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Phenotypic Variation and Leaf Morphometric Characterization of Locally Recognized Mango (*Mangifera indica* L.) Types in Hausawa Village, Dawakin Kudu, Kano State, Nigeria

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ABSTRACT

Mango (*Mangifera indica* L.) shows substantial phenotypic variation that can be documented through morphological characterization. This study assessed leaf morphometric variation among six farmer-recognized mango types in Hausawa Village, Dawakin Kudu Local Government Area, Kano State, Nigeria: Binta Siga, Gwaiwar Rago, Mai Sumuti, Kan Biri, Paparanda and Dan Kamaru. Five mature trees were selected per type, and ten mature, fully expanded leaves were collected per tree (N = 300 leaves). Leaf length, leaf breadth, petiole length and estimated leaf area were measured and averaged per tree, so the tree (n = 5 per type) was the experimental unit. Types were compared by one-way ANOVA with Tukey's HSD post-hoc tests; normality and homogeneity of variance were acceptable for all traits. Types differed significantly in all four traits ($p < .001$; $\eta^2_p = 0.714–0.992$). Binta Siga had the highest and Kan Biri the lowest mean for every trait. Leaf breadth and estimated leaf area separated all six types, Dan Kamaru and Paparanda did not differ in leaf length, and petiole length separated only Binta Siga from the other types and Paparanda from Kan Biri. Principal component and cluster analyses recovered Binta Siga, Kan Biri and Mai Sumuti as distinct groups but did not separate Paparanda from Dan Kamaru. The differences reflect phenotypic variation under local conditions rather than verified genetic differentiation. The study provides quantitative baseline data on local mango germplasm in the Sudan Savanna zone of northern Nigeria.

Keywords: Ethnobotany, Leaf Morphometrics, *Mangifera indica*, Phenotypic Diversity, Sudan Savanna

INTRODUCTION

Mango (*Mangifera indica* L., Anacardiaceae) is an economically vital fruit crop widely cultivated throughout tropical and subtropical regions (Litz, 2009). In Nigeria, mango production contributes significantly to rural livelihoods, food security, and local agricultural trade. Sustainable management, conservation, and utilization of mango germplasm rely fundamentally on understanding the extent and structure of phenotypic diversity present within local populations (Khan et al., 2015; Esan et al., 2024).

Morphological characterization remains the primary, cost-effective tool for evaluating plant genetic resources, establishing descriptor frameworks, and distinguishing phenotypic groups prior to downstream molecular analyses (IPGRI, 2006). Leaf traits—including length, breadth, petiole length, and calculated surface area—are sensitive markers of phenotypic variation, reflecting both intrinsic genetic architecture and physiological adaptation to local microclimates (Igbari et al., 2019).

Although mango morphological diversity has been documented in southwestern Nigeria (Igbari et al., 2019; Esan et al., 2024; Afariogun & Ibrahim, 2025) and other African ecosystems (Neguse et al., 2019), quantitative morphometric information on farmer-recognized mango types in northern Nigeria remains limited, particularly within the semi-arid Sudan Savanna zone. Smallholder farmers across Kano State distinguish local mango varieties based on folk taxonomy, fruit quality, growth habit, and leaf morphology. However, these local nomenclature systems lack systematic morphometric validation.

The present study provides a community-level assessment of leaf morphometric variation among six farmer-recognized mango types in Hausawa Village, Dawakin Kudu Local Government Area, Kano State, Nigeria. By quantifying leaf morphological parameters across farmer-identified groups, this study establishes a scientific baseline for documenting local mango diversity in northern Nigeria.

MATERIALS AND METHODS

Study Area

The study was conducted in Hausawa Village, Dawakin Kudu Local Government Area of Kano State, Nigeria. Hausawa Village is located at approximately latitude 11°47′N and longitude 8°35′E, at an elevation of about 480 m above sea level. Dawakin Kudu lies within the Sudan Savanna ecological zone of northern Nigeria and experiences a distinct wet and dry season, with mean annual rainfall of approximately 800–1000 mm and mean temperatures ranging from 20°C to 35°C. The study area is predominantly agricultural, with fruit trees occurring in farms and residential or village environments. Hausawa Village was selected because farmers maintain mature mango trees representing several locally recognized types and permitted access for field sampling. The location of the study area is shown in Figure 1.

