



Plant Archives

Journal homepage: <http://www.plantarchives.org>DOI Url : <https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.2.230>

QUALITATIVE CHARACTERIZATION OF TAMARIND (*TAMARINDUS INDICA* L.) GENOTYPES FOR IMPROVED SELECTION AND CONSERVATION

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(Date of Receiving-26-07-2025; Date of Acceptance-27-09-2025)

ABSTRACT

The current study analysed thirty-five Tamarind genotypes based on thirteen qualitative phenotypic traits. The findings reveal three distinct tree shapes (round, semicircular and irregular) and three categories of tree stature: tall, moderate and dwarf. The germplasm exhibits dense foliar canopies and dark-green leaves with substantial variability in floral and fruit-related colouration (bud and petal) as well as pod and pulp colour, pod shape and pod size variation. Early flowering predominates, suggesting a propensity for rapid reproductive onset under the prevailing environmental conditions. Seedpod dehiscence traits are characterised by a predominance of rigid exocarp-shell (pericarp) separation, indicating considerable mechanical resistance to dehiscence and potential implications for seed-dispersal dynamics and post-harvest handling. The accumulation of intra-genotypic phenotypic variability underscores the necessity for an integrated, genotype-phenotype framework that synergises qualitative descriptors with quantitative metrics to inform precision selection, marker-assisted breeding, varietal development and conservation planning within agroforestry, restoration and dryland rehabilitation programs for Tamarind. Qualitative parameters exhibited substantial variation across the characters under study.

Key words: Tamarind, Qualitative phenotypic traits, Germplasm, Variability, Breeding, Conservation

Introduction

Tamarindus indica L. is a multipurpose tropical fruit tree that belongs to Fabaceae (Leguminosae) and is diploid with a somatic chromosome number of $2n = 24$. (Mamathashree *et al.*, 2020). It is valued for its edible arils, culinary uses as a seasoning or condiment and various non-food applications derived from fruit and seed processing. The vernacular name “Tamarind” derives from the Arabic “Tamar-u’l-Hind”, reflecting the historical association with the Indian subcontinent, with the epithet related to the brownish pulp observed in ripe fruits (Pooja *et al.*, 2018).

India stands as the leading global producer of tamarind products (Bagula *et al.*, 2015). The crop is especially prolific in Madhya Pradesh, Bihar, Andhra Pradesh, Karnataka, Tamil Nadu and West Bengal.

Historically, India has exported tamarind pulp to Western markets, notably Europe and the Gulf states with more recent shipments directed to the United States.

Tamarind is a drought-tolerant perennial tree that provides livelihood benefits in arid and semiarid agroecosystems, while supporting a range of uses across the industrial, pharmaceutical and timber sectors. The fruit is the most frequently utilised component with tamarind pulp-based beverages representing the dominant use at 100%. The consumption of fruit snacks accounts for the next highest share at 98.3% of citations. In contrast, ethnomedicinal and ethnoveterinary uses receive the lowest proportions, at 13% and 15%, respectively. These citation percentages reflect the direct consumption advantages and broad appeal of the fruit itself (Satya *et al.*, 2018).

The edible arils of tamarind contribute essential micronutrients, including provitamin A carotenoids, which are bioavailable and capable of contributing to the recommended dietary allowance of retinol activity equivalents (RAE) in the approximate range of 500– 600 µg/day, depending on dietary context (Othieno, *et al.*, 2017).

Due to their adaptation and endurance to abiotic conditions such as drought and low soil fertility, Tamarind trees offer substantial advantages for community forestry and agroforestry systems. Ecological restoration and agricultural output in marginal areas are improved by their drought tolerance, dryland horticultural potential and suitability for wasteland reclamation (Karale *et al.*, 1999).

