Plant Archives Vol. 25, Supplement 2, 2025 pp. 3019-3024 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.supplement-2.385

COMPARATIVE EVALUATION OF LEAF MORPHOLOGICAL AND QUANTITATIVE TRAITS IN DIFFERENT MANGO (*MANGIFERA INDICA* L.) VARIETIES UNDER THE AGRO-CLIMATIC CONDITIONS OF RAIPUR, C.G., INDIA

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(Date of Receiving : 16-05-2025; Date of Acceptance : 20-07-2025)

ABSTRACT

Mango (*Mangifera indica* L.), widely known as the "king of fruits," holds significant agricultural, cultural, and economic importance in India, contributing over 40% of global mango production with 20.77 million metric tons recorded in 2021–22. Chhattisgarh, with its diverse Agro-climatic zones, contributes notably to the nation's mango diversity, cultivating 7,753 hectares and producing 473,333 metric tons annually. This study, conducted from 2023 to 2025 at the Government Horticultural Nursery, Paragaon, Raipur, aimed to assess morphological variability in leaves of 15 mango varieties under Chhattisgarh's sub-humid tropical conditions. Observations included leaf length, breadth, leaf length-to-breadth ratio, petiole length, and visual assessments of apex, base, blade shape, margin and leaf color in new and mature stages. Results revealed significant inter-varietal morphological diversity. Leaf apex shapes were predominantly acuminate (73%), followed by acute and obtuse types, whereas base shapes ranged from acute (53%) to round (47%). Entire leaf margins were more prevalent (80%) than wavy forms (20%). New leaf colors varied, with light green being most common (47%), followed by deep copper tan, light brown and deep purple. Alphonso exhibited the longest leaves (26.07 cm), Banganpalli the broadest (6.20 cm), and Dashehari the longest petioles (3.39 cm). Length-to-breadth ratio was highest in Alphonso (5.88), while Baramasi showed the lowest (3.55). These variations were primarily attributed to genetic differences among cultivars, influenced by local environmental conditions and selective pressures. The findings underline the importance of varietal characterization to support breeding, germplasm conservation, and selection of high-performing, climate-resilient mango cultivars in Chhattisgarh.
***Keywords*:** Apex and Base shape, Petiole length, Agro climatic zone, mature, mango, acute, obtuse etc.

Introduction

Mango (*Mangifera indica* L.), known as the "king of fruits" holds immense agricultural, economic and cultural significance in India, which leads the world in mango production, contributing over 40% of the global output with 20.77 million metric tons in 2021-22. Since independence, mango production in India has steadily increased, making it a cornerstone of the nation's fruit industry. Botanically, mango belongs to the order Sapindales and family Anacardiaceae. (Mukherjee, 1951). The genus *Mangifera* comprises around 69 species, mostly found in tropical Asia and is characterized by significant morphological diversity. Mango trees are semi-vigorous to vigorous evergreens that thrive in well-drained, slightly acidic soils and are well-adapted to tropical and subtropical climates. The species heterozygosity and seed propagation have led to considerable genetic variability and nomenclature ambiguities, making systematic characterization using morphological and molecular markers essential for breeding and conservation. Such studies are vital for selecting parent plants with improved yield, flavor, disease resistance, and adaptability, while also supporting varietal preservation and meeting consumer demands. In Chhattisgarh, diverse Agro-climatic zones and indigenous varieties contribute uniquely to India's mango heritage. Preserving mango diversity in Chhattisgarh is crucial for maximizing yield, reducing crop failure and enhancing resilience to climate change, while supporting sustainable cultivation and market competitiveness through the development of improved hybrids.

