

Characterization and Screening of Elite Tamarind (*Tamarindus indica* L.) Germplasms in Garo Hills of Meghalaya, India

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ABSTRACT

Tamarind is a highly cross-pollinated crop and hence, wide variability is common in this species as it is propagated through seeds. Such seedlings exhibit a wide range of variations, which aids in the selection of the superior desirable genotypes. It offers more avenues for establishing desirable clones by simple seedling selection. Plus, trees or the elite trees selected for total yield, fruit size and quality of fruit, are the starting point of any tree improvement program. Selection of a large number of elite trees serves as an immediate seed source with fairly high genetic gain. In nature, lot of variations in respect of fruit shape and size, fruit

and pulp color, TSS, acidity and earliness in bearing of this fruit are evident. Advantage of these variations can be taken to evolve a selection of superior seedling. The investigation aimed to assess the morphological, physical, and biochemical variability among twenty Garo Hills Tamarind (GHT) genotypes collected from different locations in the Garo Hills region of Meghalaya. The findings revealed a wide range of variation among the collections. Cluster analysis identified Cluster V (GHT5, GHT11, and GHT13) as the elite group based on overall performance. Among them, GHT11, collected from Rangmangre (North Garo Hills), emerged as the most promising genotype, combining high-quality biochemical traits with superior fruit physical characteristics. The findings provide valuable insights for tamarind improvement programs and highlight the genetic potential of local germplasm for commercial cultivation.

Keywords Characterization, Cluster analysis, Elite, Tamarind, Underutilized fruit.

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INTRODUCTION

Tamarind (*Tamarindus indica* L.) is a leguminous tree that belongs to the family fabaceae with subfamily Caesalpiniaceae (Stege *et al.* 2011). As described by Arbonnier (2004), the tree's morphological features

are distinct with stems are more or less pubescent, fissured and scaly. Tamarind pulp, known for its tangy flavor and rich aroma, is widely used in both household and industrial applications. It serves as a seasoning and flavoring agent in confections, curries, sauces, and as a natural alternative to chemical acidulants in beverages. The pulp is processed into various products such as juice, concentrate, powder, pickles, and paste. Tamarind has significant traditional medicinal value in Asia and Africa, treating both internal and external ailments (Shankaracharya 1998, Storrs 1995). According to Naeem *et al.* (2017) tamarind is grown in a variety of climatic and environmental conditions. Moisture, light and warmth are the key ecological requirements for its cultivation hence it is grown in unattended areas in the backyards or roadsides. Tamarind is sensitive to frost and drought-resistant. The global statistics for the production of tamarind are hard to obtain. But it is considered that the world's largest producer of tamarind products is India. It is particularly abundant in the Indian States of Andhra Pradesh, Madhya Pradesh, Bihar, Tamil Nadu, Karnataka and West Bengal. In India, tamarind is naturally grown on forest areas and wastelands.

Tamarind is predominantly cross-pollinated, which results in considerable natural variability even though it is raised from seeds. Seedlings often show diverse traits, providing opportunities to identify and select superior genotypes. This diversity makes it possible to establish improved clones through simple seedling selection. Elite trees chosen for yield, fruit size, quality, and other traits form the foundation of any tree improvement program. A broad selection of such elite trees not only serves as an immediate source of high-quality seed with better genetic potential but also supplies scion material for vegetative propagation, ensuring direct availability of improved planting stock (Anon 2008). In the wild, tamarind shows wide variation in characteristics like fruit size and shape, pulp and rind color, total soluble solids (TSS), acidity, and earliness of bearing. These natural differences can be effectively utilized to select superior seedlings. Therefore, the present study was conducted to analyze the variation in morphological and physico-chemical characters of *Tamarindus indica* fruits collected from different parts of Garo Hills and to identify the promising elite trees.

