



Exploring the Morphological and Biochemical Diversity of Tamarind (*Tamarindus indica* L.) in Karnataka

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ABSTRACT

Background: The present investigation was carried out at the Hoskote Forest Station, Bengaluru Rural District, India. The plant material consisted of Twenty eight accessions which were planted in June, 1998. The observations for the present investigation were recorded during 2018-19 and 2019-20 fruiting seasons. The RCBD design was followed to control variability and improve the accuracy of experimental results.

Methods: The accessions were evaluated for different morphological traits viz. bearing habit, fruit characteristics such as shape, pulp colour, length, width, thickness, weight, pulp weight per fruit, seed weight per fruit, number of seeds per fruit, shell weight per fruit, vein weight per fruit and their corresponding percentages (seed, pulp, fibre and shell). It also explores phytochemical traits in tamarind pulp, including titratable acidity (%), TSS (°Brix), pH, ascorbic acid (mg/100 g) and tartaric acid (%). Nutrient content in tamarind pulp, specifically manganese, potassium, calcium and magnesium was also analysed. The correlation co-efficient among all the possible morpho and phytochemical trait combinations were analyzed statistically.

Result: Significant differences among the tamarind accessions were noted, STAM-28 and HSTAM-40 recorded the highest values in all the growth, pod and yield characters. Correlation analysis revealed that Fruit weight was highly significant and showed association with fibre weight, thickness of fruit, pulp weight, fruit width, fruit length, shell weight, tartaric acid and titratable acidity content of pulp. This suggests that there is potential to select traits that can help identify superior genotypes/accessions in terms of both quality and yield of tamarind.

Key words: Correlation, Morphological traits, Phytochemical, Tamarind, Yield.

INTRODUCTION

Tamarind (*Tamarindus indica* L.) is a highly heterozygous dicotyledonous tree in the Fabaceae family, known for cross-pollination and genetic variability. It grows up to 25 metres, with alternately even-pinnate leaves and raceme flowers. The oblong, curved fruits have firm, dark brown pulp and are commonly grown in tropical and subtropical regions. Tamarind fruit has diverse industrial and medicinal uses, with the pulp, seeds, trunk and leaves serving multiple purposes. The ripe fruit comprises 54% pulp, 35% seed and 11% fibre and shell. Its pulp contains 20.8 g moisture, 64.4 g carbohydrates, 5.8 g fiber, 3.4 g protein, 2.9 g minerals and 232-285 kcal per 100 g (Muzaffar, 2017). It is highly acidic, with tartaric acid content ranging from 12.5% to 24.8% and contains leucoanthocyanidin in brown pulp and anthocyanin in red pulp.

India ranks first among different countries with an area and production of 38,855 ha and 151,282 MT, respectively. Karnataka accounts for an area and production of 9,560 ha and 33693 MT, respectively (Anonymaus, 2024). India is the only country to tap the potential of tamarind extensively with the annual pulp production of 3 lakh tones, of which 4,000 tonnes is exported to Europe, North America, USA, Australia, African, Sri Lanka, Malaysia and Pakistan after local consumption (El-Siddig *et al.*, 2006).

It is better to concentrate only on the genetically superior trees in relation to neighbouring ones and trees

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selected within the ecological zones. The degree of variability and quantitative assessment of each trait will reveal the potential of each tree and the opportunities for improving desirable and economically important traits through selective breeding. Understanding the nature and

extent of variation and correlation between different traits and yield, is essential for selecting superior accessions. Before formulating a selection programme, it is important to assess the variability within accessions and use this information to enhance fruit and pulp production.

Many elite tamarind trees, originally identified from seedling sources, have been vegetatively propagated and preserved in gene banks. Various genotypes, propagated through vegetative methods, are being cultivated across different regions of Karnataka. These genotypes need to be assessed for yield and related traits. The superior accessions could play a crucial role in selection processes and in the development of new tamarind cultivars, providing valuable insights for the enhancement of the crop.

MATERIALS AND METHODS

The study was carried out for two years, during 2018-19 and 2019-20 fruiting seasons, at the research wing of the Department of Forest, Government of Karnataka, maintained at Hosakote Forest Station, Bengaluru Rural District, to identify superior genotypes among the 28 established genotypes planted in 1998. Fifteen pods were randomly collected from all directions of the tree for each of the 28 genotypes.

This study assessed various parameters of tamarind fruit, including bearing habit, fruit characteristics, phytochemical properties and nutrient content. Bearing habit was categorized into regular, prolific and alternate bearers. Fruit shape was classified as curved or straight and pulp colour was determined using the RHS colour chart. The fruit's dimensions (length, width, thickness) and weight (fruit, pulp, seeds, shell, fibre) were measured, with percentages of seed, pulp, fiber and shell calculated based on total fruit weight.

