



Morphological Characterization and Phenotypic Diversity Assessment of Mango Selections from Dharmapuri and Krishnagiri Districts of Tamil Nadu, India

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Abstract

Mango is an important tropical fruit crop with wide phenotypic variability in tree architecture, leaf morphology, fruit quality and seed characters. Farmer-maintained mango trees in traditional orchards and village landscapes represent valuable genetic resources, but many such selections remain undocumented. The present study was undertaken to characterize eight mango selections collected from different villages of Dharmapuri and Krishnagiri districts of Tamil Nadu, India. The selected accessions were coded as PMi-1 to PMi-8 and evaluated for tree, leaf, fruit, pulp, seed, total soluble solids and yield traits using standard mango descriptor-based methods. Considerable variation was observed among the accessions for tree age, crown shape, growth habit, leaf blade shape, fruit skin colour, pulp colour, pulp texture, fibre content, seed traits, TSS and yield. Tree age ranged from 6 to 80 years, leaf blade length from 10.00 to 25.00 cm, fruit weight from 256 g to 791 g, TSS from 11.70 to 23.40 °Brix, and yield from 150 to 400 kg tree⁻¹. Among the selections, PMi-1 recorded the highest TSS, dark orange pulp and juicy texture, indicating its potential for table purpose, whereas PMi-4 recorded the highest fruit weight, pulp thickness and yield, suggesting suitability for processing or pickle use. Gower distance-based clustering separated PMi-4 and PMi-3 as distinct accessions, while PMi-6 and PMi-7 showed closer similarity. The study confirms the presence of useful phenotypic diversity among farmer-maintained mango selections and emphasizes the need for conservation, multi-season evaluation, biochemical profiling and molecular characterization.

Keywords: Mango, selections, morphological characterization, phenotypic diversity, local germplasm, TSS, Gower distance, Tamil Nadu.

1. Introduction

Mango (*Mangifera indica* L.) is one of the most important tropical fruit crops of India and is highly valued for its taste, aroma, nutritional quality, processing potential and economic importance. India is considered one of the major centres of origin and diversity of mango, where a large number of cultivars, landraces, types and farmer-selected genotypes are maintained across different agro-climatic regions. The crop shows wide variation in tree architecture, leaf morphology, flowering behaviour, fruit size, fruit shape, pulp colour, fibre content, seed characters, fruit quality and adaptation traits. This variability is mainly due to the highly heterozygous nature of mango, its long history of cultivation, open-pollinated origin and continuous farmer selection of superior local types (Mukherjee 1953; Dinesh et al. 2016; Jena et al. 2021).

Traditional orchards, homestead gardens, farm boundaries and village landscapes often maintain mango trees with desirable local traits. Farmers conserve such trees because of their fruit taste, pulp quality, aroma, bearing ability, local preference, processing suitability or specific use as table, pickle or pulp types. However, many such farmer-maintained mango selections remain undocumented and may be lost due to orchard replacement, ageing of trees, urbanization, climate stress and preference for a limited number of commercial cultivars. Therefore, systematic documentation and characterization of local mango selections are essential for conservation, crop improvement and future utilization of mango genetic resources.

Morphological characterization is an important preliminary step in the identification, documentation and evaluation of plant genetic resources. In mango, descriptor-based characterisation helps systematically and comparably record important tree, leaf, fruit, pulp, and seed characters. The NBPGR plant descriptor provides a useful framework for documenting morphological and horticultural traits of germplasm accessions (NBPGR, 2006). Such standardized descriptors help in identifying variation among local selections, distinguishing promising accessions and generating baseline information for conservation and future evaluation. In mango populations, where genetic variability is expected to be high, descriptor-based characterization is especially useful for recognizing distinct and valuable types.

Several earlier studies have shown that morphological and fruit-quality descriptors are effective in differentiating mango genotypes. Bhamini et al. (2018) reported that qualitative and quantitative morphological characters are useful for mango genotype identification. Sankaran et al. (2020), while studying 400 mango genotypes, observed substantial variation in fruit characters and emphasized their importance in genetic analysis and selection. Jena et al. (2021) also used fruit and leaf traits along with multivariate analysis to assess diversity among Indian mango genotypes. These studies indicate that morphological characterization, when supported with statistical tools such as correlation and cluster analysis, can help identify distinct and promising mango accessions.

Dharmapuri and Krishnagiri districts of Tamil Nadu are important mango-growing regions with a long history of mango cultivation. These districts contain commercial orchards as well as traditional mango trees maintained in village-level production systems. The variation in soil, rainfall, management conditions and farmer selection practices may have contributed to the maintenance of locally adapted mango types. However, many farmer-maintained mango selections from these districts have not been systematically characterized. As a result, potentially useful genotypes with desirable fruit quality, yield, processing value or adaptation traits may remain unrecognized.

In the present investigation, eight farmer-maintained mango selections were identified from different villages of Dharmapuri and Krishnagiri districts and coded as PMi-1 to PMi-8. The study was undertaken to characterize these selections using the NBPGR plant descriptor for tree, leaf, fruit, pulp, seed, total soluble solids and yield-related traits; to assess the extent of morphological and phenotypic diversity among them; and to identify promising selections for table, processing and pickle purposes (NBPGR, 2006). The information generated from this study will provide a useful baseline for conservation, vegetative propagation, multi-season evaluation, biochemical profiling, molecular characterization and future utilization of local mango germplasm.

2. Materials and Methods

2.1 Study area

The present investigation was carried out in selected mango-growing villages of Dharmapuri and Krishnagiri districts of Tamil Nadu, India, during 2019–2023 (Department of Horticulture, Dharmapuri, n.d.; Department of Horticulture, Krishnagiri, n.d.). The surveyed locations included Kullanoor and Irumathur in Dharmapuri district and Koochanur, Santhur and Chaparathi in Krishnagiri district. These districts are important mango-growing regions of Tamil Nadu and are characterized by semi-arid to sub-humid climatic conditions. The region receives rainfall mainly from the southwest and northeast monsoons and contains predominantly red, black and mixed loamy soil types. Traditional orchards, homestead gardens, village fields and farm boundaries in these districts were surveyed for identifying farmer-maintained mango selections.