MATERIALS AND METHODS

The present experiment was undertaken at Department of Horticulture, North-Eastern Hill University, Tura Campus, Meghalaya during 2024-2025. The study was conducted in a randomised block design with three replicates. This analysis identified 20 potential genotypes from different locations of Garo Hills, Meghalaya (Table 1). The fruits from various sites were measured for physical and biochemical characteristics. The bio-chemical properties of the fruits were estimated using standard procedures (AOAC 1990).

Collection of plant material

Tamarind prefers to grow in subtropical forest eco-region of Garo Hills. To locate the populations of *Tamarindus indica*, an exploration survey was undertaken across Garo Hills, Meghalaya, in 2024 during the peak fruiting season of June-July. The sampled trees were labeled and their geographic coordinates were recorded using Google Earth (Table 1). Accordingly, twenty trees were selected and specific codes GHT 1 to GHT 20 were assigned. Mature fruits were collected and observations on morphological, qualitative, and biochemical parameters of fruits were recorded for these 20 genotypes in order to select the most promising genotypes in terms of physico-chemical characteristics.

Morphological parameters of the tamarind trees

The parameters such as tree height, tree circumference, spread and number of fruits per panicle were recorded for the 20 different genotypes.

Quantitative and qualitative attributes of the fruit

The fruits from various sites were measured for physical and biochemical characteristics. The bio-chemical properties of the fruits were estimated using standard procedures (AOAC 1990).

Cluster analysis

Dendrogram of cluster analysis was prepared by Ward's minimum variance method (Ward 1963). One way classified data analysis was performed with twenty accessions having four replications each.

Table 1. GPS coordinates of different locations of tamarind trees.

Date of collection	Sources	Genotypes	Latitudes	Longitudes
8 th February, 2025 West Garo Hills	Rongram	GHT1	25.596043°	90.255447°
	Babadam market	GHT2	25.601106°	90.124242°
	Chiokgre, Jengjal	GHT3	25.679196°	90.332941°
	Babadam road	GHT4	25.590259°	90.153718°
18 th February, 2025 West Garo Hills	Upper Chandmary	GHT5	25.518498°	90.223305°
22 nd February, 2025 East Garo Hills	Naringgre Songma	GHT6	25.615492°	90.720437°
	Tosekgittim	GHT7	25.625183°	90.772598°
	Songma Adinggre	GHT8	25.506661°	90.600299°
	Dewang giri	GHT9	25.510184°	90.645229°
	Gabil Patal	GHT10	25.738289°	90.822583°
	Rangmangre	GHT11	25.910308°	90.570256°
15 th February, 2025 North Garo Hills	Mendi Market	GHT12	25.921131°	90.634487°
	Domeanthi	GHT13	25.916949°	90.652890°
	Rompara (Damra)	GHT14	25.872975°	90.608005°
	Bajong Road	GHT15	25.899411°	90.521986°
22 nd February, 2025 South Garo Hills	Jadigittim	GHT16	25.435020°	90.738166°
25 th February, 2025 South-West Garo Hills	Chekwegittim	GHT17	25.464593°	90.698058°
	Ballalgre, Rerapara	GHT18	25.542790°	90.103009°
	Gollagre	GHT19	25.557619°	90.020621°
	Alekapara, Sona Mite	GHT20	25.570512°	90.016848°

GHT- Garo Hills Tamarind

RESULTS AND DISCUSSION

Tree morphological variability among selected genotypes

Morphological traits, including tree height, trunk circumference, tree spread and number of fruits per panicle were recorded for twenty tamarind genotypes. Variation in tree height was also notable. The maxi-

Table 2. Measurement of morphological parameters of the tamarind tree.