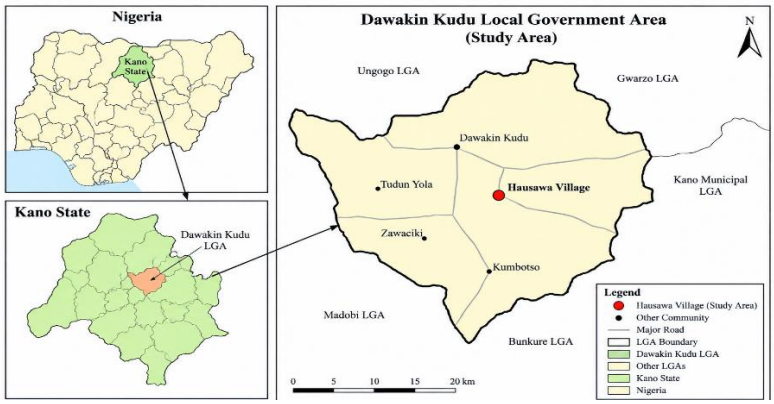


Figure 1: Map of Kano State Showing Dawakin Kudu Local Government Area and Hausawa Village (Study Area). Base Map Adapted from Google Maps (2026)

Study Design and Sampling

A field-based quantitative descriptive and comparative design was used. Six locally recognized mango types were investigated: Binta Siga, Gwaiwar Rago, Mai Sumuti, Kan Biri, Paparanda and Dan Kamaru. Five mature and apparently healthy trees were purposively selected for each type, giving 30 trees. "Apparently healthy" was defined as trees showing no visible symptoms of disease or pest infestation, with a full, uniform canopy and no signs of dieback or nutrient deficiency. Tree age was estimated to be between 15 and 30 years based on farmer information, although exact ages were not available. The sample size of five trees per type was based on similar morphological characterization studies in Nigeria (Igbari et al., 2019; Esan et al., 2024), which used 3–10 trees per accession, and was constrained by the number of mature trees available for each locally recognized type in the study village. With only five trees per type, the study has limited power to detect small differences, although the differences observed among types for the blade traits were large.

Ten healthy, mature and fully expanded leaves were collected from different portions of the canopy of each tree, giving 50 leaves per type and 300 leaves overall. To ensure representative sampling, leaves were collected from three canopy strata: upper (top third), middle (middle third) and lower (bottom third). Leaves from the outer canopy were preferentially selected to ensure full exposure to sunlight. Within each stratum, leaves were selected arbitrarily but avoided those showing damage, chlorosis or abnormal morphology. Local names and group identities were established with the assistance of three elderly farmers who had extensive experience with mango cultivation in the village. Each farmer independently identified trees belonging to each local type based on observable characteristics such as leaf size, leaf shape, tree habit and fruit characteristics. Only trees that were consistently identified by all three farmers as belonging to the same local type were included in the study, ensuring high consistency in local classification.

Leaf Measurements

Leaf length was measured from the base of the leaf blade to the apex along the midrib, excluding the petiole. Leaf breadth was measured at the widest portion of the leaf blade perpendicular to the midrib. Petiole length was measured from the point of attachment of the petiole to the stem or branch to the base of the leaf blade. Measurements were recorded in centimetres using a graduated ruler with a precision of 0.1 cm. All measurements were taken by the same trained observer to eliminate inter-observer error. To assess intra-observer reliability, ten leaves were measured twice on separate occasions, and the measurements were highly consistent ($r > 0.98$, $p < .001$).

Because a digital leaf-area meter was not available, estimated leaf area was calculated from leaf length and leaf breadth using the correction factor applied in the project dataset: LA = LL × LB × 0.67, where LA is leaf area in cm², LL is leaf length in cm and LB is leaf breadth in cm. This correction factor of 0.67 is within the range of shape coefficients (0.65–0.75) commonly reported for mango leaves, which typically have an elliptical-lanceolate shape (IPGRI, 2006). While this estimation method does not replace direct measurement with a leaf area meter, it provides a consistent and comparable index of leaf size across all samples. The estimated value was used consistently for all sampled leaves.