2.2 Survey and selection of mango accessions

Field surveys were conducted in the selected villages to identify morphologically distinct and farmer-preferred mango trees. Selection was based on farmer information, field observation and visible differences in tree, leaf and fruit characters. Trees were selected when they showed one or more desirable or distinguishing traits such as fruit size, fruit shape, pulp colour, pulp texture, aroma, fibre content, fruit taste, bearing ability, maturity behaviour or specific use for table, processing or pickle purposes. A total of eight mango selections were identified and coded as PMi-1 to PMi-8. Each selected tree was treated as a separate accession for morphological and phenotypic characterization. The selected trees represented local mango diversity maintained under farmer-managed conditions in traditional production systems.

2.3 Plant material

The selected mango accessions were of varied ages from 6 to 80 years. Passport information, such as selection code, district, village, approximate tree age, local name if available, and special reason for selection, was recorded for each accession (Table 1). The selected trees were maintained under existing farmer-managed field conditions without imposing any experimental treatment. Therefore, the study was considered a descriptor-based morphological characterization of local mango accessions rather than a replicated field experiment.

2.4 Morphological characterization

Morphological characterization was carried out using the NBPGR plant descriptor for mango (NBPGR, 2006). Descriptor-based observations were recorded for tree, leaf, fruit, pulp, seed, quality and yield-related characters. Both qualitative and quantitative traits were documented to assess phenotypic variation among the eight mango selections. The major descriptor groups included Tree descriptors – tree type, tree age, crown shape, growth habit and foliage density, Leaf descriptors – leaf blade shape, leaf attitude, leaf blade length, leaf blade width, petiole length, pulvinus thickness, venation, texture, apex shape, base shape, margin, pubescence and colour of fully developed leaf, Fruit and pulp descriptors – fruit skin waxiness, ripe fruit skin colour, pulp colour, pulp texture, skin adherence to pulp, latex oozing from peduncle, pulp thickness, fibre length, pulp juiciness and pulp aroma, Seed descriptors – seed length, seed width and seed weight, Fruit quality and yield traits – fruit weight, total soluble solids and fruit yield per tree.

2.5 Sampling procedure

For quantitative observations, representative samples were collected from each selected tree. A total of 20 fully developed leaves and 20 mature fruits were randomly sampled from all four directions of the canopy to reduce sampling bias. Leaf observations were recorded from healthy, fully expanded leaves of comparable maturity. Fruit observations were recorded at the mature or ripe stage, depending on the descriptor requirement. Qualitative traits were recorded through visual observation using descriptor states, while quantitative traits were measured using standard procedures.

2.6 Measurement of quantitative traits

Leaf blade length, leaf blade width and petiole length were measured in centimetres using a measuring scale. Fruit weight was recorded in grams using an electronic balance. Fruit pulp thickness, seed length and seed width were

measured in centimetres. Seed weight was recorded in grams after separating the seed from the fruit. Total soluble solids were measured from ripe fruit pulp using a hand refractometer or digital refractometer and expressed as °Brix. Fruit yield per tree was recorded in kilograms based on the total harvested fruit yield from each selected accession.

2.7 Data compilation and statistical analysis

The recorded qualitative and quantitative descriptor data were compiled accession-wise for all eight mango selections. Descriptive statistics such as range, mean and trait-wise variation were used to summarize the quantitative characters. Pearson's correlation coefficient was calculated among quantitative traits to understand the association among leaf, fruit, seed, quality and yield characters. The correlation results were represented as a heatmap. Since the number of accessions was limited, the correlation results were interpreted as exploratory associations. For diversity grouping, Gower distance was calculated because the dataset included both qualitative and quantitative descriptor variables. The Gower distance matrix was used to generate a UPGMA dendrogram to classify the PMi mango selections based on overall morphological dissimilarity. The clustering pattern was used to identify closely related and distinct accessions among the selected mango populations.

2.8 Interpretation of promising selections

The promising accessions were identified based on the combined expression of fruit weight, pulp colour, pulp texture, fibre content, pulp aroma, total soluble solids and yield per tree. Accessions with high TSS, juicy pulp, attractive pulp colour and lower fibre were considered more suitable for table purpose. Accessions with large fruit size, firm pulp, higher pulp thickness, strong aroma and higher yield were considered potentially suitable for processing or pickle purpose. Final recommendations were made cautiously because the accessions require further multi-season evaluation, biochemical analysis, molecular characterization and vegetative propagation under uniform conditions.

3. Results

3.1 Identification of farmer-maintained mango selections

A total of eight farmer-maintained mango selections were identified from different villages of Dharmapuri and Krishnagiri districts of Tamil Nadu and coded as PMi-1 to PMi-8. The selected accessions were maintained under farmer-managed conditions in traditional orchards, homestead gardens, village fields and farm boundaries. The accessions differed in tree age, local identity, fruit characters and farmer-reported utility. Tree age ranged from 6 years in PMi-4 to 80 years in PMi-3, indicating the presence of both old farmer-conserved trees and relatively recent local selections.

Among the selected accessions, PMi-1 was locally known as Shanthi Mulgoa and was selected for its Malgoa-like fruit type, red/dark orange pulp and high TSS. PMi-4, locally known as Gadhamar, was selected for high yield and desirable fruit quality, while PMi-7 and PMi-8 were locally known as Laddu and Seeri, respectively. PMi-8 was particularly identified as a pickle-type selection. The passport information of the selected PMi accessions is presented in Table 1.

3.2 Variation in tree descriptors

The selected PMi accessions showed variation in tree age, crown shape, growth habit and foliage density (Table 2). Semi-spherical crown shape was observed in seven accessions, namely PMi-1, PMi-2, PMi-4, PMi-5, PMi-6, PMi-7 and PMi-8, whereas PMi-3 showed an oblong crown shape. Similarly, spreading growth habit was recorded in most accessions, while PMi-3 alone exhibited erect growth habit (Figure 1).

Foliage density was intermediate in all selections except PMi-3, which showed sparse foliage. The distinct combination of oblong crown shape, erect growth habit and sparse foliage clearly differentiated PMi-3 from the other accessions. The variation in tree descriptors indicates that tree architectural characters contributed to the morphological differentiation of the selected mango accessions.