Material and Methods

The investigation was carried out from 2023 to 2025 at the Government Horticultural Nursery,

Paragaon, Raipur, located in the Chhattisgarh plains (latitude 21.25°N, longitude 81.63°E, elevation 289.15 m). The area experiences a dry, moist, and sub-humid climate with an average annual rainfall of 1200-1400 mm, mostly received during the southwest monsoon from June to September. Summers are hot, reaching up to 46°C, while winters can drop to 6°C. Observations were made on leaf length, leaf breadth, leaf length and breadth ratio, petiole length. Leaf length was measured from the apex to the base of the leaf lamina, while leaf width was recorded at the broadest part of the lamina. Petiole length was determined from the base of the leaf lamina to the pelvinus using a measuring scale. The leaf length to breadth ratio was calculated using the recorded values of leaf length and leaf breadth. The shapes of the leaf blade, apex, and base were visually recorded and classified according to mango descriptors (IPGRI, 2006). Leaf blades were categorized into three types: elliptic-lanceolate, oblong-lanceolate and ovate-lanceolate. Similarly, apex shapes were grouped as obtuse, acute, or acuminate, while base shapes were identified as acute, obtuse or round.

Results and Discussions

Leaf apex shape

Table 1 and Figure 1 illustrate the leaf apex shapes of 15 mango varieties, classified into acuminate, acute, and obtuse types. Among these, 11 varieties including Banarasi Langra, Banganpalli, Baramasi, Chhattisgarh Nandiraj and Chausa exhibited an acuminate apex, representing 73% of the sample. Two varieties, Gaddemaar and Kishanbhog, showed an acute apex (13%), while Alphonso and Kalepad displayed obtuse and lanceolate apex shapes (7%). This variability in leaf apex morphology is likely influenced by genetic factors as well as environmental, nutritional, and edaphic conditions. These findings corroborate earlier studies by Bhamini *et al.* (2018) and Vieccelli *et al.* (2016).

Leaf base shape

The data on leaf base shape of 15 mango varieties is presented in Table 1 and illustrated in Figure 1. The leaf bases were categorized into three types: acute, obtuse, and round. Among the varieties studied, eight namely Alphonso, Banarasi Langra, Baramasi, Banganpalli, Dashehari, Mallika, Neelum and Sundari exhibited an acute leaf base. The remaining seven varieties, including Chhattisgarh Nandiraj, Chausa, Gaddemaar, Kalepad, Kishanbhog, Neeleshan, and Totapari, showed a round leaf base. The frequency of the acute leaf base type was 53%, slightly higher than the 47% observed for the round type. Variability in leaf base shape, along with leaf length and apex shape, is influenced mainly by genetic differences among mango cultivars, as well as environmental factors such as soil, climate and tree vigor. Epigenetic factors and selective pressures also contribute to this morphological diversity. These findings align with previous research by Majumder *et al.* (2011), Uddin *et al.* (2011), Rymbai *et al.* (2014) and Bhamini *et al.* (2018).

Leaf margin

The data on leaf margin of 15 mango varieties is detailed in Table 1 and illustrated in Figure 1, categorizing margins into entire and wavy types. Among the varieties studied, 12 including Alphonso, Banarasi Langra, Baramasi, Banganpalli, Mallika, Neelum, Sundari, Gaddemaar, Kalepad, Kishanbhog, Neeleshan and Totapari exhibited an entire leaf margin. The remaining three varieties, Chhattisgarh Nandiraj, Chausa and Dashehari, displayed wavy leaf margins. The entire leaf margin type was predominant, accounting for 80% of the varieties, while the wavy margin was observed in 20%. Variability in leaf margin, along with other morphological traits such as leaf length, base and apex shape, primarily arises from genetic differences among mango cultivars. Environmental factors like soil, climate, and tree health, as well as epigenetic mechanisms and selective pressures, further influence these traits. These results align with previous findings reported by Majumder *et al.* (2011), Uddin *et al.* (2011), Rymbai *et al.* (2014) and Bhamini *et al.* (2018).