Phytochemical traits such as titratable acidity (%), total soluble solids (°Brix), pH, ascorbic acid (mg/100 g) and tartaric acid (%) were analyzed using standard methods. Nutrient content including manganese, potassium, calcium and magnesium, was determined using DTPA (Diethylene Triamine penta acetic acid) method, flame photometer method, oxalatory method and thiazole yellow method respectively. The experimental data collected on various parameters during the study were statistically analyzed using the Analysis of Variance (ANOVA) method for a randomized complete block design (RCBD). Nutrients such as Mg, Ca, K and Mn were analyzed for all 28 genotypes at the Department of Horticulture, College of Agriculture, UAS, GKVK, Bengaluru.

The correlation coefficients for all possible combinations of morphometric and phytochemical traits, based on fruit shape and levels, were calculated using the formula provided by Al-Jibouri *et al.* (1958).

$$\text{Morphometric correlation} = r_{xy}(m) = \frac{\text{Cov}_{xy}(m)}{\sqrt{V_x(m) \times V_y(m)}}$$

$$\text{Phytochemical correlation} = r_{xy}(p) = \frac{\text{Cov}_{xy}(p)}{\sqrt{V_x(p) \times V_y(p)}}$$

Where,

$\text{Cov}_{xy}(m)$ = Morphometric covariance between x and y.

$\text{Cov}_{xy}(p)$ = Phytochemical covariance between x and y.

$V_x(m)$ = Morphometric variance of character 'x'.

$V_x(p)$ = Phytochemical variance of character 'x'.

$V_y(m)$ = Morphometric variance of character 'y'.

$V_y(p)$ = Phytochemical variance of character 'y'.

RESULTS AND DISCUSSION

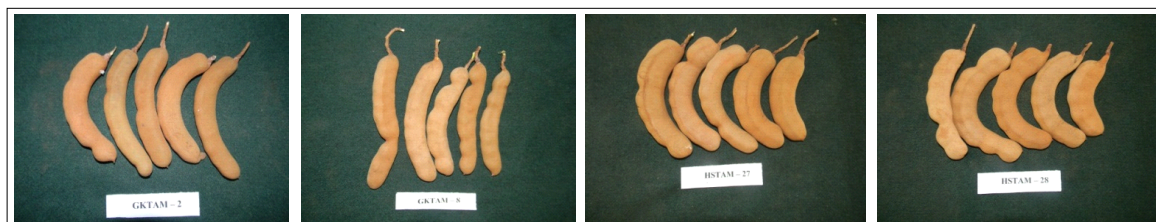
The growth traits of 28 tamarind genotypes, including bearing habit, fruit shape and pulp colour, were analyzed and are presented in Table 1. All the genotypes exhibited a regular bearing habit during the 2018-19 and 2019-20 seasons. Straight and curved fruits were observed (Fig 1). The straight fruit shape was observed in genotypes HSTAM-29, HSTAM-30, HSTAM-32, HSTAM-33, HSTAM-39, HSTAM-48, HSTAM-49 and HSTAM-50, while the remaining genotypes were having curved fruit shape. The pulp colour of the tamarind genotypes was classified into five categories: reddish brown, light brown, deep brown, strong brown and brown. Strong brown pulp was observed in HSTAM-29, while brown was seen in HSTAM-26, 34 and 38. Deep brown appeared in HSTAM-24, 25 and 33. Reddish brown was recorded in eight genotypes, including HSTAM-23, 27 and 28, while light brown was noted in fourteen genotypes, including HSTAM-31, 32 and 35. The results are in similar line as reported by Rao and Subramanyam (2010); Algabal *et al.* (2012) and Bhogave *et al.* (2018).

Among the pooled averages morphological trait data represented in Table 2, the maximum fruit length was recorded in T_6 [HSTAM-28(21.36 cm)], which was statistically at par with T_5 [HSTAM-27 (19.73 cm)], T_{26} [HSTAM-48 (18.91 cm)] and T_{22} [HSTAM-44 (17.74 cm)]. The shortest fruit length was observed in T_{14} [HSTAM-36 (11.23 cm)]. For fruit width, the maximum value was recorded in T_6 [HSTAM-28 (3.34 cm)], followed by T_{26} [HSTAM-48 (3.27 cm)], T_4 [HSTAM-26 (2.87 cm)] and T_{23} [HSTAM-45 (2.87 cm)]. The minimum fruit width was noted in T_{14} [HSTAM-36(2.20 cm)]. The maximum fruit thickness was observed in T_5 [HSTAM-27/KLR-13 (2.19 cm)], followed by T_{22} [HSTAM-44(2.07 cm)], T_{21} [HSTAM-43(2.04 cm)] and T_6 [HSTAM-28 (1.96 cm)]. The minimum thickness was recorded in T_{14} [HSTAM-36 (1.24 cm)]. Regarding fruit weight, the maximum value was observed in T_6 [HSTAM-28(30.25 g)], which was statistically at par with T_{18} [HSTAM-40 (29.37 g)], T_{26} [HSTAM-48 (29.01 g)] and T_2 [HSTAM-24 (28.84 g)]. The minimum fruit weight was recorded in T_{14} [HSTAM-36 (15.99 g)].