3.3 Variation in leaf morphological characters

Leaf morphological descriptors showed considerable variation among the eight PMi selections (Table 3). Four types of leaf blade shapes were observed: oblanceolate, lanceolate, oblong and elliptic. Lanceolate leaf shape was most common and was recorded in PMi-2, PMi-5, PMi-6, PMi-7 and PMi-8. PMi-1 had oblanceolate leaves, PMi-3 had oblong leaves and PMi-4 had elliptic leaves (Figure 2).

Leaf attitude also varied among the selections. Horizontal leaf attitude was observed in six accessions, whereas PMi-3 had erect leaves and PMi-4 had drooping leaves. Leaf blade length ranged from 10.00 cm in PMi-8 to 25.00 cm in PMi-5. Leaf blade width varied from 3.60 cm in PMi-8 to 6.20 cm in PMi-5. Petiole length ranged from 1.50 cm in PMi-8 to 6.00 cm in PMi-5. Thus, PMi-5 recorded the maximum leaf blade length, leaf blade width and petiole length, while PMi-8 recorded the minimum values for these traits.

Leaf texture varied as membranous, coriaceous and chartaceous. Leaf apex shape was acute in most accessions, whereas PMi-3 showed obtuse apex and PMi-4 showed acuminate apex. Leaf margin was entire in most accessions, while PMi-6 and PMi-7 showed wavy leaf margins. Leaf pubescence was absent in all accessions. Fully developed leaf colour varied from pale green to green and dark green. These variations indicate that leaf descriptors were useful in differentiating PMi accessions, particularly PMi-3, PMi-4, PMi-5 and PMi-8.

3.4 Variation in fruit, pulp and seed descriptors

Fruit, pulp and seed descriptors showed marked variation among the selected accessions (Table 4). Fruit skin waxiness was present in seven accessions, while PMi-4 alone showed non-waxy fruit skin. Ripe fruit skin colour varied among accessions. Green skin colour was recorded in PMi-1 and PMi-4, yellow in PMi-2, PMi-3, PMi-6 and PMi-7, reddish-yellow in PMi-5, and greenish-yellow in PMi-8 (Figure 3).

Pulp colour also showed clear variation. PMi-1 had dark orange pulp, PMi-5 had golden-yellow pulp, PMi-3 had yellow-orange pulp, PMi-4 had greenish-yellow pulp, and PMi-6, PMi-7 and PMi-8 had yellow pulp. Pulp texture ranged from soft to firm. PMi-2 and PMi-7 recorded soft pulp, PMi-3 and PMi-4 had firm pulp, while PMi-1, PMi-5, PMi-6 and PMi-8 had intermediate pulp texture.

Adherence of fruit skin to pulp varied from free to strong. Free adherence was observed in PMi-1 and PMi-7, weak adherence in PMi-2 and PMi-6, intermediate adherence in PMi-5 and PMi-8, and strong adherence in PMi-3 and PMi-4. Quantity of latex oozing from the peduncle was low in PMi-1, PMi-4 and PMi-5; medium in PMi-2, PMi-3 and PMi-6; and high in PMi-7 and PMi-8.

Fruit pulp thickness ranged from 1.86 cm in PMi-5 to 2.73 cm in PMi-4. PMi-4 recorded the highest pulp thickness, followed by PMi-1. Fibre length in the pulp varied as short, medium and long. Short fibre was observed in PMi-1, PMi-2 and PMi-7, whereas long fibre was observed in PMi-3, PMi-5 and PMi-8. Pulp aroma was mild in PMi-1 and PMi-2, intermediate in PMi-3, PMi-5, PMi-6 and PMi-7, and strong in PMi-4 and PMi-8. The strong aroma of PMi-4 and PMi-8 supports their possible suitability for pickle or processing purposes.

Seed characters also varied among accessions. Seed length ranged from 7.00 cm in PMi-2 and PMi-3 to 12.00 cm in PMi-4. Seed width ranged from 3.80 cm in PMi-8 to 5.60 cm in PMi-4. Seed weight varied from 22.46 g in PMi-3 to 35.06 g in PMi-5. PMi-4 recorded the longest and widest seed, whereas PMi-5 recorded the highest seed weight.

3.5 Variation in fruit weight, TSS and yield

The selected PMi accessions showed wide variation in fruit weight, total soluble solids and fruit yield per tree (Table 5). Fruit weight ranged from 256 g in PMi-5 to 791 g in PMi-4. PMi-4 recorded the highest fruit weight, followed by PMi-1 with 402 g. The remaining accessions recorded fruit weight between 275 g and 310 g, indicating that PMi-4 was clearly distinct as a large-fruited selection.

Total soluble solids varied from 11.70 °Brix in PMi-4 to 23.40 °Brix in PMi-1. PMi-1 recorded the highest TSS, followed by PMi-3 with 22.10 °Brix, PMi-6 with 20.20 °Brix, PMi-5 with 19.80 °Brix and PMi-7 with 19.50 °Brix. The high TSS of PMi-1 and PMi-3 indicates their potential value as sweet table-purpose selections.

Fruit yield per tree ranged from 150 kg tree⁻¹ in PMi-2 to 400 kg tree⁻¹ in PMi-4. PMi-4 recorded the highest yield, followed by PMi-1 with 300 kg tree⁻¹, PMi-7 with 280 kg tree⁻¹, and PMi-5 and PMi-8 with 260 kg tree⁻¹ each. The high fruit weight and yield of PMi-4 indicate its potential for processing or pickle-type use, whereas PMi-1 combined high TSS, good fruit weight, dark orange pulp and good yield, suggesting its suitability for table purpose.

3.6 Correlation among quantitative traits

Correlation analysis among quantitative traits showed clear associations among fruit, seed, quality and yield traits (Figure 4). Fruit weight showed positive association with pulp thickness, seed length, seed width and fruit yield per tree. This indicates that larger fruits generally had thicker pulp, larger seed dimensions and higher yield contribution. Fruit yield per tree was also positively associated with fruit weight, suggesting that fruit size contributed substantially to total yield in the selected accessions.

However, fruit weight showed a negative association with TSS. This pattern was clearly reflected in PMi-4, which recorded the highest fruit weight and yield but the lowest TSS. In contrast, PMi-1 recorded the highest TSS with good fruit weight and yield. This indicates that large fruit size and sweetness did not always occur together among the PMi mango selections. Therefore, selection should be based on intended use: high TSS and eating quality for table purpose, and fruit size, pulp thickness, firm texture and yield for processing or pickle purpose.