New and old leaf colour

Table 1 presents data on the colour of newly developed and mature leaves in 15 mango varieties. Newly emerged leaves were categorized into light green, light green with brownish tinge, light brick red, reddish brown and deep coppery tan. Among these, seven varieties including Dashehari, Gaddemaar, Kalepad, Kishanbhog, Sundari and Totapari displayed light green leaves, while four varieties such as Alphonso, Baramasi, Chhattisgarh Nandiraj and Neeleshan exhibited deep purple leaves. The remaining varieties, including Chausa, Neelum, Banarasi Langra, and Mallika, showed light brown or deep copper tan leaf colours. The most frequent leaf colour observed was light green (47%), followed by deep copper tan (27%), with deep coppery tan and light brown each accounting for 13%. Variability in new leaf colour is attributed to genetic differences among cultivars and environmental influences such as soil, climate and tree vigor, as well as selective pressures and epigenetic factors, consistent with findings by Sinha *et al.* (2018), Islam *et al.* (2019) and others.

Leaf length (cm)

The study revealed significant variation in leaf length among 15 mango varieties over two years, as detailed in Table 2 In the first year, leaf length ranged from 19.34 cm (Baramasi) to 26.30 cm (Alphonso), with Alphonso and Neeleshan showing the longest leaves and Baramasi, Chhattisgarh Nandiraj, and Gaddemaar having the shortest. In the second year, leaf length varied from 19.59 cm (Baramasi) to 26.40 cm (Mallika), with Mallika, Alphonso and Neeleshan exhibiting the longest leaves. Pooled analysis confirmed Alphonso as having the maximum average leaf length (26.07 cm), closely followed by Mallika (25.81 cm), while Baramasi consistently had the shortest leaves (19.47 cm). Several varieties, such as Kalepad, Banarasi Langra, Banganpalli and Sundari, showed statistically similar leaf lengths. These differences in leaf length are attributed to the inherent genetic characteristics of each variety and their adaptation to local Agro-climatic conditions. The findings align with previous studies by Bhamini *et al.* (2018), Vieccelli *et al.* (2016), Uddin *et al.* (2011), Ramessur *et al.* (2011), Majumder *et al.* (2011) and Sinha *et al.* (2018) all of which reported significant variability in leaf size among mango genotypes.

Leaf breadth

The study observed significant variation in leaf breadth among 15 mango varieties over two years, as detailed in Table 2. In the first year, leaf breadth ranged from 3.92 cm (Dashehari) to 6.37 cm (Banganpalli), with Banganpalli showing the widest leaves. In the second year, the range was 3.87 cm (Dashehari) to 6.03 cm (Banganpalli), again highlighting Banganpalli as superior in leaf breadth. Pooled analysis confirmed Banganpalli as having the maximum average leaf breadth (6.20 cm), followed by Totapari (5.81 cm), while Dashehari consistently had the minimum (3.90 cm). Several varieties, such as Kalepad, Alphonso and Banarasi Langra, showed statistically similar leaf breadths. The observed differences in leaf breadth are attributed to the inherent genetic characteristics of each variety and their adaptation to local agro-climatic conditions. These findings are consistent with previous research by Rymbai *et al.* (2014), Vieccelli *et al.* (2016) and others.

Leaf length breadth ratio

The present study revealed significant differences in leaf length-breadth ratios among 15 mango varieties, as detailed in Table 2. In pooled analysis, Alphonso recorded the highest ratio (5.88), followed by Chausa and Dashehari (5.34 each), while Baramasi showed the lowest (3.55). Varieties such as Totapari, Neelum, Chhattisgarh Nandiraj and Sundari exhibited statistically similar ratios, indicating a degree of uniformity among certain genotypes. The observed variation in length-breadth ratios is primarily attributed to genetic differences among the varieties, rather than environmental or edaphic factors. These findings are consistent with previous research by Vieccelli *et al.* (2016), Uddin *et al.* (2011), Ramessur *et al.* (2011), Majumder *et al.* (2011), Sinha *et al.* (2018) who also reported significant genetic influence on leaf morphological traits in mango genotypes. Overall, the results highlight the importance of genetic diversity in shaping leaf morphology among mango cultivars.