Statistical Analysis

The ten leaves sampled from each tree were treated as subsamples rather than independent biological replicates. Their measurements were averaged within each tree, giving five tree-level observations per type and 30 observations overall. Means and standard errors were calculated for each type. Normality of residuals was checked with the Shapiro–Wilk test and homogeneity of variance with Levene's test. One-way ANOVA was used to test for differences among the six types for each trait at $\alpha = 0.05$, and partial eta-squared (η^2_p) was calculated as the effect size: $\eta^2_p = (F \times df_effect) / (F \times df_effect + df_error)$. Effect sizes were interpreted as small (0.01), medium (0.06) or large (0.14) following Cohen's guidelines. Significant ANOVAs were followed by Tukey's HSD tests. Because petiole length had the most unequal within-type variances, its comparisons were also repeated with the Games–Howell procedure as a sensitivity check. Residual normality and homogeneity of variance were acceptable for all four traits (Levene's p = .279–.972). Relationships among traits were described with Pearson correlation coefficients. Principal component analysis (PCA) was run on the correlation matrix of the four traits for the 30 trees, and the trees were clustered by Ward's method on standardized traits. Analyses were performed in SPSS version 26 (IBM Corp., Armonk, NY, USA).

RESULTS AND DISCUSSION

Descriptive Variation Among Locally Recognized Mango Types

Table 1 presents the descriptive statistics for the four leaf morphometric traits among the six locally recognized mango types. Binta Siga had the highest mean for each measured trait, with leaf length of 26.27 ± 0.24 cm, leaf breadth of 6.85 ± 0.05 cm, petiole length of 3.65 ± 0.05 cm and estimated leaf

area of 120.48 ± 1.39 cm^2. Kan Biri had the lowest means for all four traits, with leaf length of 17.07 ± 0.16 cm, leaf breadth of 4.01 ± 0.06 cm, petiole length of 2.13 ± 0.15 cm and estimated leaf area of 45.88 ± 0.87 cm^2.

Table 1: Descriptive Statistics (Mean ± Standard Error) for Four Leaf Morphometric Traits Among Six Locally Recognized Mango Types in Hausawa Village, Kano State, Nigeria (*n* = 5 Trees per Type)

Locally recognized type	Leaf length (cm)	Leaf breadth (cm)	Petiole length (cm)	Leaf area (cm^2)
Binta Siga	26.27 ± 0.24	6.85 ± 0.05	3.65 ± 0.05	120.48 ± 1.39
Gwaiwar Rago	23.52 ± 0.22	6.21 ± 0.05	2.51 ± 0.23	97.84 ± 1.24
Paparanda	22.26 ± 0.11	5.79 ± 0.07	2.84 ± 0.09	86.29 ± 0.86
Dan Kamaru	21.82 ± 0.11	5.24 ± 0.04	2.70 ± 0.07	76.66 ± 0.92
Mai Sumuti	19.44 ± 0.14	4.85 ± 0.06	2.68 ± 0.18	63.16 ± 1.02
Kan Biri	17.07 ± 0.16	4.01 ± 0.06	2.13 ± 0.15	45.88 ± 0.87

The present study demonstrates substantial variation in leaf morphology among six mango types recognized locally by farmers in Hausawa Village. The leaf length values recorded here (17.07–26.27 cm) are within the range reported by Igbari et al. (2019) for South-west Nigerian cultivars (15.2–32.5 cm) and by Neguse et al. (2019) for Ethiopian accessions (14.8–28.3 cm). Similarly, leaf breadth values (4.01–6.85 cm) overlap with those reported by Afariogun and Ibrahim (2025) for Lagos and Ogun States populations (3.5–7.1 cm). These comparisons suggest that the mango materials in Hausawa Village harbor comparable levels of leaf morphometric diversity to those documented in other parts of Nigeria and Africa, reinforcing the value of community-level documentation. The study is also useful because it supplies quantitative evidence from a rural community in Kano State, an area less represented in the mango characterization literature.