The data on pulp weight per fruit are presented in Table 2. The maximum pulp weight per fruit was observed in T_6 [HSTAM-28(15.50 g)], which was statistically at par with T_2 [HSTAM-24(15.42 g)], T_{26} [HSTAM-48 (14.82 g)] and T_{13} [HSTAM-35(13.88 g)]. The minimum pulp weight per fruit was recorded in T_{14} [HSTAM-36(6.87 g)]. For seed weight

Table 1: Bearing habit, shape of fruit and colour of pulp of tamarind genotypes maintained at Hosakote Forest Station, Bengaluru rural district.

Treatment	Genotype	Bearing habit	Shape of fruit	Colour of pulp
T ₁	HSTAM-23	Regular	Curved	Reddish brown
T ₂	HSTAM-24	Regular	Curved	Deep brown
T ₃	HSTAM-25	Regular	Curved	Dark brown
T ₄	HSTAM-26	Regular	Curved	Brown
T ₅	HSTAM-27	Regular	Curved	Reddish brown
T ₆	HSTAM-28	Regular	Curved	Reddish brown
T ₇	HSTAM-29	Regular	Straight	Strong brown
T ₈	HSTAM-30	Regular	Straight	Reddish brown
T ₉	HSTAM-31	Regular	Curved	Light brown
T ₁₀	HSTAM-32	Regular	Straight	Light brown
T ₁₁	HSTAM-33	Regular	Straight	Dark brown
T ₁₂	HSTAM-34	Regular	Curved	Brown
T ₁₃	HSTAM-35	Regular	Curved	Light brown
T ₁₄	HSTAM-36	Regular	Curved	Light brown
T ₁₅	HSTAM-37	Regular	Curved	Light brown
T ₁₆	HSTAM-38	Regular	Curved	Brown
T ₁₇	HSTAM-39	Regular	Straight	Reddish brown
T ₁₈	HSTAM-40	Regular	Curved	Reddish brown
T ₁₉	HSTAM-41	Regular	Curved	Light brown
T ₂₀	HSTAM-42	Regular	Curved	Light brown
T ₂₁	HSTAM-43	Regular	Curved	Light brown
T ₂₂	HSTAM-44	Regular	Curved	Light brown
T ₂₃	HSTAM-45	Regular	Curved	Light brown
T ₂₄	HSTAM-46	Regular	Curved	Light brown
T ₂₅	HSTAM-47	Regular	Curved	Light brown
T ₂₆	HSTAM-48	Regular	Straight	Reddish brown
T ₂₇	THTAM-49	Regular	Straight	Reddish brown
T ₂₈	GHTAM-50	Regular	Straight	Light brown

**Fig 1:** Variability in size and shape of fruits of tamarind accessions.

per fruit, the maximum value was recorded in T₆ [HSTAM-28(8.01 g)], which was at par with T₃ [HSTAM-25(7.72 g)], T₁₈ [HSTAM-40(7.19 g)] and T₁₃ [HSTAM-35(6.99 g)]. The minimum seed weight per fruit was observed in T₁₄ [HSTAM-36 (4.11 g)].

The data on different fruit characters presented in Table 3 shows, the maximum number of seeds per fruit in T₆ [HSTAM-28(11.55)], followed by T₁₂, T₂₅ and T₁₃. The least number of seeds per fruit was recorded in T₉ [HSTAM-31(6.52)]. The maximum shell weight per fruit was recorded in T₁₈ [HSTAM-40(7.09 g)], followed by T₃ [HSTAM-25(6.47 g)], T₁₃ [HSTAM-35(6.79 g)] and T₂ [HSTAM-24(6.62 g)].

The minimum shell weight was observed in T₁₄ [HSTAM-36(2.99 g)]. For fibre weight per fruit, the maximum value was recorded in T₆ [HSTAM-28(1.44 g)], which was at par with T₁₈ [HSTAM-40(1.43 g)], T₃ [HSTAM-25(1.36 g)] and T₂ [HSTAM-24(1.29 g)]. The minimum fibre weight was observed in T₁₄ [HSTAM-36(0.59 g)]. HSTAM-28 exhibited superior performance in most fruit traits, with a few accessions showing similar results in certain traits. This suggests that HSTAM-28 significantly influenced all fruit traits, either through direct or indirect effects. Similar variation in fruit parameter of tamarind was noticed by Divakara (2008); Singh (2014); Reddy *et al.* (2024).