3.7 Diversity analysis and clustering of PMi accessions

Gower distance-based UPGMA clustering separated the eight PMi accessions into distinct groups based on combined qualitative and quantitative descriptor data (Figure 5). The dendrogram showed that PMi-4 formed a distinct cluster, mainly due to its maximum fruit weight, highest pulp thickness, highest yield, non-waxy fruit skin, firm pulp and strong aroma. PMi-3 also showed distinct separation, mainly due to its oblong crown shape, erect growth habit, sparse foliage and high TSS.

The remaining accessions, PMi-1, PMi-2, PMi-5, PMi-6, PMi-7 and PMi-8, formed a broader group with comparatively higher similarity. Among them, PMi-6 and PMi-7 showed the closest similarity, indicating a closer phenotypic relationship based on the recorded descriptors. The greatest divergence was observed between PMi-3 and PMi-4, showing that these two accessions were the most distinct among the evaluated selections.

3.8 Identification of promising selections

Based on the combined evaluation of fruit weight, pulp colour, pulp texture, fibre length, aroma, TSS and yield, PMi-1 and PMi-4 emerged as the most promising selections for different uses. PMi-1 recorded the highest TSS, dark orange pulp, juicy texture, short fibre, low latex oozing and good yield, indicating its potential as a table-purpose selection. PMi-4 recorded the highest fruit weight, highest pulp thickness, highest yield, firm pulp and strong aroma, suggesting its suitability for processing or pickle-type use. PMi-3 was distinct for high TSS and

unique tree architecture, while PMi-5 had attractive reddish-yellow fruit skin and golden-yellow pulp. PMi-8 showed strong aroma and pickle-type character. These accessions may be useful for future conservation, vegetative propagation, biochemical evaluation and molecular characterization.

Overall, the results confirmed the presence of considerable morphological and phenotypic diversity among farmer-maintained mango selections from Dharmapuri and Krishnagiri districts. The observed variation in tree, leaf, fruit, pulp, seed, TSS and yield traits indicates that these local selections represent valuable germplasm resources for future mango improvement and conservation.

4. Discussion

The present study documented clear morphological and phenotypic variation among eight farmer-maintained mango selections collected from Dharmapuri and Krishnagiri districts of Tamil Nadu. The observed variation in tree architecture, leaf morphology, fruit skin colour, pulp colour, pulp texture, fibre content, seed characters, total soluble solids and yield confirms that traditional village landscapes and farmer-managed orchards can act as important reservoirs of mango diversity. This is scientifically meaningful because mango is a highly heterozygous perennial fruit crop, and open-pollinated populations often express wide variation in fruit and plant traits. Dinesh et al. (2016) emphasized that mango improvement in India depends strongly on the availability and conservation of diverse genetic resources, and that heterozygosity is one of the major reasons for wide variability in mango populations.

The use of the NBPGR plant descriptor in the present study helped record accession-wise morphological and horticultural characters in a systematic manner (NBPGR, 2006). Descriptor-based characterization is especially important in mango because many farmer-maintained trees are known locally by informal names, fruit appearance, taste, aroma or use, but they are not formally documented. Standardized descriptors allow such selections to be described in a comparable format and provide baseline information for germplasm conservation, varietal identification and future evaluation. Similar descriptor-based characterization has been widely used in mango; Bhamini et al. (2018) characterized 24 mango genotypes using DUS descriptors and reported that morphological descriptors related to plant, leaf, inflorescence, fruit and stone characters were useful for differentiating mango genotypes.

The wide tree-age range observed in the present study, from 6 years in PMi-4 to 80 years in PMi-3, indicates that the surveyed region maintains both old farmer-conserved trees and relatively recent local selections. Older accessions, such as PMi-3 and PMi-1, may represent trees retained over a long period because of desirable local traits, while younger selections, such as PMi-4, may represent recently identified promising types. Such age variation is common in farmer-managed mango landscapes, where trees are retained based on fruit quality, household use, processing suitability, yield or local preference rather than formal varietal status. However, tree architecture traits such as crown shape, growth habit and foliage density must be interpreted carefully because they may be influenced by age, pruning history, spacing and local growing conditions. In the present study, PMi-3 was distinct due to its oblong crown, erect growth habit and sparse foliage, but this character should be confirmed after vegetative propagation under uniform management.

Leaf morphological descriptors also contributed to accession differentiation. The presence of oblanceolate, lanceolate, oblong and elliptic leaf blade shapes among only eight selections indicates meaningful variation in vegetative morphology. PMi-5 recorded the highest leaf blade length, leaf blade width and petiole length, whereas PMi-8 recorded the lowest values for these traits. PMi-3 and PMi-4 were also distinct due to oblong and elliptic leaf shapes, respectively. Leaf characters are useful in mango identification because they can be recorded even before fruiting and may help in preliminary field recognition of accessions. Earlier studies also support this observation; Jena et al. (2021) reported significant diversity among selected Indian mango genotypes based on fruit and leaf traits, and Bhamini et al. (2018) observed that leaf descriptors are useful for distinguishing mango genotypes.

The fruit and pulp descriptors recorded in the present study were more directly relevant for selection because they influence consumer preference, market value and processing suitability. Considerable variation was observed for fruit skin waxiness, ripe fruit skin colour, pulp colour, pulp texture, fibre length, pulp juiciness, pulp aroma and skin adherence to pulp. PMi-1 showed dark orange pulp, juicy texture, short fibre and high TSS, whereas PMi-4 showed firm pulp, strong aroma, highest pulp thickness and non-waxy green skin. PMi-8 also showed strong aroma and pickle-type character. Such variation is important because fruit quality in mango is not determined by a single trait but by a combination of pulp colour, sweetness, aroma, fibre content, texture, acidity, pulp recovery and consumer preference. Khadivi et al. (2022), while evaluating mango genotypes using morphological and pomological characters, also emphasized the role of fruit and pulp traits in identifying promising genotypes.