Two features of Table 1 deserve comment. First, the standard errors for leaf length, breadth and area are small relative to the differences between types (for example, 0.11–0.24 cm for leaf length against a spread of about 9 cm between the largest and smallest types). With five trees per type, this implies that trees sharing a local name were morphologically similar in blade dimensions, and that farmers in the village apply names consistently, at least for the trees sampled. Second, petiole length was more variable within types than the blade traits (standard errors of 0.15–0.23 cm in Gwaiwar Rago, Mai Sumuti and Kan Biri), which weakens its ability to separate types. Whether the uniformity of blade traits reflects vegetative propagation, nucellar seed propagation, shared growing conditions or a combination of these cannot be determined from leaf data alone.

Analysis of Variance and Effect Sizes

One-way ANOVA indicated significant differences among the six locally recognized types for all four traits (Table 2). The largest F-statistic was observed for estimated leaf area ($F_{5,24}$ = 601.797), followed by leaf length ($F_{5,24}$ = 345.492), leaf breadth ($F_{5,24}$ = 310.145) and petiole length ($F_{5,24}$ = 11.985); all tests had $p < .001$. Effect sizes were very large for leaf area, leaf length and leaf breadth (η^2_p = 0.992, 0.986 and 0.985, respectively) and large for petiole length (η^2_p = 0.714). The locally recognized type therefore accounted for 98.5–99.2% of the variance in the three blade traits but for about 71% of the variance in petiole length. Levene's test was not significant for any trait (p = .279–.972), so the assumption of homogeneous variances was met.

Table 2: One-way ANOVA Results (df = 5, 24) and Levene's Test for Four Leaf Morphometric Traits Among Six Locally Recognized Mango Types

Trait	*F*-value	*p*-value	η^2_p	Levene's *W*	Levene's *p*
Leaf length	345.492	< .001	0.986	0.54	.745
Leaf breadth	310.145	< .001	0.985	0.17	.972
Petiole length	11.985	< .001	0.714	1.35	.279
Leaf area	601.797	< .001	0.992	0.25	.934

Note. η^2_p = Partial Eta-Squared (Equal to Eta-Squared in a One-Way Design)

This finding is consistent with previous mango characterization studies showing that quantitative vegetative traits can contribute to the differentiation of cultivars and accessions (Igbari et al., 2019; Neguse et al., 2019; Esan et al., 2024). The very large effect sizes for the blade traits indicate that the differences among locally recognized types are not only statistically significant but also practically meaningful. This suggests that the farmer-recognized categories capture real phenotypic differentiation, even if the underlying causes (genetic, environmental or both) remain unresolved. Effect sizes of this magnitude should nevertheless be read in light of the design: the types were sampled from a single village, with five trees per type, and the groups were defined in advance by farmers rather than drawn at random from the whole mango population. The estimates describe how well the local names separate the trees sampled here, not how well they would separate mango trees in general.

Pairwise Comparisons and Trait-By-Trait Interpretation

Tukey's HSD results showed that all 15 pairwise comparisons were significant for leaf breadth and estimated leaf area (Table 3). For leaf length, all pairwise comparisons were significant except Paparanda versus Dan Kamaru (mean difference = 0.44 cm, 95% CI: −0.31 to 1.19, p = .484). Petiole length separated the types much less clearly: only 6 of 15 comparisons were significant (Binta Siga against each of the other five types, and Paparanda against Kan Biri). The full set of pairwise differences, confidence intervals and *p*-values is given in Supplementary Table S1. These results indicate that the blade measurements strongly differentiated the six groups, whereas petiole length contributed only partial separation.

