26, STAM-28, STAM-29, STAM-34, STAM-36, STAM-37, STAM-38, STAM-39, STAM-40). Among all the genotype studied, yellow flowers with red veins were the most common, comprising 52% of the flower pigmentation types, while pale yellow with red veins accounted for 48% (Fig. 2).

Mature pod shape

Mature pod shape for forty-two genotypes studied was classified into three categories *viz.*, curved, semi curved and straight (Table 1). Among all genotypes, 12 genotypes were recorded with curved shape (STAM-04, STAM-21, STAM-22, STAM-23, STAM-28, STAM-30, STAM-32, STAM-33, STAM-34, STAM-36, STAM-41, STAM-42) whereas, 16 genotypes were recorded with semi curved shape (STAM-01, STAM-02, STAM-03, STAM-06, STAM-09, STAM-11, STAM-12, STAM-13, STAM-15, STAM-18, STAM-16, STAM-24, STAM-26, STAM-27, STAM-39, STAM-40) and the rest 14 genotypes were straight shaped (STAM-05, STAM-07,

Plate 1: Variation in fruit (pod) shape of tamarind genotypes

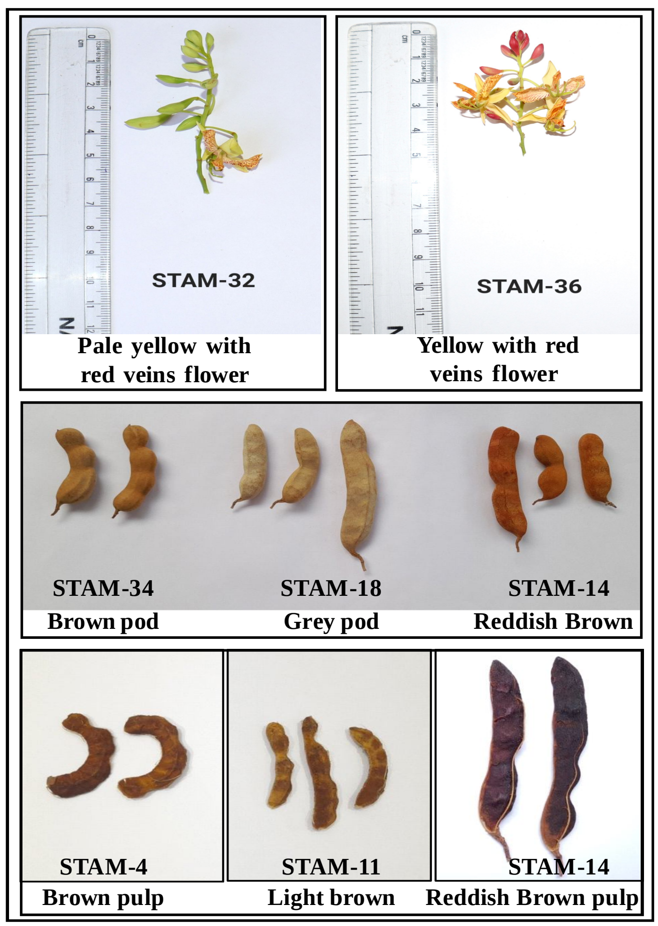

Plate 2: Variability in flower, pod and pulp colour of tamarind genotypes

STAM-08, STAM-10, STAM-14, STAM-16, STAM-17, STAM-20, STAM-25, STAM-29, STAM-31, STAM-35, STAM-37, STAM-38). The majority of pods were semi curved in shape, accounting for 38% and straight pods were observed in 33% genotypes, while 29% tamarind genotypes exhibited curved shape pod (Fig. 2).

Mature fruit (pod) colour

Mature fruit (pod) colour for forty-two genotypes studied was classified into three categories *viz.*, brown, grey and reddish brown (Table 1). Among all genotypes, 27 genotypes were recorded with brown colour (STAM-01, STAM-02, STAM-04, STAM-05, STAM-07, STAM-10, STAM-11, STAM-12, STAM-13, STAM-15, STAM-16, STAM-17, STAM-19, STAM-21, STAM-22, STAM-23, STAM-28, STAM-29, STAM-30, STAM-31, STAM-32, STAM-34, STAM-35, STAM-36, STAM-37, STAM-38, STAM-42) while, 14 genotypes were recorded with grey colour (STAM-03, STAM-06, STAM-08, STAM-9, STAM-18, STAM-20, STAM-24, STAM-25, STAM-26, STAM-27, STAM-33, STAM-39, STAM-40, STAM-41) and 1 genotype was recorded with reddish brown colour (STAM-14). Among all the genotypes studied, 64% exhibited brown fruit colour, whilte grey colour observed in 33% of tamarind genotypes and reddish brown colour fruit was noted in 3% of tamarind genotypes (Fig. 2).