Pulp colour variation observed among the PMi selections is also important from a nutritional and quality perspective. Dark orange and golden-yellow pulp, as recorded in PMi-1 and PMi-5, may indicate higher carotenoid accumulation, although this must be confirmed through biochemical analysis. Mango pulp colour is often associated with carotenoid pigments and consumer appeal. Therefore, PMi-1 and PMi-5 should be prioritized for future biochemical profiling, including carotenoids, total sugars, acidity, antioxidant activity and TSS:acid ratio. Megha et al. (2022) highlighted the importance of physico-chemical and biochemical profiling in mango genotypes because fruit quality changes across developmental stages and varies among genotypes.

The observed variation in fruit weight, TSS and yield clearly separated the selections based on possible end use. Fruit weight ranged from 256 g in PMi-5 to 791 g in PMi-4, while TSS ranged from 11.70 °Brix in PMi-4 to 23.40 °Brix in PMi-1. Yield ranged from 150 kg tree⁻¹ in PMi-2 to 400 kg tree⁻¹ in PMi-4. This contrast is important because PMi-4 was superior for fruit size and yield but recorded the lowest TSS, whereas PMi-1 had the highest

TSS along with good fruit weight and yield. Therefore, PMi-4 should not be described as the best selection overall; rather, it is promising for processing or pickle-type use. PMi-1 is more suitable for table purposes because it combines high TSS, dark orange pulp, juicy texture, short fibre and low latex oozing.

The high fruit weight of PMi-4 is particularly notable when compared with earlier diversity studies in mango. Sankaran et al. (2020), in a large-scale study involving 400 mango genotypes, reported significant differences for quantitative and qualitative fruit traits and grouped the genotypes into several clusters based on fruit characteristics. This supports the present observation that fruit traits can serve as powerful descriptors for differentiating mango accessions. However, fruit weight alone is not sufficient for selecting a superior table mango, because consumer acceptance depends on sweetness, flavour, fibre, aroma, pulp texture, acidity and pulp recovery. Therefore, the large fruit size of PMi-4 should be interpreted mainly as a processing, pickle or yield-oriented advantage.

The negative association observed between fruit weight and TSS in the present study is an important selection insight. PMi-4 had the highest fruit weight and yield but the lowest TSS, while PMi-1 had the highest TSS with moderate-to-good fruit size and yield. This indicates that large fruit size and sweetness did not necessarily occur together among the PMi selections. Such a trade-off has practical importance because different end uses require different selection criteria. For table purpose, high TSS, attractive pulp colour, juiciness, low fibre and pleasant aroma are more important. For processing or pickle purpose, fruit size, pulp thickness, firmness, aroma and yield may be more important. Thus, selection should be use-specific rather than based on a single superior trait.

Seed characters also contributed to accession differentiation. PMi-4 recorded the highest seed length and seed width, while PMi-5 recorded the highest seed weight. Seed size is useful for descriptor-based identification, but from a commercial perspective, large seed size may reduce edible pulp recovery unless compensated by higher fruit size and pulp thickness. In PMi-4, the large seed was accompanied by the highest fruit weight and highest pulp thickness, which partly supports its processing value. However, the present study did not estimate pulp recovery percentage, peel weight, stone weight, acidity or TSS:acid ratio. These traits should be included in future studies to confirm the actual processing efficiency and table quality of the promising selections.

The Gower distance-based UPGMA clustering provided additional support to the field-based descriptor observations. PMi-4 formed a separate cluster due to its large fruit size, highest pulp thickness, highest yield, firm pulp, strong aroma and non-waxy skin. PMi-3 also separated because of its distinct tree architecture, sparse foliage and high TSS. PMi-6 and PMi-7 showed closer similarity based on the recorded descriptors. The use of Gower distance was appropriate because the dataset contained both qualitative descriptor states and quantitative measurements. Multivariate analysis is widely used in mango diversity studies for grouping accessions and identifying distinct material; Jena et al. (2021) used fruit and leaf traits with multivariate tools to assess Indian mango diversity, while Sankaran et al. (2020) grouped 400 mango genotypes based on fruit characteristics.

The separate placement of PMi-3 and PMi-4 in the dendrogram suggests that these two accessions are morphologically distinct within the studied set. However, this should be interpreted as phenotypic distinctness, not confirmed genetic distinctness. Morphological traits can be influenced by tree age, environment, nutrition, rootstock, management and sampling stage. Molecular marker studies are therefore necessary to validate whether the observed differences represent true genetic divergence. Samal et al. (2012) used RAPD and ISSR markers to evaluate genetic diversity among commercial cultivars, hybrids and local mango genotypes of India, while recent SNP-based studies have also shown the usefulness of molecular markers in understanding mango population structure and genetic diversity.

The conservation value of the PMi selections is high because farmer-maintained trees are vulnerable to loss. Replacement by commercial cultivars, old tree removal, urban expansion, pest and disease pressure, climate stress and changes in land use can reduce local mango diversity. Once such trees are lost, their unique trait combinations may not be recovered. Dinesh et al. (2016) noted that India has large mango diversity and that genetic resources are important for future mango improvement. Therefore, promising selections such as PMi-1, PMi-3, PMi-4, PMi-5 and PMi-8 should be conserved through vegetative propagation and maintained in field gene banks or institutional orchards for further evaluation.

From a crop improvement perspective, PMi-1 appears useful as a table-purpose selection because it recorded the highest TSS, dark orange pulp, juicy texture, short fibre and good yield. PMi-4 appears more useful as a processing or pickle-purpose selection because it recorded the highest fruit weight, highest pulp thickness, firm pulp, strong aroma and highest yield. PMi-3 may be useful as a distinct morphological accession because of its erect growth habit, oblong crown, sparse foliage and high TSS. PMi-5 has attractive reddish-yellow skin and golden-yellow pulp, which may be useful for visual appeal and biochemical evaluation. PMi-8 has strong aroma and pickle-type characteristics, making it worth further processing-quality assessment. These selections should be evaluated over multiple years before any final recommendation is made.

The present study also highlights the importance of linking morphological characterization with end-use classification. Mango selections cannot be judged only on yield or fruit size. A high-yielding selection may not be ideal for table purpose if sweetness is low, and a high-TSS selection may not be ideal for processing if fruit size or pulp recovery is poor. Therefore, the future evaluation of PMi selections should include fruit number per tree, pulp percentage, peel percentage, stone percentage, acidity, TSS:acid ratio, reducing and non-reducing sugars, carotenoids, shelf life, firmness, consumer preference and processing recovery. Such multi-trait evaluation will allow more accurate classification of selections into table, pickle, processing or breeding-use categories.