Genotype	Tree height (m)	Tree circum- ference (m)	Tree Spread E-W (m)	Number of fruits per panicle
GHT1	12.80	2.51	8.50	4
GHT2	10.00	1.23	8.10	6
GHT3	9.30	1.50	8.50	1
GHT4	6.90	0.80	6.40	1
GHT5	7.50	1.48	6.90	1
GHT6	5.70	0.80	4.50	5
GHT7	8.20	1.60	6.80	8
GHT8	6.40	1.00	4.30	5
GHT9	11.80	1.50	8.40	7
GHT10	11.70	9.30	5.40	4
GHT11	7.60	1.50	7.00	6
GHT12	7.30	1.50	9.40	4
GHT13	10.50	1.80	12.20	5

Table 2. Continued.

Genotype	Tree height (m)	Tree circum- ference (m)	Tree Spread E-W (m)	Number of fruits per panicle
GHT14	10.60	1.93	7.70	7
GHT15	14.30	3.46	11.70	1
GHT16	9.70	1.30	7.90	6
GHT17	13.20	0.52	3.10	1
GHT18	17.50	2.19	13.40	8
GHT19	15.10	2.80	18.10	4
GHT20	9.70	2.10	10.30	1
Average	10.29	2.04	8.43	4.25

imum height was observed in GHT18 at 17.50 meters, while the minimum height was recorded in GHT6 at 5.70 meters (Table 2). For trunk circumference, GHT10 recorded the maximum at 9.30 meters, whereas GHT17 had the minimum at 0.52 meters. In terms of tree spread, GHT19 exhibited the widest canopy at 18.10 meters, while GHT17 again recorded the smallest spread at 3.10 meters. The maximum number of fruits per cluster was recorded eight in number.

Physical parameters of the tamarind fruit

The present study revealed significant differences

Table 3. Physical parameters of tamarind fruits.

Genotype	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (g)	Fruit volume (ml)	Pulp weight (g)	Pulp Diameter (cm)	Pulp %	Stone weight (g)	Pulp:stone ratio	Specific gravity
GHT1	15.20	2.40	14.97	31.67	9.52	1.40	63.57	4.37	2.18	0.99
GHT2	15.30	3.07	20.21	23.33	16.62	1.83	82.19	12.63	1.31	1.01
GHT3	13.20	2.83	18.79	40.00	12.88	2.00	73.59	9.68	1.33	0.94
GHT4	15.06	2.53	20.21	33.33	15.32	2.03	75.80	12.05	1.27	0.94
GHT5	15.47	3.07	14.94	23.33	10.13	1.77	67.83	7.90	1.28	1.00
GHT6	10.77	2.07	10.90	20.00	8.94	1.63	80.42	4.22	2.08	1.09
GHT7	17.20	2.27	21.00	21.67	14.79	1.90	70.44	10.59	1.33	1.40
GHT8	19.83	3.07	26.24	33.33	16.26	2.10	61.95	12.63	1.28	1.05
GHT9	15.10	2.70	18.77	31.67	12.29	1.80	65.47	8.41	1.46	1.25
GHT10	14.93	2.40	17.52	16.67	11.89	1.67	67.83	7.97	1.50	1.17
GHT11	19.87	3.37	32.61	43.33	28.32	2.37	85.91	23.88	1.18	1.09
GHT12	17.43	2.47	18.73	31.67	13.18	1.63	70.17	10.66	1.23	1.25
GHT13	15.07	2.77	16.71	41.67	14.44	1.77	86.39	11.01	1.31	1.11
GHT14	15.07	2.63	23.02	40.00	12.98	1.90	56.38	9.38	1.38	1.00
GHT15	16.60	2.70	20.74	40.00	13.86	1.77	66.81	11.53	1.20	1.38
GHT16	13.73	2.33	13.14	33.33	8.85	1.53	67.30	7.08	1.25	1.32
GHT17	18.70	2.50	25.32	21.67	15.28	1.83	60.33	12.18	1.25	1.02
GHT18	18.73	2.77	19.33	40.00	13.72	2.23	71.07	9.68	1.41	1.29
GHT19	18.70	3.00	24.32	33.33	18.56	1.70	76.30	12.56	1.47	0.97
GHT20	16.00	2.73	24.19	23.33	13.86	1.43	57.30	10.79	1.28	1.21
CD (5%)	0.79	0.18	0.82	4.23	0.67	0.21	4.63	0.74	0.14	0.08
SE(m)	0.27	0.06	0.29	1.48	0.23	0.07	1.62	0.26	0.05	0.03
SE(d)	0.39	0.09	0.40	2.09	0.33	0.11	2.29	0.36	0.07	0.04
CV (%)	2.95	3.95	2.47	8.22	2.88	7.10	3.98	4.27	6.02	4.42