Tamarind trees have spherical crowns and stems that branch close to the ground reaching heights of around 20 to 30 m. Tamarind exhibits a slow growth rate, approximately 0.5 to 0.8 m annually. The tree has characteristic pinnately compound leaves, tough bark and deep roots. Their fruit consists of a brittle, straight or curved pod with a scaly, brownish epicarp and they produce drooping flowers on terminal racemes (El- Siddig *et al.* 2006). Tartaric acid (8.4-12.4% in ripe pods) is the primary ingredient in the pulp which contains reducing sugars, pectin, tannin, fibre and cellulose.

Tamarind predominantly exhibits an outcrossing reproductive system, with an outcrossing rate ranging from 0.67 to 0.68, although some degree of selfing also occurs. Within a population, there is significant genetic variation; relatively low variation exists between populations. The presence of herkogamous floral structures, protogyny and self- incompatibility mechanisms in Tamarind likely facilitates outcrossing under natural conditions, promoting genetic diversity within populations (Shanthi, 2003).

Open-pollinated, highly cross-pollinated Tamarind populations exhibit substantial heterogeneity and heterozygosity, especially in Karnataka (Singh *et al.*, 2010). The multipurpose tree supports livelihoods through food, ceremonial, charcoal and medicinal uses (Ranaivosona *et al.*, 2015). Elevated outcrossing drives morphological variation making genotype evaluation valuable for tree improvement. This study aims to quantify qualitative variation among Tamarind genotypes to inform genetic characterisation, improvement and conservation strategies.

Materials and Methods

Geographical location of the experimental site

The experimental studies were conducted at the Fruit Research Station, Sangareddy, Telangana, India (17°632

Table 1: The list of genotypes used for the study is given in the table below.

S. No	Name of the Genotype	S. No	Name of the Genotype
1.	SRDTi-01	19.	SRDTi-22
2.	SRDTi-02	20.	SRDTi-23
3.	SRDTi-03	21.	SRDTi-24
4.	SRDTi-04	22.	SRDTi-25
5.	SRDTi-05	23.	SRDTi-26
6.	SRDTi-06	24.	SRDTi-27
7.	SRDTi-07	25.	SRDTi-29
8.	SRDTi-08	26.	SRDTi-30
9.	SRDTi-10	27.	SRDTi-31
10.	SRDTi-11	28.	SRDTi-32
11.	SRDTi-12	29.	SRDTi-33
12.	SRDTi-13	30.	SRDTi-34
13.	SRDTi-16	31.	SRDTi-37
14.	SRDTi-17	32.	SRDTi-38
15.	SRDTi-18	33.	SRDTi-39
16.	SRDTi-19	34.	SRDTi-40
17.	SRDTi-20	35.	SRDTi-41
18.	SRDTi-21		

N latitude and 78°082 E longitude, with an elevation of 560.30 MSL) in a semi-arid tropical climate zone and the experiment was designed in Randomized Block Design (RBD) with two replications.

Genotype details

In the study, thirty-five Tamarind genotypes were evaluated, with two replications per genotype for phenotyping qualitative traits (as shown in Table 1).

Methods

Tree height (m)

The tree height was measured using an altimeter. The measurement was obtained from the lowest point on the ground to the tip of the tree. The tree height was

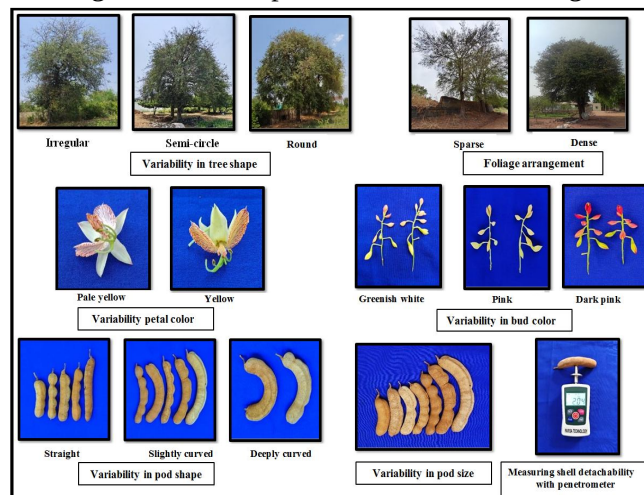


Plate 1: Tamarind (*Tamarindus indica* L.) Genotypes

then determined using the formula proposed by Gowda *et al.*, (2011).