Petiole length

The study observed significant variation in petiole length among 15 mango varieties, as summarized in Table 2. In the first year, petiole length ranged from 1.73 cm (Banganpalli) to 3.48 cm (Dashehari) with Dashehari consistently exhibiting the longest petioles and Banganpalli the shortest. The second year showed similar trends, with petiole lengths ranging from 1.70 cm (Baramasi) to 3.29 cm (Dashehari). Pooled analysis confirmed Dashehari as having the maximum average petiole length (3.39 cm), followed by Totapari (3.05 cm), while Baramasi had the minimum (1.80 cm). Several varieties, such as Baramasi, Banganpalli, Neelum, Sundari and Mallika, showed statistically similar petiole lengths. The observed differences are attributed to the inherent genetic characteristics of each variety and their adaptation to local agro-climatic conditions. These findings align with previous studies by Bhamini *et al.* (2018), Vieccelli *et al.* (2016) and others, confirming significant genetic influence on petiole length in mango.

Table 1: Variabilities on leaf morphological characteristics like- leaf shape including Apex and Base, leaf margin, colour of new leaf and colour of fully matured leaf of mango varieties during year 2023-2024 and 2024-2025

Varieties	Leaf apex shape	Leaf base shape	Leaf margin	Colour of new leaf	Colour of fully matured leaf
Alphonso	Obtuse	Acute	Entire	Deep purple	Dark green
Banarasi Langra	Acuminate	Acute	Entire	Deep coppery tan	Dark green
Banganpalli	Acuminate	Acute	Entire	Light green	Dark green
Baramasi	Acuminate	Acute	Entire	Deep purple	Dark green
CG Nandiraj	Acuminate	Obtuse	Wavy	Deep Purple	Dark green

Chausa	Acuminate	Obtuse	Wavy	Light brown	Light green
Dashehari	Acuminate	Acute	Wavy	Light green	Dark green
Gaddemaar	Acute	Obtuse	Entire	Light green	Dark green
Kalepad	Lanceolate	Obtuse	Entire	Light green	Dark green
Kishanbhog	Acute	Obtuse	Entire	Light green	Dark green
Mallika	Acuminate	Acute	Entire	Deep coppery tan	Dark green
Neeleshan	Acuminate	Obtuse	Entire	Deep purple	Dark green
Neelum	Acuminate	Acute	Entire	Light brown	Dark green
Sundari	Acuminate	Acute	Entire	Light green	Dark green
Totapari	Acuminate	Obtuse	Entire	Light green	Dark green