Table 3: Tukey's HSD Mean-Separation Letters for Four Leaf Morphometric Traits Among Six Locally Recognized Mango Types. Types Sharing a Letter Within a Trait are not Significantly Different (α = .05)

Trait	Binta Siga	Gwaiwar Rago	Paparanda	Dan Kamaru	Mai Sumuti	Kan Biri
Leaf length	a	b	c	c	d	e
Leaf breadth	a	b	c	d	e	f
Petiole length	a	bc	b	bc	bc	c
Leaf area	a	b	c	d	e	f

Leaf Length

Leaf length varied from 17.07 cm in Kan Biri to 26.27 cm in Binta Siga. The significant ANOVA result and the Tukey pattern indicate that leaf length provided considerable discriminatory information among the local groups. The absence of a significant difference between Paparanda and Dan Kamaru suggests that not every pair of locally recognized types is separable using a single leaf character. Similar observations have been reported in morphological characterization studies in which individual traits distinguish some accessions but overlap among others (Igbari et al., 2019; Neguse et al., 2019).

Leaf Breadth

Leaf breadth showed an especially clear pattern, ranging from 4.01 cm in Kan Biri to 6.85 cm in Binta Siga. All 15 pairwise comparisons were significant, indicating that this trait separated each of the six groups under the sampling conditions of the study. This agrees with the general utility of leaf width or breadth as a quantitative mango descriptor (IPGRI, 2006; Igbari et al., 2019). The result also indicates that leaf breadth may be particularly informative when combined with other vegetative characters in a broader characterization programme. Notably, the two types that overlapped for leaf length (Paparanda and Dan Kamaru) were clearly separated by breadth, which illustrates the value of using several traits together.

Petiole Length

Petiole length ranged from 2.13 cm in Kan Biri to 3.65 cm in Binta Siga. The overall ANOVA was significant, but the effect was weaker than for the blade traits and the post-hoc groupings overlapped extensively (Table 4). Binta Siga formed a group of its own (a), Kan Biri was grouped with Dan Kamaru, Mai Sumuti and Gwaiwar Rago (c), and Paparanda was grouped with those three types (b, bc). Because petiole length showed the largest within-type variation, the comparisons were repeated with the Games–Howell procedure, which does not assume equal variances. It produced identical groupings, so the conclusions do not depend on the equal-variance assumption (Supplementary Table S1). Petiole length is therefore best treated as a supplementary vegetative character that reliably distinguishes Binta Siga but does not, on its own, separate the remaining types.

Table 4: Petiole Length (Mean ± SE, *n* = 5 Trees) and Tukey's HSD / Games–Howell Groupings Among Six Locally Recognized Mango Types

Mango type	Petiole length (cm)	Group (Tukey and Games–Howell)
Binta Siga	3.65 ± 0.05	a
Paparanda	2.84 ± 0.09	b
Dan Kamaru	2.70 ± 0.07	bc
Mai Sumuti	2.68 ± 0.18	bc
Gwaiwar Rago	2.51 ± 0.23	bc
Kan Biri	2.13 ± 0.15	c

Note. Means Sharing the Same Letter are not Significantly Different (α = .05). Both Procedures gave Identical Groupings

Estimated Leaf Area

Estimated leaf area showed the widest numerical separation among the groups, from 45.88 cm^2 in Kan Biri to 120.48 cm^2 in Binta Siga. The ANOVA produced the largest F-statistic among the four traits, and all 15 pairwise comparisons were significant. Because leaf area in this study was calculated from leaf length and breadth, its strong separation is expected to be related partly to the simultaneous differences in those component dimensions (r = .99 with each; Table 6). Leaf area should therefore not be treated as an entirely independent morphological character. Nevertheless, the consistent differences provide useful descriptive evidence of variation in leaf size among the locally recognized groups.

Distribution of Trait Values and Overall Pattern

Figure 2 presents boxplots, with the individual tree means overlaid, for leaf length, leaf breadth, petiole length and estimated leaf area. The plots illustrate the consistent ranking of Binta Siga as the type with the largest leaves and Kan Biri as the type with the smallest leaves across all four traits. They also show why petiole length separated the types poorly: the boxes for Gwaiwar Rago, Mai Sumuti and Kan Biri are wide, and two trees in each of these types lie noticeably away from the other three.