Height of the tree = (Distance from base of the observer x tan q) + height of the observer *i.e.*, Tree height = (10 x tan q) + 1.59

Tree stature

Based on biometric measurements of tree height, it was categorized into stature classes as follows: Tall (25–30 m), Medium (20–25 m) and Dwarf (10–20 m).

Stem colour

Following the Tamarind descriptors, stem colour was determined based on visual inspection and categorized as light brown, brown and dark brown.

Leaf colour

Visual inspection was used to determine leaf colour and the Tamarind genotypes were then divided into two distinct groups based on foliar pigmentation: light green and dark green.

Foliage arrangement

The leaf arrangement was visually evaluated based on tamarind descriptors and classified into one of two categories:

- (i) Dense: where leaves were many and closely spaced
- (ii) Sparse: where leaves were more scattered and fewer in number.

Flowering time

Flowering time is classified as early, mid or late depending on the stage at which flower initiation begins.

Bud colour

Buds were visually observed and categorized by colour into greenish-white, pink and dark pink.

Petal colour

Based on Tamarind descriptors, the visual observation for petal colour was divided into two categories: pale yellow and yellow.

Pod colour

The pod colour of the thirty-five genotypes was determined using the Royal Horticultural Society (RHS) colour chart. Each genotype was assessed for light brown, brown or dark brown colour.

Pulp colour

The Royal Horticultural Society (RHS) colour chart was used to evaluate the color of the pulp in terms of:

- i) light brown
- ii) brown and

- iii) dark brown were used to evaluate different genotypes.

Pod shape

The pod shape was examined visually and classified based on tamarind descriptors as strongly curved, curved, slightly curved or straight.

Pod size

Pods were measured and classified as medium (7–13 cm), large (13–19 cm) or very large (>19 cm) using Divakara *et al.*, (2012) and Bhogave (2017) classifications with the following Tamarind descriptors.

Shell detachability

The detachability of Tamarind shell was quantitatively evaluated using a penetrometer to classify genotypes as easy (5–10 N), hard (10–20 N) or very hard (20–30 N) based on shell cracking pressure and qualitatively categorizing into three groups in the ease of pod separation as easy, slightly hard or hard.

Results and Discussion

Observations of morphological characteristics across thirty-five tamarind genotypes demonstrated substantial variability in thirteen traits. Qualitative assessments and their frequency distributions are summarized in Table 1 and 2, respectively. Differentiating accessions within a species relies on rapid characterization to identify distinctive phenotypic features, thereby elucidating the genetic diversity and composition of the collected genotypes. Phenotypic variance is quantified using specific morphological descriptors.

Tree stature

Tree stature is categorized based on the height *i.e.*, dwarf, medium and tall. Among the thirty-five genotypes evaluated, six genotypes were identified as dwarf (SRDTi-07, 17, 19, 38, 39 and 40), twenty-three genotypes as medium (SRDTi-01, 02, 03, 04, 05, 06, 08, 11, 13, 16, 18, 20, 21, 23, 24, 25, 27, 29, 30, 31, 32, 33 and 34) and the remaining six genotypes as tall (SRDTi-10, 12, 22, 26, 37 and 41).

Tree shape

A diverse range of tree shapes was observed among the genotypes, *i.e.*, irregular, semi-circular and round. The irregular tree shape was observed in twelve genotypes (SRDTi-05, 06, 07, 12, 13, 16, 17, 18, 19, 20, 21 and 35) a semi-circle tree shape was observed in sixteen genotypes (SRDTi-01, 02, 03, 04, 08, 11, 22, 23, 25, 26, 27, 30, 31, 33, 34 and 39) and a round tree shape was observed in seven genotypes (SRDTi-10, 24, 29, 37, 38, 40 and 41).