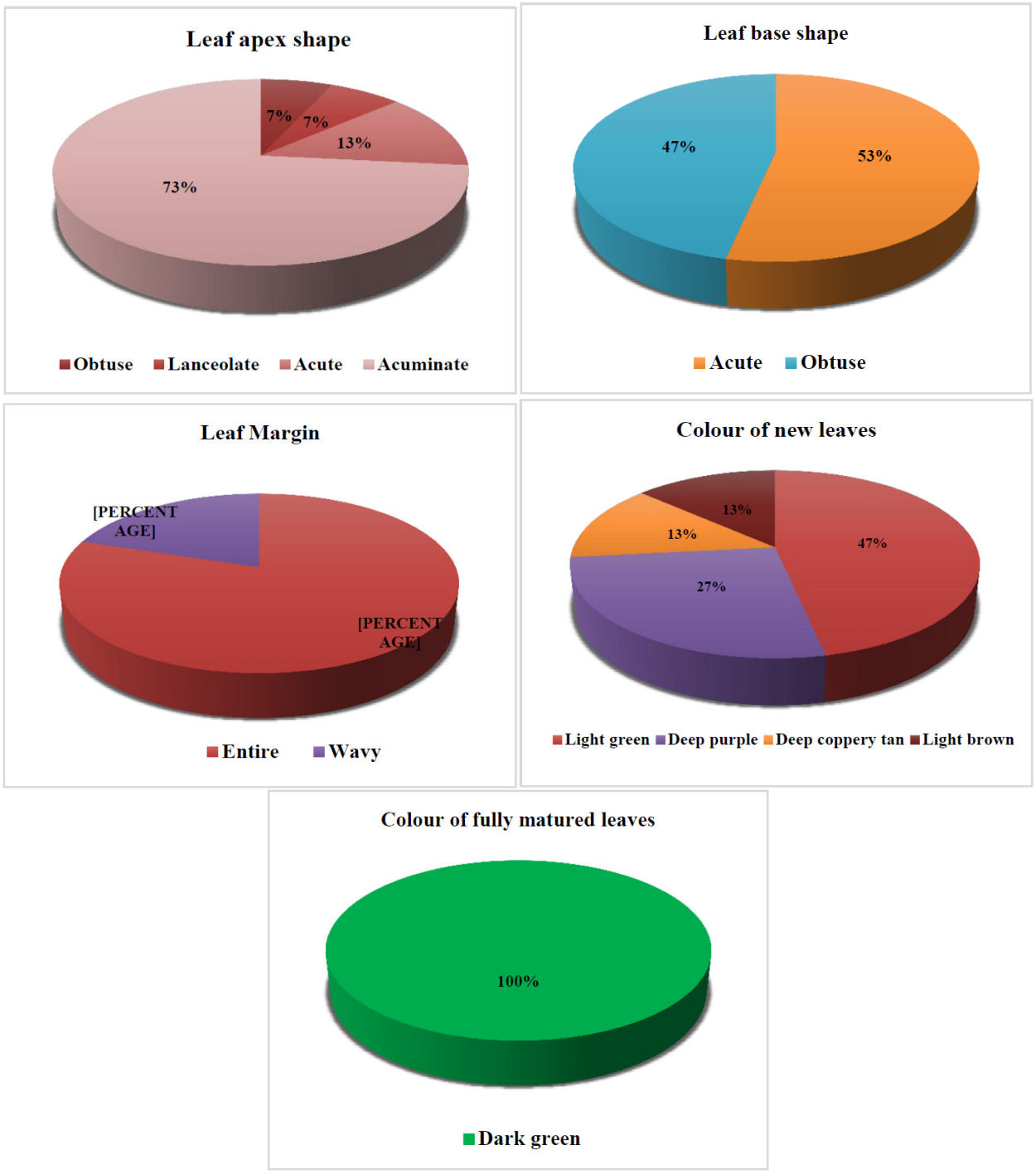

Fig. 1: Pie diagram of variability in leaves (apex, base, margin and colour) of different mango varieties

Table 2: Variabilities on leaf length, breadth, length breadth ratio and petiole of mango varieties during years 2023, 2024 and pooled