Mature fruit pulp colour

Mature fruit pulp colour for forty-two genotypes studied was classified into three categories *viz.*, brown, light brown and reddish brown (Table 1). Among all genotypes, 36 genotypes were recorded with brown pulp colour (STAM-01, STAM-02, STAM-03, STAM-4, STAM-06, STAM-07, STAM-08, STAM-09, STAM-10, STAM-12, STAM-13, STAM-15, STAM-18, STAM-19, STAM-20, STAM-21, STAM-22, STAM-23, STAM-24,

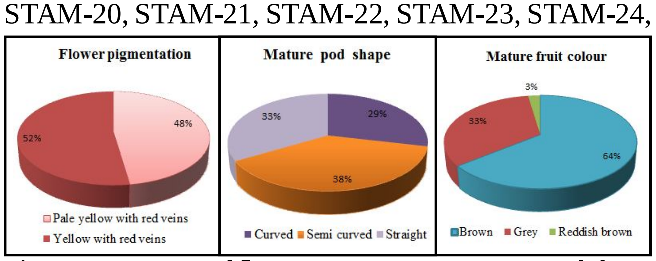

Fig. 2: Percentage of flower pigmentation, mature pod shape and mature fruit colour of tamarind genotypes.

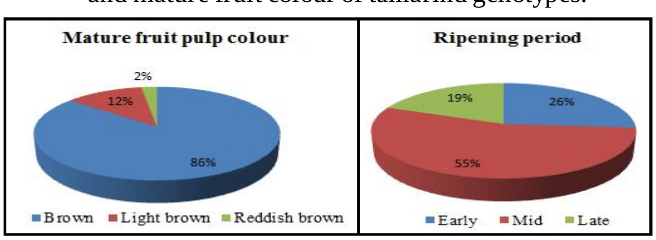

Fig. 3: Percentage of mature fruit pulp colour and ripening period of tamarind genotypes.

STAM-25, STAM-26, STAM-27, STAM-28, STAM-30, STAM-31, STAM-32, STAM-33, STAM-34, STAM-35, STAM-36, STAM-37, STAM-38, STAM-39, STAM-40, STAM-41, STAM-42) whereas, 5 genotypes were recorded with light brown pulp (STAM-5, STAM-11, STAM-16, STAM-17, STAM-29) and 1 genotype was recorded with reddish brown pulp colour (STAM-14). The larger proportion of mature fruit pulp colour was noted in colour Brown with 86 %, followed by light brown with 12%, while reddish brown colour was noted in 2% genotypes (Fig. 3).

Ripening period

Ripening period for forty-two genotypes studied was classified into three categories *viz.*, early, mid and late ripening period (Table 1). Among all genotypes, 12 genotypes were recorded with early ripening period (STAM-07, STAM-08, STAM-16, STAM-19, STAM-23, STAM-25, STAM-28, STAM-31, STAM-31, STAM-35, STAM-38, STAM-41) whereas, 23 genotypes were recorded with mid-season ripening period (STAM-01, STAM-03, STAM-04, STAM-09, STAM-10, STAM-11, STAM-13, STAM-14, STAM-17, STAM-18, STAM-20, STAM-21, STAM-22, STAM-24, STAM-27, STAM-29, STAM-30, STAM-33, STAM-34, STAM-36, STAM-37, STAM-39, STAM-40) and the rest 8 genotypes were recorded with late ripening period (STAM-02, STAM-05, STAM-06, STAM-12, STAM-15, STAM-26, STAM-32, STAM-42). Among all the genotypes evaluated, early fruit ripening was observed in 26% of the tamarind genotypes. A majority accounting for 55% exhibited mid-season ripening period, while remaining 19% were characterized by late ripening period (Fig. 3).

Conclusion

The findings of this study reveal wide morphological variation among tamarind (*Tamarindus indica* L.) genotypes, reflecting the genetic diversity and adaptability to different growing conditions. Traits such as growth habit, tree foliage type, new flush colour, flower pigmentation, mature pod shape, mature pod colour, pulp colour and ripening period showed marked differences, each offering valuable insights for genetic improvement. Variation growth habit and foliage type points to opportunities for selecting trees that combine high productivity with suitability for diverse planting systems, including high-density orchards. New flush and flower colours, beyond their ornamental appeal, serve as reliable early stage indicators of genotypic diversity, aiding identification and selection. Pod characteristics like shape and colour along with pulp colour, remain critical determinants of market acceptance and processing suitability. Differences in ripening duration further support the classification of genotypes into early, mid season and late maturing groups, providing growers with flexibility in harvesting and post harvest handling. This work emphasizes the need to conserve tamarind's genetic resources while effectively using observed phenotypic diversity in future breeding programs. Integrating morphological characterization with molecular approaches can accelerate the development of improved cultivars that meet the demands of growers, processors and consumers, ensuring sustainability and economic resilience of tamarind cultivation.

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