Although the present study provides useful baseline information, some limitations must be acknowledged. The study was based on eight farmer-maintained trees under existing field conditions, and the trees differed in age and management background. Therefore, the results should be interpreted as preliminary morphological and

phenotypic characterization rather than a replicated varietal evaluation trial. The absence of ANOVA is justified because the accessions were not evaluated under a uniform replicated design. However, future work should vegetatively propagate the promising selections and evaluate them under uniform field conditions across multiple seasons and locations. This will help confirm trait stability, yield consistency, fruit quality and distinctness.

Overall, the study demonstrates that Dharmapuri and Krishnagiri districts possess valuable farmer-maintained mango diversity. The PMi selections showed meaningful variation in vegetative, fruit, pulp, seed, quality and yield traits. PMi-1, PMi-4, PMi-3, PMi-5 and PMi-8 deserve priority for conservation and further evaluation. The combination of NBPGR descriptor-based characterization, correlation analysis and Gower distance-based clustering provides a useful framework for preliminary identification of promising local mango accessions (NBPGR, 2006). However, biochemical profiling, molecular marker analysis and multi-season grafted evaluation are required before these selections can be recommended for formal release, registration or commercial multiplication.

5. Conclusion

The present study documented considerable morphological and phenotypic diversity among eight farmer-maintained seedling-origin mango selections, PMi-1 to PMi-8, identified from different villages of Dharmapuri and Krishnagiri districts of Tamil Nadu. The selected accessions showed clear variation in tree architecture, leaf morphology, fruit skin colour, pulp colour, pulp texture, fibre content, pulp thickness, seed traits, total soluble solids and yield. This variation confirms that traditional orchards, homestead gardens and village landscapes of these districts still maintain valuable local mango genetic resources.

Among the evaluated selections, PMi-1 was identified as a promising table-purpose selection due to its highest TSS, dark orange pulp, juicy texture, short fibre, low latex oozing and good yield. PMi-4 was the most promising selection for processing or pickle-type use because of its maximum fruit weight, highest pulp thickness, firm pulp, strong aroma and highest yield per tree. PMi-3 was distinct for its oblong crown, erect growth habit, sparse foliage and high TSS, while PMi-5 showed attractive reddish-yellow fruit skin and golden-yellow pulp. PMi-8 also showed strong aroma and pickle-type character, indicating its potential value for processing.

The correlation and diversity analysis further supported the existence of meaningful variation among the PMi selections. Fruit weight was positively associated with pulp thickness, seed size and yield, whereas fruit weight showed a negative association with TSS, indicating that large fruit size and sweetness may not always occur together. Gower distance-based clustering separated PMi-4 and PMi-3 as phenotypically distinct accessions, while PMi-6 and PMi-7 showed closer similarity.

Overall, the study highlights the importance of conserving farmer-maintained mango selections from Dharmapuri and Krishnagiri districts before they are lost due to orchard replacement, ageing of trees or preference for commercial cultivars. The promising accessions identified in this study should be conserved through vegetative propagation and further evaluated under uniform field conditions over multiple seasons. Future studies should include biochemical profiling, pulp recovery, acidity, TSS:acid ratio, shelf life, consumer preference, processing suitability and molecular marker analysis to confirm their stability, distinctness and potential use in mango improvement programmes.

Statements & Declarations

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Conflict of interest

The authors declare that they have no conflict of interest or personal relationships that could have appeared to influence the work reported in the paper.

Author Contributions

All authors contributed to the conception and design of the study. Material preparation and data collection were performed by Senthamizh Selvi B, Aneesa Rani MS, and Srividhya S. Data analysis was carried out by Hariprasanth T. The first draft of the manuscript was prepared collaboratively by all authors, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Table 1. Passport information of selected PMi mango accessions

Selection code	District	Village	Approx. tree age (years)	Local name	Special reason for selection
PMi-1	Krishnagiri	Koochanur	55	Shanthi Mulgoa	Farmer-reported Malgoa-like fruit; dark orange pulp and high TSS
PMi-2	Krishnagiri	Santhur	7	-	High yield potential and farmer-reported Imampasand-like taste
PMi-3	Krishnagiri	Chaparathi	80	-	Bangalora-like fruit morphology with high TSS
PMi-4	Dharmapuri	Kullanoor	6	Gadhamar	Large-fruited, high-yielding local selection with good taste
PMi-5	Dharmapuri	Irumathur	>50	-	High-yielding local selection with acceptable eating quality
PMi-6	Dharmapuri	Irumathur	>50	-	High-yielding local selection with acceptable eating quality
PMi-7	Dharmapuri	Irumathur	>50	Laddu	High-yielding local selection with good taste
PMi-8	Dharmapuri	Irumathur	>50	Seeri	Strong-aroma pickle-type local selection

Table 2. Tree descriptors of selected PMi mango accessions

Selection code	Tree age (years)	Crown shape	Tree growth habit	Foliage density
PMi-1	55	Semi-spherical	Spreading	Intermediate
PMi-2	7	Semi-spherical	Spreading	Intermediate
PMi-3	80	Oblong	Erect	Sparse
PMi-4	6	Semi-spherical	Spreading	Intermediate
PMi-5	50	Semi-spherical	Spreading	Intermediate
PMi-6	50	Semi-spherical	Spreading	Intermediate
PMi-7	50	Semi-spherical	Spreading	Intermediate
PMi-8	50	Semi-spherical	Spreading	Intermediate