Table 2: Length of fruit, width of fruit, thickness of fruit weight of fruit and pulp weight per fruit of tamarind genotypes maintained at Hosakote Forest Station, Bengaluru rural district.

Treatment	Genotype	Length of fruit (cm)	Width of fruit (cm)	Thickness of fruit (cm)	Weight of fruit (g)	Pulp weight per fruit (g)	Seed weight per fruit (g)
T ₁	HSTAM-23	12.11	2.87	1.60	22.22	10.42	5.51
T ₂	HSTAM-24	16.60	2.58	1.82	28.84	15.42	6.47
T ₃	HSTAM-25	16.40	2.58	1.75	26.24	13.88	7.72
T ₄	HSTAM-26	15.49	2.87	1.87	24.93	11.57	5.48
T ₅	HSTAM-27	19.73	2.75	2.19	24.67	12.23	5.89
T ₆	HSTAM-28	21.36	3.34	1.96	30.25	15.50	8.01
T ₇	HSTAM-29	15.60	2.27	1.68	18.32	8.69	5.31
T ₈	HSTAM-30	14.29	2.49	1.71	20.32	10.13	5.22
T ₉	HSTAM-31	16.68	2.25	1.70	18.26	9.45	4.77
T ₁₀	HSTAM-32	15.48	2.41	1.81	17.28	8.16	4.32
T ₁₁	HSTAM-33	15.88	2.33	1.73	21.90	10.63	5.05
T ₁₂	HSTAM-34	16.57	2.76	1.82	19.14	9.54	5.50
T ₁₃	HSTAM-35	16.97	2.71	1.49	27.31	13.62	6.99
T ₁₄	HSTAM-36	11.23	2.20	1.24	15.99	6.87	4.11
T ₁₅	HSTAM-37	16.01	2.61	1.69	18.48	8.98	4.90
T ₁₆	HSTAM-38	17.18	2.56	1.80	19.40	10.03	4.70
T ₁₇	HSTAM-39	16.29	2.73	1.66	23.90	11.81	5.71
T ₁₈	HSTAM-40	16.53	2.60	1.71	29.37	12.32	7.19
T ₁₉	HSTAM-41	16.34	2.71	1.64	23.22	12.45	5.98
T ₂₀	HSTAM-42	15.92	2.68	1.56	25.06	11.82	6.29
T ₂₁	HSTAM-43	17.19	2.70	2.04	21.99	10.66	5.68
T ₂₂	HSTAM-44	17.74	2.83	2.07	25.87	12.37	6.23
T ₂₃	HSTAM-45	15.45	2.82	1.78	17.52	8.64	4.51
T ₂₄	HSTAM-46	16.09	2.56	1.65	17.21	8.95	4.51
T ₂₅	HSTAM-47	16.89	2.73	1.83	26.15	11.76	5.64
T ₂₆	HSTAM-48	18.91	3.27	1.79	29.01	14.82	6.15
T ₂₇	HTAM-49	15.64	2.84	1.82	26.46	12.82	5.86
T ₂₈	GHTAM-50	16.43	2.44	1.84	18.93	9.34	4.60
Mean		16.32	2.66	1.76	22.79	11.17	5.61
Range	Max.	21.36	3.34	2.19	30.25	15.50	8.01
	Min.	11.23	2.20	1.24	15.99	6.87	4.11
Ftest (p<0.05)		*	*	*	*	*	*
S.Em±		0.72	0.11	0.10	0.83	0.44	0.25
C.D at 5%		2.04	0.31	0.29	2.34	1.25	0.70

The maximum seed percentage was recorded in T₃ [HSTAM-25(29.40%)], followed by T₇ [HSTAM-29(29.08%)], T₁₂ [HSTAM-34(28.77%)] and T₁₅ [HSTAM-37(26.68%)]. The minimum seed percentage was observed in T₂₆ [HSTAM-48(21.17%)] (Fig 2). For pulp percentage, the maximum value was observed in T₁₉ [HSTAM-41(53.77%)], followed by T₂ [HSTAM-24(53.44%)], T₃ [HSTAM-25(52.83%)] and T₂₄ [HSTAM-46(51.83%)]. The minimum pulp percentage was recorded in T₁₈ [HSTAM-40(41.54%)] (Table 3).