Stem colour

Three distinct stem colours were noted among the genotypes, classified as light brown, brown and dark brown. Dark brown stem colour was observed in nine genotypes (SRDTi-01, 03, 13, 22, 23, 24, 37, 40 and 41) and brown stem colour was observed in thirteen genotypes (SRDTi-02, 08, 10, 12, 20, 25, 26, 27, 29, 33, 34, 38 and 39) and light brown stem colour was observed in thirteen genotypes (SRDTi-04, 05, 06, 07, 11, 16, 17, 18, 19, 21, 30, 31 and 32).

Foliage arrangement

Foliage arrangement among the genotypes was

categorised as either sparse or dense. Dense foliage was observed in twenty genotypes (SRDTi-01, 02, 03, 04, 05, 08, 10, 11, 22, 24, 25, 27, 29, 30, 31, 37, 38, 39, 40 and 41) while a sparse arrangement was observed in fifteen genotypes (SRDTi-06, 07, 12, 13, 16, 17, 18, 19, 20, 21, 23, 26, 32, 33 and 34).

Leaf colour

Leaf colour among the genotypes was divided into two categories: light green and dark green. Dark green leaves were observed in twenty-five genotypes (SRDTi-01, 04, 05, 06, 07, 08, 10, 11, 12, 13, 17, 18, 20, 21, 25, 26, 29, 30, 31, 32, 33, 37, 39, 40 and 41) while light green

Table 2: Characterization of qualitative traits in thirty-five Tamarind genotypes.

Genotype	Tree stature	Tree shape	Stem colour	Foliar arrangement	Leaf colour	Flowering time	Bud colour
SRDTi - 01	Medium	Semi Circular	Dark Brown	Dense	Dark Green	Mid	Dark Pink
SRDTi - 02	Medium	Semi Circular	Brown	Dense	Light Green	Early	Pink
SRDTi - 03	Medium	Semi Circular	Dark Brown	Dense	Light Green	Early	Dark Pink
SRDTi - 04	Medium	Semi Circular	Light Brown	Dense	Dark Green	Early	Pink
SRDTi - 05	Medium	Irregular	Light Brown	Dense	Dark Green	Early	Pink
SRDTi - 06	Medium	Irregular	Light Brown	Sparse	Dark Green	Early	Greenish White
SRDTi - 07	Dwarf	Irregular	Light Brown	Sparse	Dark Green	Early	Pink
SRDTi - 08	Medium	Semi Circular	Brown	Dense	Dark Green	Early	Dark Pink
SRDTi - 10	Tall	Round	Brown	Dense	Dark Green	Early	Dark Pink
SRDTi - 11	Medium	Semi Circular	Light Brown	Dense	Dark Green	Mid	Dark Pink
SRDTi - 12	Tall	Irregular	Brown	Sparse	Dark Green	Mid	Pink
SRDTi - 13	Medium	Irregular	Dark Brown	Sparse	Dark Green	Mid	Dark Pink
SRDTi - 16	Medium	Irregular	Light Brown	Sparse	Light Green	Late	Dark Pink
SRDTi - 17	Dwarf	Irregular	Light Brown	Sparse	Dark Green	Mid	Dark Pink
SRDTi - 18	Medium	Irregular	Light Brown	Sparse	Dark Green	Mid	Pink
SRDTi - 19	Dwarf	Irregular	Light Brown	Sparse	Light Green	Mid	Dark Pink
SRDTi - 20	Medium	Irregular	Brown	Sparse	Dark Green	Early	Pink
SRDTi - 21	Medium	Irregular	Light Brown	Sparse	Dark Green	Mid	Dark Pink
SRDTi - 22	Tall	Semi Circular	Dark Brown	Dense	Light Green	Late	Dark Pink
SRDTi - 23	Medium	Semi Circular	Dark Brown	Sparse	Light Green	Early	Pink
SRDTi - 24	Medium	Round	Dark Brown	Dense	Light Green	Early	Dark Pink
SRDTi - 25	Medium	Semi Circular	Brown	Dense	Dark Green	Early	Pink
SRDTi - 26	Tall	Semi Circular	Brown	Sparse	Dark Green	Mid	Pink
SRDTi - 27	Medium	Semi Circular	Brown	Dense	Light Green	Early	Dark Pink
SRDTi - 29	Medium	Round	Brown	Dense	Dark Green	Early	Pink
SRDTi - 30	Medium	Semi Circular	Light Brown	Dense	Dark Green	Early	Dark Pink
SRDTi - 31	Medium	Semi Circular	Light Brown	Dense	Dark Green	Early	Pink
SRDTi - 32	Medium	Irregular	Light Brown	Sparse	Dark Green	Early	Pink
SRDTi - 33	Medium	Semi Circular	Brown	Sparse	Dark Green	Early	Pink
SRDTi - 34	Medium	Semi Circular	Brown	Sparse	Light Green	Early	Pink
SRDTi - 37	Tall	Round	Dark Brown	Dense	Dark Green	Early	Pink
SRDTi - 38	Dwarf	Round	Brown	Dense	Light Green	Early	Dark Pink
SRDTi - 39	Dwarf	Semi Circular	Brown	Dense	Dark Green	Early	Dark Pink
SRDTi - 40	Dwarf	Round	Dark Brown	Dense	Dark Green	Early	Dark Pink
SRDTi - 41	Tall	Round	Dark Brown	Dense	Dark Green	Early	Dark Pink