among the tamarind genotypes in terms of fruit physical characteristics (Table 3). The maximum fruit length was recorded in GHT11 (19.86 cm), while the minimum was observed in GHT6 (10.77 cm). These results are consistent with findings by Okello *et al.* (2018), who observed tamarind fruit lengths ranging from 4.30 cm to 29.80 cm. The variation in fruit length appears to be genotype dependent. GHT11 also showed the highest fruit weight (32.61 g), whereas the lowest fruit weight was recorded in GHT6 (10.90 g). Sharma *et al.* (2015) previously reported fruit weights ranging from 8.64 g to 27.70 g in tamarind. The increase in fruit weight may be attributed to efficient translocation and accumulation of carbohydrates, as noted by Coombe (1976). In terms of fruit breadth, GHT11 again had the maximum value (3.37 cm), and GHT6 had the minimum (2.07 cm). Similar variation was reported by Okello *et al.* (2018), who found fruit diameters of tamarind ranging from 1.10 cm to 3.00 cm. The highest pulp weight was found in GHT11 (28.32 g), while the lowest was in GHT6 (8.85 g). Sharma *et al.* (2015) previously reported pulp weights

between 4.10 g and 15.77 g, while Okello *et al.* (2018) recorded values ranging from 0.19 g to 22.00 g.

The pulp percentage was maximum in GHT13 (86.39%) and minimum in GHT14 (56.38%). Fruit volume was highest in GHT11 (43.33 ml), followed closely by GHT13 (41.66 ml). Pulp diameter reached a maximum in GHT11 (2.37 cm), whereas the minimum was noted in GHT1 (1.4 cm). Specific gravity was highest in GHT7 (1.4) and lowest in GHT3 (0.94). Kumar *et al.* (2017) reported a fruit density of 0.887 g/cm³, and Pradhan *et al.* (2015) observed that specific gravity remained relatively stable throughout the developmental stages of the fruit. The stone weight was recorded as highest in GHT11 (23.88 g) and lowest in GHT6 (4.22 g). Chaturvedi *et al.* (2025) reported seed weights in tamarind ranging from 23.14 g to 214.08 g, indicating substantial variation. The pulp-to-stone ratio was maximum in GHT1 (2.18), while the lowest ratio was observed in GHT11 (1.18).

Table 4. Biochemical parameters of tamarind fruits.