Table 3. Leaf morphological descriptors of selected PMi mango accessions

Selection code	Leaf blade shape	Leaf attitude	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Pulvinus thickness	Leaf venation	Leaf texture	Leaf apex	Leaf base	Leaf margin	Leaf pubescence	Mature leaf colour
PMi-1	Oblanceolate	Horizontal	23	5	2.10	Thin	Medium	Membranous	Acute	Acute	Entire	Absent	Pale green
PMi-2	Lanceolate	Horizontal	19.50	4.20	3	Thick and tapering	Medium	Coriaceous	Acute	Acute	Entire	Absent	Green
PMi-3	Oblong	Erect	18.40	4.50	1.80	Thick and tapering	Medium	Coriaceous	Obtuse	Acute	Entire	Absent	Green
PMi-4	Elliptic	Drooping	24	5.60	3	Thick and tapering	Medium	Chartaceous	Acuminate	Acute	Entire	Absent	Dark green
PMi-5	Lanceolate	Horizontal	25	6.20	6	Thick and tapering	Medium	Chartaceous	Acute	Acute	Entire	Absent	Green
PMi-6	Lanceolate	Horizontal	18.50	4.30	1.80	Thick and tapering	Medium	Membranous	Acute	Acute	Wavy	Absent	Green
PMi-7	Lanceolate	Horizontal	19.40	5.50	2.50	Thick and tapering	Medium	Chartaceous	Acute	Acute	Wavy	Absent	Green
PMi-8	Lanceolate	Horizontal	10	3.60	1.50	Thin	Medium	Chartaceous	Acute	Acute	Entire	Absent	Dark green

Table 4. Fruit, pulp and seed descriptors of selected PMi mango accessions

Selection code	Fruit skin waxiness	Ripe fruit skin colour	Ripe pulp colour	Ripe pulp texture	Skin adherence to pulp	Late xoozing from peduncle	Pulp thickness (cm)	Fibre length	Pulp juiciness	Pulp aroma	Seed length (cm)	Seed width (cm)	Seed weight (g)
PMi-1	Waxy	Green	Dark orange	Intermediate	Free	Low	2.43	Short	Juicy	Mild	7.50	5.50	23.60
PMi-2	Waxy	Yellow	Light yellow	Soft	Weak	Medium	2.15	Short	Juicy	Mild	7	4.32	22.90
PMi-3	Waxy	Yellow	Yellow orange	Firm	Strong	Medium	2.20	Long	Juicy	Intermediate	7	4.20	22.46
PMi-4	Non-waxy	Green	Greenish yellow	Firm	Strong	Low	2.73	Medium	Slightly juicy	Strong (pickle)	12	5.60	34.36
PMi-5	Waxy	Reddish yellow	Golden yellow	Intermediate	Intermediate	Low	1.86	Long	Juicy	Intermediate	7.65	4	35.06
PMi-6	Waxy	Yellow	Yellow	Intermediate	Weak	Medium	2	Medium	Juicy	Intermediate	8.25	4	32.84
PMi-7	Waxy	Yellow	Yellow	Soft	Free	High	1.93	Short	Slightly juicy	Intermediate	9.50	4.50	33.45

Selection code	Fruit skin waxiness	Ripe fruit skin colour	Ripe pulp colour	Ripe pulp texture	Skin adherence to pulp	Late x oozi ng from peduncle	Pulp thickness (cm)	Fibre length	Pulp juiciness	Pulp aroma	Seed length (cm)	Seed width (cm)	Seed weight (g)
PMi-8	Waxy	Greenish yellow	Yellow	Intermediate	Intermediate	High	2	Long	Juicy	Strong (pickle)	7.25	3.80	30.16

Table 5. Fruit weight, total soluble solids and fruit yield of selected PMi mango accessions

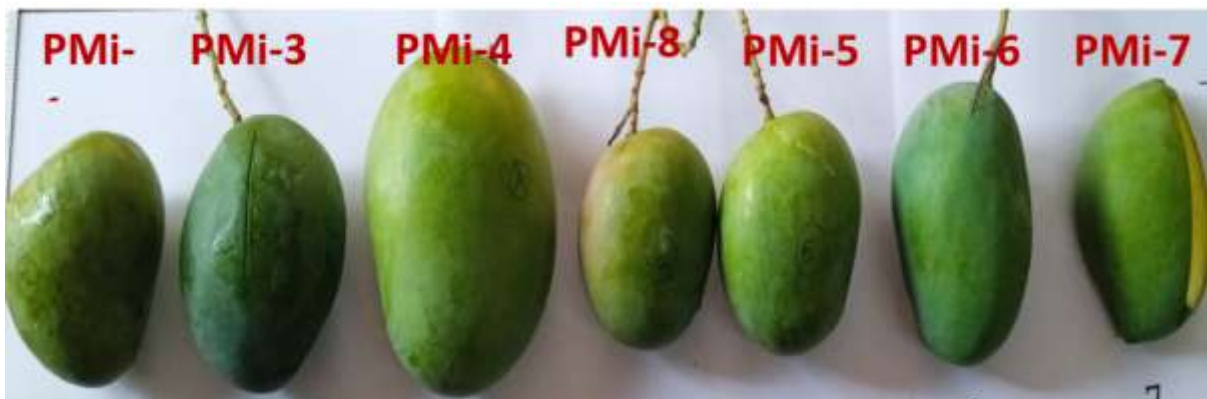
Selection code	Fruit weight (g)	TSS (deg Brix)	Fruit yield/tree (kg)
PMi-1	402	23.40	300
PMi-2	275	16.80	150
PMi-3	285	22.10	200
PMi-4	791	11.70	400
PMi-5	256	19.80	260
PMi-6	295	20.20	180
PMi-7	310	19.50	280
PMi-8	283	13.40	260