The data on fibre and shell percentages are presented in Table 3. The maximum fibre percentage was recorded in T₂₁ [HSTAM-43(5.78%)], followed by T₆ [HSTAM-28(5.11%)] and T₄ [HSTAM-26(4.92%)]. The minimum fibre percentage

was observed in T₁₄ [HSTAM-41(3.76%)]. For shell percentage, the maximum value was observed in T₂₄ [HSTAM-46(30.07%)], followed by T₁₈ [HSTAM-40(25.26%)], T₁₃ [HSTAM-35(24.88%)] and T₁₀ [HSTAM-32(24.45%)]. The minimum shell percentage was recorded in T₆ [HSTAM-28(18.10%)]. Similar variation was in Hanamashetti and Sulikeri (1997); Mastan *et al.* (1997); Prabhushankar *et al.* (2004) and Reddy *et al.* (2023).

The phytochemical traits, including titratable acidity, total soluble solids (TSS) and pH, were assessed across different tamarind genotypes (Table 4). The maximum titratable acidity was recorded in the genotype T₁₂ [HSTAM-34] with 17.69%, followed by T₆ [HSTAM-28] (15.61%),

Table 3: Number of seed per fruit, shell weight per fruit (g), fibre weight per fruit (g), seed (%), pulp (%), fibre (%) and shell (%) of tamarind genotypes maintained at Hosakote Forest Station, Bengaluru rural district.

Treatment	Genotype	Number of seed per fruit	Shell weight per fruit (g)	Fibre weight per fruit (g)	Seed (%)	Pulp (%)	Fibre (%)	Shell (%)
T ₁	HSTAM-23	7.42	4.84	1.05	24.96	47.19	4.75	21.88
T ₂	HSTAM-24	7.69	6.62	1.29	22.41	53.43	4.47	22.95
T ₃	HSTAM-25	8.59	6.47	1.36	29.40	52.83	4.80	22.88
T ₄	HSTAM-26	9.85	5.05	1.22	22.01	46.54	4.92	20.32
T ₅	HSTAM-27	8.77	5.19	1.20	23.98	49.75	4.87	21.11
T ₆	HSTAM-28	11.55	5.10	1.44	21.98	51.20	5.11	18.10
T ₇	HSTAM-29	7.25	4.27	0.77	29.08	47.59	4.20	23.38
T ₈	HSTAM-30	8.03	3.95	0.83	25.92	50.29	4.13	19.61
T ₉	HSTAM-31	6.52	4.13	0.86	26.10	51.55	4.70	22.50
T ₁₀	HSTAM-32	6.81	4.20	0.79	25.12	47.63	4.62	24.45
T ₁₁	HSTAM-33	9.29	4.25	0.95	23.15	48.81	4.37	19.52
T ₁₂	HSTAM-34	11.39	4.34	1.16	28.77	49.86	6.09	22.69
T ₁₃	HSTAM-35	10.96	6.79	1.24	25.63	49.95	4.53	24.88
T ₁₄	HSTAM-36	7.09	2.99	0.59	25.78	43.12	3.68	18.73
T ₁₅	HSTAM-37	10.56	4.27	0.85	26.68	48.85	4.63	23.22
T ₁₆	HSTAM-38	9.45	4.43	0.86	24.27	51.80	4.42	22.90
T ₁₇	HSTAM-39	9.38	5.34	1.05	23.91	49.43	4.38	22.37
T ₁₈	HSTAM-40	10.82	7.43	1.43	24.42	41.88	4.87	25.26
T ₁₉	HSTAM-41	10.80	5.17	0.87	25.85	53.77	3.76	22.30
T ₂₀	HSTAM-42	10.90	5.40	1.05	25.11	47.16	4.18	21.53
T ₂₁	HSTAM-43	10.50	5.23	1.27	25.88	48.54	5.78	23.79
T ₂₂	HSTAM-44	10.15	5.51	1.26	24.10	47.91	4.87	21.32
T ₂₃	HSTAM-45	10.52	4.25	0.81	25.80	49.40	4.61	24.31
T ₂₄	HSTAM-46	9.91	5.18	0.82	26.22	51.83	4.74	30.07
T ₂₅	HSTAM-47	11.37	5.29	1.18	21.60	45.05	4.51	20.25
T ₂₆	HSTAM-48	7.63	5.36	1.22	21.17	51.02	4.19	18.44
T ₂₇	THTAM-49	8.25	5.50	1.22	22.16	48.47	4.60	20.82
T ₂₈	GHTAM-50	7.40	4.31	0.77	24.34	49.38	4.09	22.80
Mean		9.24	5.03	1.05	24.85	49.08	4.60	22.23
Range	Max.	11.55	7.43	1.44	29.40	53.77	6.09	30.07
	Min.	6.52	2.99	0.59	21.17	41.88	3.76	18.10
Ftest (p<0.05)		*	*	*	*	*	*	*
S.Em±		0.34	0.27	0.04	0.56	1.86	0.13	0.58
C.D at 5%		0.95	0.77	0.11	1.59	5.29	0.37	1.64