Genotype	TSS (°Brix)	Titrate acidity (%)	Ascorbic acid (mg/100g)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Anthocyanin (mg/100g)
GHT1	50.40	5.63	73.60	17.67	6.32	10.78	4.98
GHT2	52.67	5.97	55.60	14.65	6.52	7.71	6.53
GHT3	54.00	5.59	54.80	16.66	6.52	9.63	4.50
GHT4	41.73	5.97	57.20	16.23	6.32	9.41	3.60
GHT5	46.73	5.29	100.00	15.81	4.61	10.63	5.37
GHT6	41.93	6.78	71.60	16.23	5.60	10.09	4.64
GHT7	41.67	5.80	58.80	15.44	6.38	8.60	5.22
GHT8	43.07	6.02	74.80	15.01	4.37	10.10	4.16
GHT9	46.27	6.61	72.80	13.96	4.72	8.77	5.19
GHT10	48.47	8.06	54.80	19.39	6.00	12.72	6.58
GHT11	40.53	8.36	86.80	16.23	4.47	11.17	5.13
GHT12	42.13	6.66	54.80	15.81	6.32	9.01	4.63
GHT13	37.33	11.86	86.80	18.79	6.59	11.58	3.55
GHT14	41.73	9.43	75.20	14.65	6.32	7.91	5.72
GHT15	40.60	7.30	56.00	17.17	6.52	10.11	5.67
GHT16	42.13	8.24	56.40	17.17	4.80	11.75	5.59
GHT17	40.53	6.74	75.60	15.01	5.50	9.03	3.74
GHT18	44.33	8.15	76.00	16.66	4.47	11.57	4.42
GHT19	40.80	7.68	54.73	15.81	6.38	8.95	6.67
GHT20	40.07	7.21	53.53	16.23	6.52	9.22	4.02
CD (5%)	2.02	0.41	3.59	1.29	0.16	1.21	0.53
SE(m)	0.71	0.14	1.25	0.45	0.06	0.42	0.18
SE(d)	1.00	0.20	1.77	0.64	0.08	0.60	0.26
CV (%)	2.79	3.50	3.22	4.80	1.67	7.38	6.36

Biochemical parameters of tamarind fruit

Among the qualitative characters studied, the highest total soluble solids (TSS) content was recorded in GHT3 (54.00 °Brix), while the lowest was observed in GHT13 (37.33 °Brix) (Table 4). The TSS values recorded in this study align with previous findings by Deshmukh *et al.* (2015), who reported up to 53.70 °Brix, though Mishra *et al.* (2025) noted a slightly lower range of 17.33–26.46 °Brix. The maximum titratable acidity was found in GHT13 (13.80%), whereas the minimum was recorded in GHT5 (6.20%) (Table 4). These values are comparable with earlier studies by Sharma *et al.* (2015), who reported acidity levels between 10–12%. Ascorbic acid content was highest in GHT5 (100 mg/100g) and lowest in GHT20 (53.53 mg/100g). This is consistent with findings by Chaturvedi *et al.* (2025) and Mishra *et al.* (2025), who reported ranges of 54.5–92 mg/100g and 82.54–138.49 mg/100g, respectively.

The highest total sugar content was observed in GHT10 (19.39%), while the lowest was recorded in

GHT9 (13.96%). These results are within the range reported by Mishra *et al.* (2025) (12.45–18.81%). Reducing sugar content was maximum in GHT13 (6.59%) and minimum in GHT8 (4.37%). The results are similar to the range of 6–10.8% reported by Sharma *et al.* (2015). The highest non-reducing sugar content was found in GHT10 (12.72%), whereas the lowest was observed in GHT9 (9.18%). These findings align with earlier reports by Mamathashree *et al.* (2022) and Pooja *et al.* (2018).

Table 5. Cluster formation for morphological characteristics of the tree and physical traits of fruits.

Cluster	Number of cluster	Cluster type
I	4	GHT2, GHT3, GHT4, GHT13
II	11	GHT1, GHT5, GHT7, GHT8, GHT9, GHT10, GHT12, GHT14, GHT16, GHT17, GHT20
III	1	GHT6,
IV	3	GHT15, GHT18, GHT19
V	1	GHT11