Varieties	Leaf length (cm)			Leaf breadth (cm)			Leaf length breadth ratio			Petiole length (cm)		
	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled	2023-24	2024-25	Pooled
Alphonso	26.30^{h}	25.83^{g}	26.07^{l}	4.53^{c}	4.34^{b}	4.44^{bc}	5.81^{g}	5.96^{l}	5.88^{g}	2.68^{fg}	2.63^{gh}	2.66^{ef}
Banarasi Langra	22.56^{d}	21.34^{b}	21.95^{d}	4.75^{d}	4.71^{cd}	4.73^{d}	4.75^{de}	4.53^{fgh}	4.64^{d}	2.64^{f}	2.70^{hi}	2.67^{ef}
Banganpalli	22.51^{d}	22.78^{cd}	22.65^{e}	6.37^{i}	6.03^{j}	6.20^{k}	3.54^{a}	3.78^{b}	3.66^{a}	1.73^{a}	1.89^{b}	1.81^{a}
Baramasi	19.34^{a}	19.59^{a}	19.47^{a}	5.35^{fg}	5.63^{h}	5.49^{i}	3.62^{a}	3.48^{a}	3.55^{a}	1.89^{b}	1.70^{a}	1.80^{a}
CG Nandiraj	19.84^{ab}	19.94^{a}	19.89^{b}	4.49^{c}	4.58^{c}	4.54^{c}	4.42^{bc}	4.35^{ef}	4.39^{c}	2.69^{fg}	2.54^{f}	2.62^{e}
Chausa	23.93^{ef}	24.30^{f}	24.12^{fg}	5.45^{g}	5.34^{efg}	5.40^{hi}	4.39^{bc}	6.28^{m}	5.34^{f}	2.75^{g}	2.81^{jk}	2.78^{g}
Dashehari	23.47^{e}	22.18^{c}	22.83^{e}	3.92^{a}	3.87^{a}	3.90^{a}	5.99^{g}	4.68^{hi}	5.34^{f}	3.48^{i}	3.29^{m}	3.39^{i}
Gaddemaar	20.19^{b}	21.32^{b}	20.76^{c}	4.63^{cd}	4.74^{d}	4.69^{d}	4.36^{b}	4.81^{ij}	4.59^{d}	1.91^{b}	2.04^{c}	1.98^{b}
Kalepad	21.36^{c}	22.49^{cd}	21.93^{d}	4.19^{b}	4.43^{b}	4.31^{b}	5.10^{f}	4.12^{cd}	4.61^{d}	2.49^{de}	2.56^{fg}	2.53^{d}
Kishanbhog	23.61^{e}	22.65^{cd}	25.01^{h}	5.20^{ef}	5.46^{gh}	5.33^{fgh}	4.54^{bcd}	5.09^{k}	4.81^{e}	2.53^{e}	2.83^{k}	2.68^{ef}
Mallika	25.31^{g}	26.40^{g}	25.81^{i}	5.29^{efg}	5.20^{e}	5.25^{efg}	4.79^{e}	4.87^{j}	4.83^{e}	2.34^{c}	2.41^{e}	2.38^{c}
Neeleshan	26.18^{h}	26.31^{g}	25.04^{h}	5.14^{e}	5.19^{e}	5.17^{e}	5.09^{f}	4.54^{gh}	4.82^{e}	2.65^{f}	2.73^{ij}	2.69^{f}
Neelum	24.68^{fg}	23.89^{ef}	23.93^{f}	5.37^{fg}	5.41^{fg}	5.39^{ghi}	4.60^{cde}	3.98^{c}	4.29^{bc}	2.37^{c}	2.29^{d}	2.33^{c}
Sundari	22.39^{d}	23.17^{de}	22.78^{e}	5.13^{e}	5.26^{ef}	5.20^{ef}	4.36^{b}	4.41^{fg}	4.39^{c}	2.43^{cd}	2.31^{d}	2.37^{c}
Totapari	24.58^{fg}	24.47^{f}	24.53^{gh}	5.79^{h}	5.83^{i}	5.81^{j}	4.25^{b}	4.20^{de}	4.22^{b}	3.08^{h}	3.01^{l}	3.05^{h}
SE(m) ±	0.28	0.29	0.20	0.06	0.07	0.05	0.08	0.06	0.05	0.03	0.03	0.02
C.D. at 5%	0.80	0.82	0.56	0.17	0.19	0.14	0.22	0.18	0.15	0.09	0.08	0.06

The superscript letter indicates that the treatment means with the same letters are *at par* at 5% level of significance, while the means with different letters are significantly different at 5% level of significance. These letters have been affixed based on CD-value comparison of treatment means.

Summary and Conclusions

This study demonstrates substantial diversity in leaf morphological traits among 15 mango varieties, emphasizing the importance of these characteristics for varietal identification and selection, particularly during the vegetative stage. The majority of varieties exhibited acuminate leaf apices (73%), with acute and obtuse types also present, mirroring established patterns in mango taxonomy. Leaf base shapes were primarily acute (53%) or round (47%) and most varieties had entire leaf margins (80%), with a minority displaying wavy edges. Young leaf colour showed notable variation, with light green being most common, but other hues such as deep copper tan, deep purple, and light brown were also observed, reflecting the genetic and environmental influences on this trait. Mature leaves were uniformly dark green across all varieties. Quantitative measurements revealed significant differences: leaf length ranged from approximately 19.3 cm to 26.4 cm, with Alphonso and Mallika being the longest and Baramasi the shortest. Leaf breadth was greatest in Banganpalli and narrowest in Dashehari, while the leaf length-breadth ratio was highest in Alphonso and lowest in Baramasi. Petiole length also varied widely. These findings confirm that genetic factors are the primary drivers of leaf morphological diversity, although environmental adaptation also contributes, providing valuable information for breeding and cultivar selection.

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