T₃ [HSTAM-25] (15.13%) and T₂₅ [HSTAM-47] (14.78%). Conversely, the minimum titratable acidity was observed in T₁₇ [HSTAM-43] (7.36%). For total soluble solids (TSS), the maximum value was found in T₁₅ [HSTAM-37] with 18.65 °Brix, which was comparable to T₂₂ [HSTAM-44] (17.84 °Brix), T₁₃ [HSTAM-35] (16.75 °Brix) and T₂₇ [THTAM-49] (17.31 °Brix). The minimum TSS was recorded in T₃ [HSTAM-25] with 12.82 °Brix. Regarding pH, the maximum value was observed in T₂₂ [HSTAM-44] (3.39), followed by T₆ [HSTAM-28] (3.25), T₅ [HSTAM-25] (3.27) and T₃ [HSTAM-29] (3.21). The minimum pH value was recorded in T₁₂ [HSTAM-34] with 2.38. Bottom of Form Significant variations were

observed among the genotypes for ascorbic acid and tartaric acid contents (Table 4). The maximum ascorbic acid content was found in T₅ [HSTAM-27] (12.92 mg/100 g), followed by T₂₁ [HSTAM-43] (11.54 mg/100 g), T₇ [HSTAM-29] (10.83 mg/100 g) and T₁₉ [HSTAM-41] (10.40 mg/100 g). The minimum ascorbic acid content was recorded in T₃ [HSTAM-25] (5.89 mg/100 g). Regarding tartaric acid, T₆ [HSTAM-28] exhibited the maximum percentage (11.82%), closely followed by T₁₈ [HSTAM-40] (11.25%), T₁₁ [HSTAM-33] (10.79%) and T₂₁ [HSTAM-43] (10.77%). The minimum tartaric acid percentage was observed in T₂₀ [HSTAM-42] (6.71%).

Table 4: Titratable acidity percentage, TSS, pH, ascorbic acid and tartaric acid percentage of tamarind genotypes maintained at Hosakote Forest Station, Bengaluru Rural District.

Treatment	Genotype	Titrateable acidity (%)	Total soluble solids, (°brix)	pH	Ascorbic acid (mg/100 g)	Tartaric acid (%)
T ₁	HSTAM-23	12.26	16.38	2.67	8.38	7.22
T ₂	HSTAM-24	11.37	14.39	2.60	6.84	9.46
T ₃	HSTAM-25	15.13	12.82	3.27	5.89	7.59
T ₄	HSTAM-26	12.71	13.33	2.72	7.46	7.58
T ₅	HSTAM-27	8.45	16.99	2.74	12.92	10.80
T ₆	HSTAM-28	15.61	16.38	3.25	5.91	11.82
T ₇	HSTAM-29	11.65	16.11	3.21	10.83	6.90
T ₈	HSTAM-30	13.34	14.24	2.86	9.05	8.81
T ₉	HSTAM-31	11.15	17.19	2.64	6.65	8.72
T ₁₀	HSTAM-32	12.83	16.96	2.81	7.22	9.68
T ₁₁	HSTAM-33	9.55	16.42	3.21	8.26	10.79
T ₁₂	HSTAM-34	17.69	15.75	2.38	7.19	6.75
T ₁₃	HSTAM-35	12.23	16.75	3.08	7.35	7.72
T ₁₄	HSTAM-36	13.50	17.66	3.21	9.63	6.78
T ₁₅	HSTAM-37	10.11	18.65	3.16	8.42	7.56
T ₁₆	HSTAM-38	11.89	16.78	3.18	9.17	8.85
T ₁₇	HSTAM-39	12.27	15.49	2.75	10.20	9.84
T ₁₈	HSTAM-40	12.15	15.69	2.89	7.14	11.25
T ₁₉	HSTAM-41	11.65	16.80	2.75	10.40	10.21
T ₂₀	HSTAM-42	8.82	14.83	2.90	9.55	6.71
T ₂₁	HSTAM-43	7.36	13.80	3.18	11.54	10.77
T ₂₂	HSTAM-44	13.42	17.84	3.39	6.70	8.90
T ₂₃	HSTAM-45	12.43	16.47	3.12	9.18	8.88
T ₂₄	HSTAM-46	12.77	15.11	2.88	10.24	10.75
T ₂₅	HSTAM-47	14.78	14.69	2.91	8.55	7.78
T ₂₆	HSTAM-48	11.67	15.34	3.15	7.86	6.89
T ₂₇	THTAM-49	9.56	17.31	2.84	9.66	9.72
T ₂₈	GHTAM-50	10.81	17.02	2.69	10.15	10.63
Mean		12.04	15.97	2.94	8.68	8.91
Range	Max.	17.69	18.65	3.39	12.92	11.82
	Min.	7.36	12.82	2.38	5.89	6.71
Ftest (p≤0.05)		*	*	*	*	*
S.Em±		0.24	0.22	0.06	0.09	0.04
C.D at 5%		0.69	0.61	0.17	0.26	0.13

**Fig 2:** Variability in seed traits of tamarind genotypes.

Table 5: Nutrient composition (Mg, Ca, K and Mn percentage) of tamarind genotypes maintained at Hosakote Forest Station, Bengaluru Rural District.