Continue 2 ...

Genotype	Petal colour	Pod colour	Pulp colour	Pod shape	Pod size	Shell detachability
SRDTi - 01	Pale Yellow	Light Brown	Brown	Curved	Very Big	Hard
SRDTi - 02	Yellow	Light Brown	Brown	Curved	Medium	Hard
SRDTi - 03	Yellow	Greyish Brown	Brown	Curved	Very Big	Hard
SRDTi - 04	Yellow	Light Brown	Dark Brown	Slightly Curved	Medium	Easy
SRDTi - 05	Yellow	Reddish Brown	Reddish Brown	Slightly Curved	Medium	Easy
SRDTi - 06	Pale Yellow	Dark Brown	Dark Brown	Slightly Curved	Big	Hard
SRDTi - 07	Pale Yellow	Brown	Brown	Slightly Curved	Medium	Hard
SRDTi - 08	Pale Yellow	Dark Brown	Dark Brown	Curved	Big	Hard
SRDTi - 10	Yellow	Brown	Dark Brown	Curved	Big	Hard
SRDTi - 11	Yellow	Light Brown	Dark Brown	Slightly Curved	Big	Hard
SRDTi - 12	Yellow	Greyish Brown	Dark Brown	Deeply Curved	Medium	Hard
SRDTi - 13	Pale Yellow	Dark Brown	Dark Brown	Curved	Small	Hard
SRDTi - 16	Pale Yellow	Dark Brown	Dark Brown	Straight	Small	Hard
SRDTi - 17	Pale Yellow	Dark Brown	Brown	Curved	Very Big	Easy
SRDTi - 18	Pale Yellow	Light Brown	Dark Brown	Curved	Medium	Hard
SRDTi - 19	Yellow	Brown	Light Brown	Curved	Big	Hard
SRDTi - 20	Pale Yellow	Light Brown	Light Brown	Curved	Big	Hard
SRDTi - 21	Yellow	Greyish Brown	Dark Brown	Slightly Curved	Big	Hard
SRDTi - 22	Pale Yellow	Light Brown	Dark Brown	Curved	Big	Hard
SRDTi - 23	Pale Yellow	Brown	Light Brown	Curved	Medium	Easy
SRDTi - 24	Pale Yellow	Dark Brown	Brown	Deeply Curved	Medium	Hard
SRDTi - 25	Pale Yellow	Dark Brown	Brown	Curved	Medium	Hard
SRDTi - 26	Pale Yellow	Light Brown	Dark Brown	Curved	Medium	Easy
SRDTi - 27	Pale Yellow	Light Brown	Dark Brown	Slightly Curved	Big	Hard
SRDTi - 29	Yellow	Greyish Brown	Light Brown	Slightly Curved	Big	Hard
SRDTi - 30	Pale Yellow	Brown	Brown	Curved	Big	Hard
SRDTi - 31	Pale Yellow	Brown	Dark Brown	Curved	Big	Hard
SRDTi - 32	Pale Yellow	Greyish Brown	Dark Brown	Curved	Big	Very Hard
SRDTi - 33	Pale Yellow	Greyish Brown	Dark Brown	Curved	Big	Hard
SRDTi - 34	Pale Yellow	Dark Brown	Light Brown	Straight	Medium	Easy
SRDTi - 37	Pale Yellow	Brown	Light Brown	Curved	Big	Hard
SRDTi - 38	Pale Yellow	Greyish Brown	Light Brown	Slightly Curved	Medium	Very Hard
SRDTi - 39	Pale Yellow	Light Brown	Dark Brown	Slightly Curved	Big	Hard
SRDTi - 40	Pale Yellow	Greyish Brown	Brown	Slightly Curved	Big	Hard
SRDTi - 41	Pale Yellow	Brown	Brown	Curved	Big	Hard