Variation in Leaf Characters



Figure 1. Variation in Leaf Characters



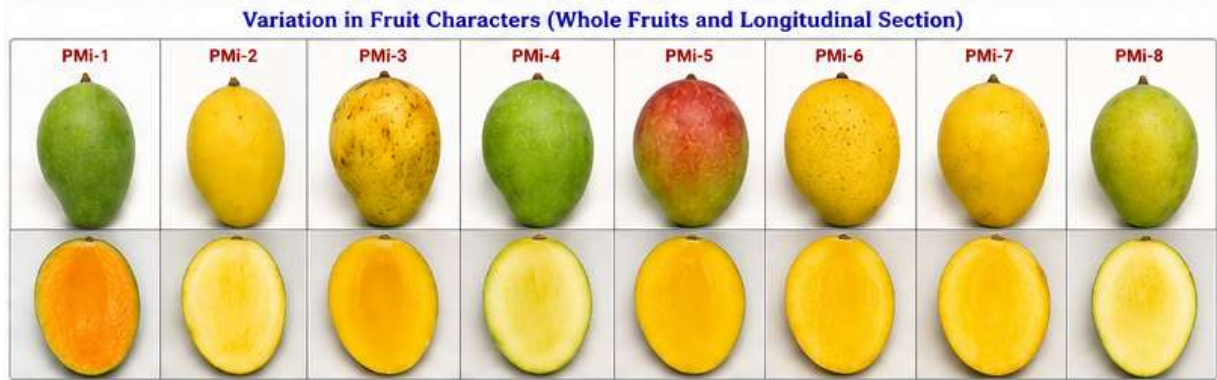


Figure 2. Variation in fruit characters

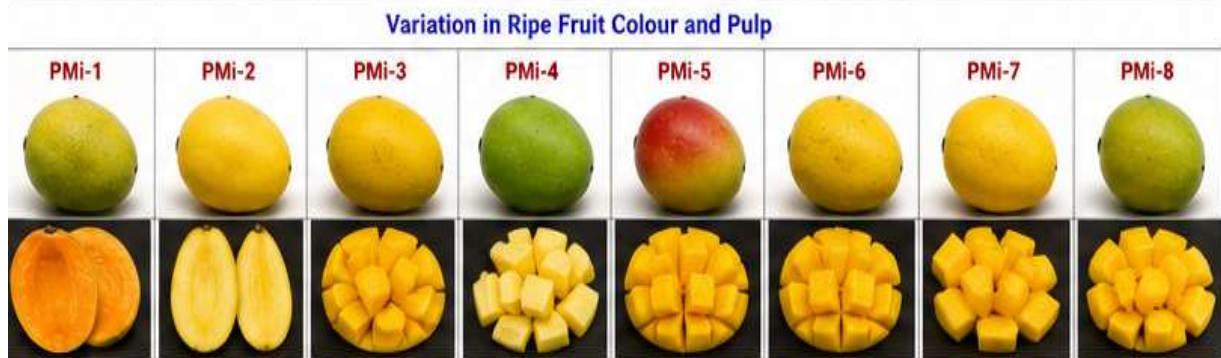


Figure 3. Variation in fruit pulp texture and colour

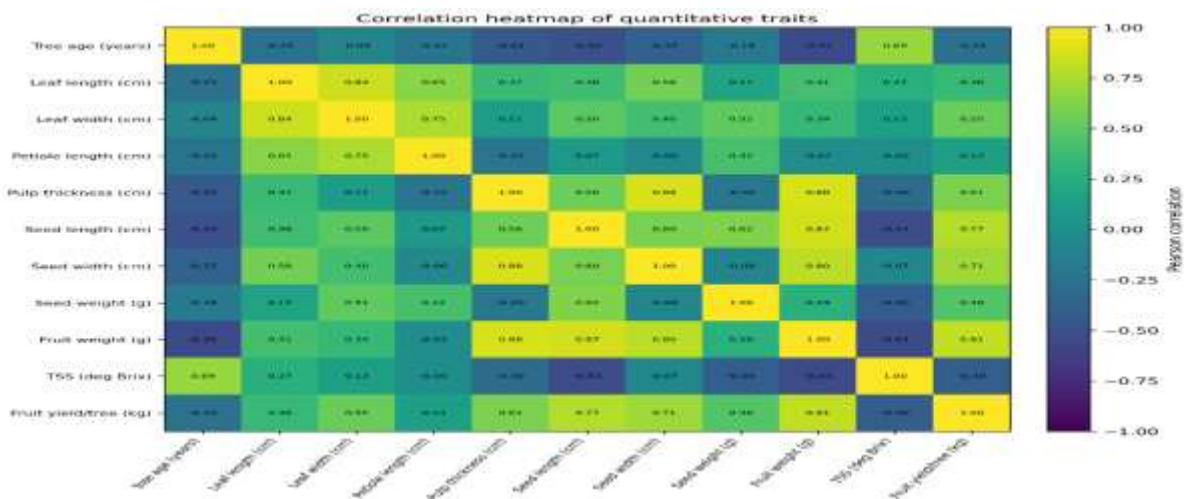


Figure 4. Correlation heatmap of quantitative tree, leaf, fruit, seed, quality and yield traits

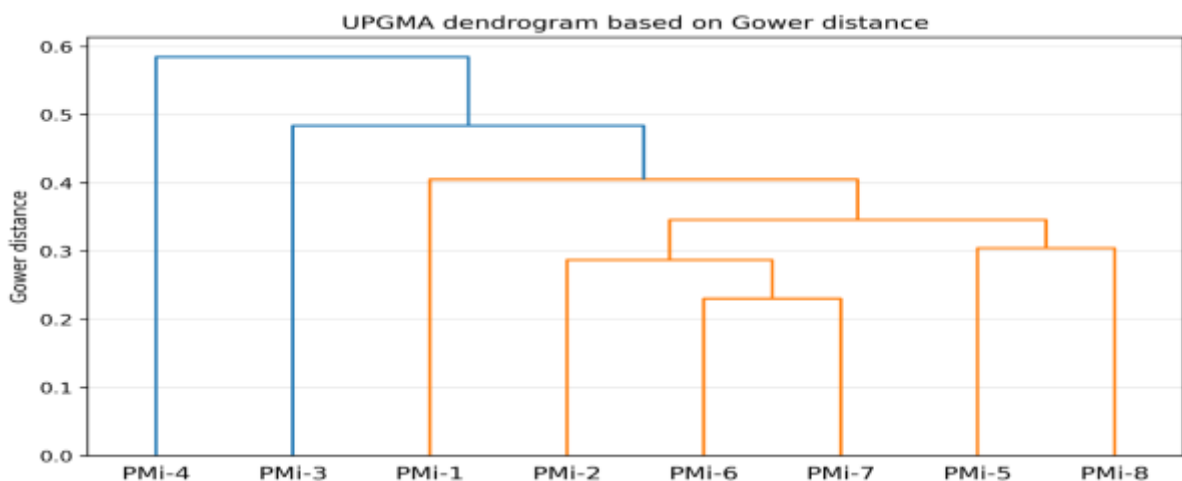


Figure 5. UPGMA dendrogram based on Gower distance using mixed qualitative and quantitative descriptors.