Treatment	Genotype	Mg (%)	Ca (%)	K (%)	Mn (%)
T ₁	HSTAM-23	0.98	2.84	20.18	2.24
T ₂	HSTAM-24	1.54	3.11	22.37	2.42
T ₃	HSTAM-25	1.36	2.29	20.39	2.36
T ₄	HSTAM-26	2.45	2.80	15.35	2.65
T ₅	HSTAM-27	0.95	3.14	18.33	2.35
T ₆	HSTAM-28	2.54	3.23	24.18	2.37
T ₇	HSTAM-29	1.29	2.85	15.18	2.18
T ₈	HSTAM-30	1.28	2.65	20.49	2.27
T ₉	HSTAM-31	1.79	2.84	18.18	1.83
T ₁₀	HSTAM-32	1.19	2.36	18.43	2.46
T ₁₁	HSTAM-33	1.22	2.86	16.89	2.23
T ₁₂	HSTAM-34	2.16	3.51	20.18	2.24
T ₁₃	HSTAM-35	1.33	3.00	22.87	1.62
T ₁₄	HSTAM-36	1.04	3.26	14.52	2.36
T ₁₅	HSTAM-37	1.07	2.49	15.35	2.62
T ₁₆	HSTAM-38	1.16	3.31	18.33	2.35
T ₁₇	HSTAM-39	1.08	3.31	20.69	2.81
T ₁₈	HSTAM-40	1.42	3.23	16.57	2.60
T ₁₉	HSTAM-41	1.56	2.22	19.56	2.35
T ₂₀	HSTAM-42	0.85	2.13	22.29	2.26
T ₂₁	HSTAM-43	1.53	2.26	21.29	2.57
T ₂₂	HSTAM-44	1.33	3.00	22.12	2.34
T ₂₃	HSTAM-45	1.04	3.26	14.52	2.21
T ₂₄	HSTAM-46	1.07	2.49	21.10	1.97
T ₂₅	HSTAM-47	1.16	3.31	18.15	1.79
T ₂₆	HSTAM-48	2.05	2.86	24.18	3.29
T ₂₇	THTAM-49	1.53	2.26	15.18	2.49
T ₂₈	GHTAM-50	1.33	3.00	23.45	2.37
Mean		1.34	2.80	19.34	2.36
Range	Max.	2.54	3.51	24.18	3.29
	Min.	0.85	2.13	14.52	1.62
Ftest (p≤0.05)		*	*	*	*
S.Em±		0.09	0.04	0.98	0.20
C.D at 5%		0.28	0.10	2.71	0.61

The higher values for titratable acidity, pH, ascorbic acid and tartaric acid in certain tamarind fruit pulps, particularly in HSTAM-28, can be attributed to genetic factors. Similar trends were observed in HSTAM-25, followed by HSTAM-28. These findings align with the results reported by Hanamashetti and Sulikeri (1997); El-Siddig *et al.* (2006); Divakara (2009); Sharma *et al.* (2015) and Mayavel *et al.* (2025).

The data on magnesium and calcium percentages are shown in Table 5. The maximum magnesium percentage was observed in T₆ [HSTAM-28(2.54 %)], followed by T₁₂ [HSTAM-34(2.16 %)] and T₂₆ [HSTAM-48 (2.05%)]. The minimum magnesium percentage was recorded in T₂₀ [HSTAM-42(0.85 %)]. In terms of calcium percentage, the maximum value was recorded in T₁₂ [HSTAM-34(3.51 %)], followed by T₅ [HSTAM-25 (3.14%)] and T₁₄

[HSTAM-35(3.26 %)]. The minimum calcium percentage was observed in T₂₂ [HSTAM-42(2.13%)].

The data on potassium and manganese percentages are presented in Table 5. The maximum potassium percentage was observed in T₆ [HSTAM-28(24.18%)], followed by T₂ [HSTAM-24(23.37%)] and T₁₄ [HSTAM-36(22.41%)]. The minimum potassium percentage was recorded in T₂₃ [HSTAM-45(14.52 %)]. In terms of manganese percentage, the maximum value was recorded in T₂₆ [HSTAM-48 (3.29%)], followed by T₁₇ [HSTAM-39(2.81%)] and T₆ [HSTAM-28(2.65%)]. The minimum manganese percentage was observed in T₁₃ [HSTAM-35(1.62%)].