leaves were observed in ten genotypes (SRDTi-02, 03, 16, 19, 22, 23, 24, 27, 34 and 38).

Flowering time

The genotypes exhibited variability in flowering time categorized as early, mid and late flowering stages. Early flowering was recorded in twenty-four genotypes (SRDTi-02, 03, 04, 05, 06, 07, 08, 10, 20, 23, 24, 25, 27, 29, 30, 31, 32, 33, 34, 37, 38, 39, 40 and 41),

Mid-flowering was recorded in nine genotypes (SRDTi-01, 11, 12, 13, 17, 18, 19, 21 and 26) and late flowering was recorded in two genotypes (SRDTi-16 and 22).

Bud colour

Bud colour among the tamarind genotypes varied significantly with three distinct categories observed: greenish white, pink and dark pink. Among the thirty-five genotypes, Greenish white bud colour was observed in

one genotype (SRDTi-06), pink bud colour in sixteen genotypes (SRDTi-02, 04, 05, 07, 12, 18, 20, 23, 25, 26, 29, 31, 32, 33, 34 and 37) and dark pink bud colour in eighteen genotypes (SRDTi-01, 03, 08, 10, 11, 13, 16, 17, 19, 21, 22, 24, 27, 30, 38, 39, 40 and 41).

Petal colour

Genotypes varied for the colour of the petals exhibited as yellow and pale yellow. Among 35 genotypes, pale yellow petal colour was observed in twenty-five genotypes (SRDTi-01, 06, 07, 08, 13, 16, 17, 18, 20, 22, 23, 24, 25, 26, 27, 30, 31, 32, 33, 34, 37, 38, 39, 40 and 41) and yellow colour was observed in ten genotypes (SRDTi-02, 03, 04, 05, 10, 11, 12, 19, 21 and 29).

Pod colour

Greyish brown, light brown, brown, dark brown and reddish brown were among the colours observed as per the Tamarind descriptors. Greyish brown pod colour was

Table 3: Frequency distribution of qualitative traits in thirty-five Tamarind genotypes.

Traits	Classes	Frequency
Tree stature	Dwarf	06
	Medium	23
	Tall	06
Tree shape	Irregular	12
	Semi-circle	16
	Round	07
Stem colour	Dark brown	09
	Brown	13
	Light brown	13
Foliage arrangement	Dense	20
	Sparse	15
Leaf colour	Dark green	25
	Light green	10
Flowering time	Early	24
	Mid	09
	Late	02
Bud colour	Greenish white	01
	Pink	16
	Dark pink	18
Petal colour	Pale yellow	25
	Yellow	10
Pod colour	Reddish brown	01
	Greyish brown	08
	Light brown	08
	Brown	10
	Dark brown	08
Pulp colour	Reddish brown	01
	Dark brown	17
	Brown	10
	Light brown	07
Pod shape	Straight	02
	Slightly curved	11
	Curved	20
	Deeply curved	02
Pod size	Very big (>19 cm)	03
	Big (13-19 cm)	18
	Medium (7-13 cm)	12
	Small (<13 cm)	02
Shell detachability	Very hard	02
	Hard	27
	Easy	06