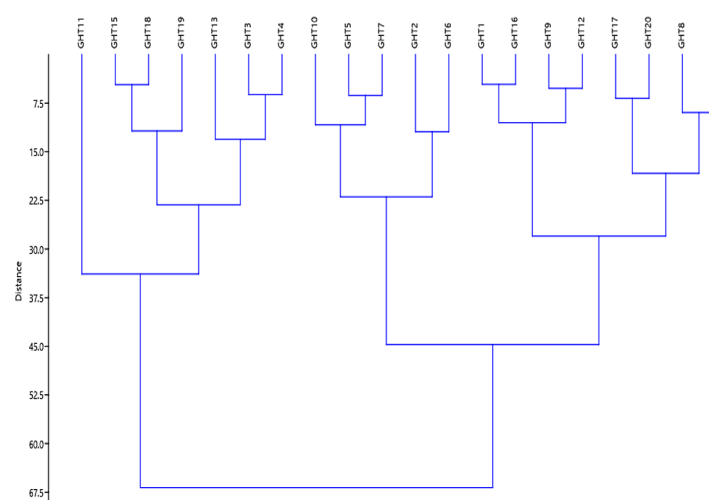
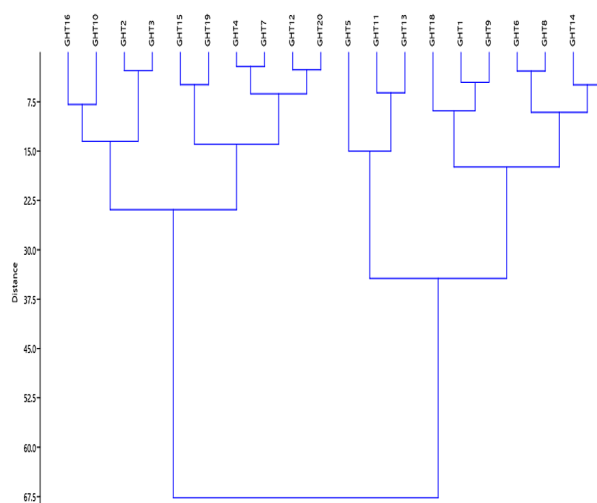
Table 6. Cluster formation for morphological characteristics of the tree and biochemical traits of fruits.

Cluster	Number of cluster	Type of cluster
I	5	GHT4, GHT7, GHT12, GHT16, GHT20
II	3	GHT2, GHT3, GHT10
III	7	GHT1, GHT6, GHT8, GHT9, GHT14, GHT17, GHT18
IV	2	GHT15, GHT19
V	3	GHT5, GHT11, GHT13

Cluster analysis of tamarind genotypes

Cluster V was identified as the elite group, comprising

genotypes GHT5, GHT11, and GHT13 (Tables 5–6 & Figure 1–2). These genotypes exhibited exceptional performance in both physical and biochemical characteristics, making Cluster V the most promising group in the study. GHT11 emerged as the top-performing genotype, with outstanding values in pulp percentage, sugars, ascorbic acid, and anthocyanin content. GHT5 recorded the highest ascorbic acid content (mg/100g) and exhibited strong physical attributes. GHT13 had the highest anthocyanin content and strong sugar levels, making it a highly desirable genotype in terms of nutritional and sensory quality.

**Fig. 1.** Ward's minimum variance dendrogram of tamarind genotypes between tree morphology and physical characters of fruits**Fig. 2.** Ward's minimum variance dendrogram of tamarind genotypes between tree morphology and biochemical parameters of fruits.

CONCLUSION

GHT11 emerged as the best-performing genotype, demonstrating superiority in both biochemical and physical traits. Biochemically, it recorded high total soluble solids (16.23%), ascorbic acid content (86.80 mg/100g), anthocyanin content (6.58 mg/100g), and maintained a balanced level of acidity. In terms of physical attributes, GHT11 showed the highest pulp percentage (85.91%), the highest pulp weight (28.32 g), the highest pulp-to-stone ratio (1.88), and the highest fruit weight (32.61 g). Therefore, GHT11, collected from Rangmangre, North Garo Hills, Meghalaya, stands out as the most promising genotype across both physical and biochemical parameters.

Genotypes GHT5, GHT11, and GHT13 were identified as the elite group under cluster V. These genotypes exhibited well in both physical and biochemical characteristics, making Cluster V the most promising group in the study. The genotypes within this cluster are ideal candidates for use in breeding programs, commercial cultivation, and high-value markets.

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