The nutrient composition of tamarind fruit pulp across all tested genotypes revealed that HSTAM-28 exhibited significantly the maximum percentages of magnesium,

Table 6: Correlation matrix of tamarind physico-chemical characters.

	Weight of fruit (g)	Length of fruit (cm)	Width of fruit (cm)	Thickness of fruit (cm)	Pulp weight per fruit (g)	Shell weight per fruit (g)	Fibre weight per fruit (g)	Titratable acidity (%)	TSS (°Brix)	pH	Ascorbic acid (mg/100 g)	Tartaric acid (%)
Weight of fruit (g)	1.00	0.54*	0.59*	0.43*	0.95**	0.83**	0.85**	0.23	0.01	-0.03	-0.16	0.31*
Length of fruit (cm)		1.00	0.55*	0.61**	0.55*	0.52*	0.60**	0.12	-0.02	-0.07	-0.09	0.24
Width of fruit (cm)			1.00	0.47*	0.65**	0.53*	0.63**	0.40*	0.14	-0.05	-0.10	0.08
Thickness of fruit (cm)				1.00	0.46*	0.43*	0.58**	0.14	0.23	-0.02	-0.04	0.37*
Pulp weight per fruit (g)					1.00	0.82**	0.86**	0.26	0.01	-0.08	-0.12	0.32*
Shell weight per fruit (g)						1.00	1.00	0.21	-0.03	-0.15	-0.20	0.26
Fibre weight per fruit (g)							1.00	0.24	0.03	-0.16	-0.27	0.25
Titratable acidity (%)								1.00	0.02	0.06	-0.34	-0.11
TSS (°Brix)									1.00	0.11	0.03	0.20
pH										1.00	-0.08	-0.03
Ascorbic acid (mg/100 g)											1.00	0.09
Tartaric acid (%)												1.00

* and ** indicates significant at 5 % and 1% level probability respectively.

potassium and manganese. However, HSTAM-48 was found to be at par with HSTAM-28 in terms of magnesium and potassium content. The nutrient composition of tamarind fruit pulp is genetically controlled, as demonstrated by the variation among the genotypes mentioned above. These findings are consistent with the studies of Ishola *et al.* (1990); Bhattacharya *et al.* (2008) and Parvez *et al.* (2003).

Correlation Studies

The correlation analysis of different traits reveals significant relationships that contribute to the understanding of yield-contributing characteristics (Table 6). Fruit weight exhibited a strong positive correlation with pulp weight (0.95**), fibre weight (0.85**) and shell weight (0.83**), concluding that larger fruits have more pulp, fibre and shell weight. Moderate correlations with fruit dimensions like width (0.59*) and length (0.54*) were observed, though the correlation with acidity (0.23) was non-significant.

Length of fruit exhibited significant positive correlations with fibre weight (0.60**), fruit thickness (0.61**) and pulp weight (0.55*), suggesting that longer fruits often have a more substantial pulp and thicker texture. Similarly, fruit width showed positive correlation with pulp weight (0.65**), fibre weight (0.63**) and fruit weight (0.59*), demonstrating that wider fruits generally have more pulp and weight. Thickness of fruit was positively associated with most other traits, including fruit length (0.61**) and fiber weight (0.58**). Pulp weight was strongly correlated with fruit weight (0.95**) and shell weight (0.82**), showing these are important factors in determining pulp yield. Shell weight had strong positive correlations with fiber weight (0.86**) and fruit weight (0.83**), showing that thicker shells correlate with larger fruits. The titratable acidity showed significant positive correlation with fruit width (0.40*), but weak or non-significant relationships with other traits. The traits such as TSS, pH and ascorbic acid showed non-significant correlation with all the traits studied. Similar results were also reported by Divakara (2008); Algabal *et al.* (2012); Singh and Nandini (2014) and Bhogave *et al.* (2018).

CONCLUSION

The study showed significant variation among tamarind genotypes in morphometric, phytochemical and nutrient characteristics. HSTAM-28 outperformed others with the maximum fruit weight (30.27 g), pulp weight (15.65 g), seed weight (9.22 g) and potassium content (24.08%). HSTAM-40 had the maximum shell weight, while HSTAM-41 showed the greatest pulp percentage and HSTAM-46 the maximum seed percentage. In phytochemical traits, HSTAM-28 had the maximum tartaric acid, whereas HSTAM-27 had the maximum ascorbic acid content. HSTAM-48 recorded the maximum manganese percentage and HSTAM-34 had the maximum calcium percentage. Correlation analyses indicated a strong positive relationship between fruit weight, fibre weight, pulp weight and other fruit traits.

These findings suggest that certain genotypes, especially HSTAM-28, have great potential for improving tamarind production and quality, highlighting their importance in breeding programme for better yield and nutritional value.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

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