recorded in eight genotypes (SRDTi-03, 12, 21, 29, 32, 33, 38 and 40), light brown pod colour was recorded in ten genotypes (SRDTi-01, 02, 04, 11, 18, 20, 22, 26, 27 and 39), brown pod colour was recorded in eight genotypes (SRDTi-07, 10, 19, 23, 30, 31, 37 and 41) dark

The brown pod colour was recorded in eight genotypes (SRDTi-06, 08, 13, 16, 17, 24, 25, and 34) and reddish brown was recorded in one genotype (SRDTi-05).

Pulp colour

Pulp colour was classified into light brown, brown, dark brown and reddish brown. Light brown pulp colour was observed in seven genotypes (SRDTi-19, 20, 23, 29, 34, 37 and 38), brown pulp colour was observed in ten genotypes (SRDTi-01, 02, 03, 07, 17, 24, 25, 30, 40 and 41), dark brown pulp colour was observed in seventeen genotypes (SRDTi-04, 06, 08, 10, 11, 12, 13, 16, 18, 21, 22, 26, 27, 32, 33 and 39) and reddish brown pulp colour was observed in one genotype (SRDTi-05).

Pod shape

Pod shapes were classified as straight, slightly curved, curved and deeply curved. Straight pods were recorded in two genotypes (SRDTi-16 and 34), slightly curved pods in eleven genotypes (SRDTi-04, 05, 06, 07, 11, 21, 27, 29, 38, 39 and 40), curved pods in twenty genotypes (SRDTi-01, 02, 03, 08, 10, 13, 17, 18, 19, 20, 22, 23, 25, 26, 30, 31, 32, 33, 37 and 41) and deeply curved pods in two genotypes (SRDTi-12 and 24).

Pod size

Pod sizes were divided into four groups based on length, width and curvature: small, medium, big and very big. Small pod size was observed in two genotypes (SRDTi-13 and 16), medium pod size was observed in twelve genotypes (SRDTi-02, 04, 05, 07, 12, 18, 23, 24, 25, 26, 34 and 38), a big pod size was observed in eighteen genotypes (SRDTi-06, 08, 10, 11, 19, 20, 21, 22, 27, 29, 30, 31, 32, 33, 37, 39, 40 and 41) and very big pod size was observed in three genotypes (SRDTi-01, 03 and 17).

Shell detachability

The ease of separating the shell from the pod was categorised as easy, hard or very hard. Easy shell detachability was recorded in six genotypes (SRDTi-04, 05, 17, 23, 26 and 34), hard shell detachability was recorded in twenty-seven genotypes (SRDTi-01, 02, 03, 06, 07, 08, 10, 11, 12, 13, 16, 18, 19, 20, 21, 22, 24, 25, 27, 29, 30, 31, 33, 37, 39, 40 and 41) and very hard shell detachability two genotypes (SRDTi-32 and 38).

Singh and Nandini (2011) reported that reproductive organ colouration can serve not only as a morphological marker in progeny testing but also potentially enhance fruit set by attracting pollinators. Similar findings have been reported in tamarind by Prabhushankar and Melanta (2004) and Rao and Subramanyam (2010). Phenological variations are closely tied to climatic factors; high rainfall, land-use patterns and both abiotic and biotic stresses can influence the vegetative and reproductive development of genotypes (Fandohan *et al.*, 2015 and Okello *et al.*, 2018).

Conclusion

Thirty-five tamarind genotypes show diversity across thirteen morpho-phenotypic traits, including tree shape, stem colour, foliage arrangement and leaf colour. Flowering is mostly early with variation in bud and petal colours, while pods differ in size, shape, shell hardness and pulp colour. A genotype–phenotype matrix, multi-environment trials and pollinator studies can guide breeding, conservation and sustainable agroforestry practices.

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