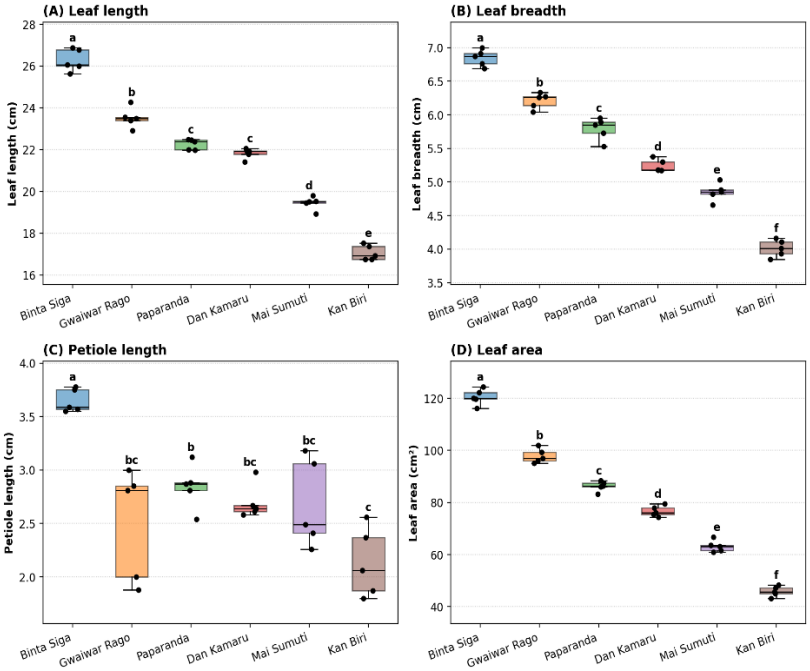


Figure 2: Boxplots of (A) leaf Length, (B) Leaf Breadth, (C) Petiole Length and (D) Estimated Leaf Area Among Six Locally Recognized Mango Types in Hausawa Village, Kano State, Nigeria. Points are Individual tree Means (n = 5 per Type); Boxes Show the Interquartile Range, the Line is the Median and Whiskers Show the Range. Types Sharing a Letter Within a Panel are not Significantly Different (Tukey's HSD, α = .05; Games–Howell Gave Identical Groupings for Petiole Length)

Principal Component Analysis

Principal component analysis of the four standardized traits (correlation matrix, 30 trees) showed that the first two components together explained 99.3% of the total variance (Table 5). PC1 accounted for 88.7% (eigenvalue = 3.55) and was the only component with an eigenvalue above 1. All four traits loaded strongly and positively on PC1 (0.81–0.99), so PC1 is an axis of overall leaf size. PC2 accounted for a further 10.5% and was defined mainly by petiole length (loading = 0.58) in contrast to leaf breadth and leaf length, so it describes petiole length relative to blade size.

Table 5: Eigenvalues, Percentage of Variance Explained and Trait Loadings (Correlations Between Traits and Components) for the First Two Principal Components

Component	Eigenvalue	Variance (%)	Cumulative (%)	LL	LB	PL	LA
PC1	3.550	88.74	88.74	0.983	0.975	0.811	0.987
PC2	0.421	10.53	99.27	-0.136	-0.195	0.584	-0.152

Note. LL = Leaf Length; LB = Leaf Breadth; PL = Petiole Length; LA = Leaf Area

In the biplot (Figure 3), the six types were arranged along PC1 in the order Binta Siga, Gwaiwar Rago, Paparanda, Dan Kamaru, Mai Sumuti and Kan Biri, and Binta Siga and Kan Biri sat at opposite ends with no overlap with any other type. Mai Sumuti and Kan Biri were also separated from the rest. Paparanda and Dan Kamaru overlapped, which agrees with their shared letter for leaf length. Gwaiwar Rago separated from Paparanda mainly on PC2, because its petioles were short relative to its blade size. Because leaf area is calculated from leaf length and breadth, and these three traits are correlated at r = .97–.99 (Figure 4, Table 6), the four traits carry effectively three independent pieces of information, and the dominance of PC1 partly reflects this redundancy.

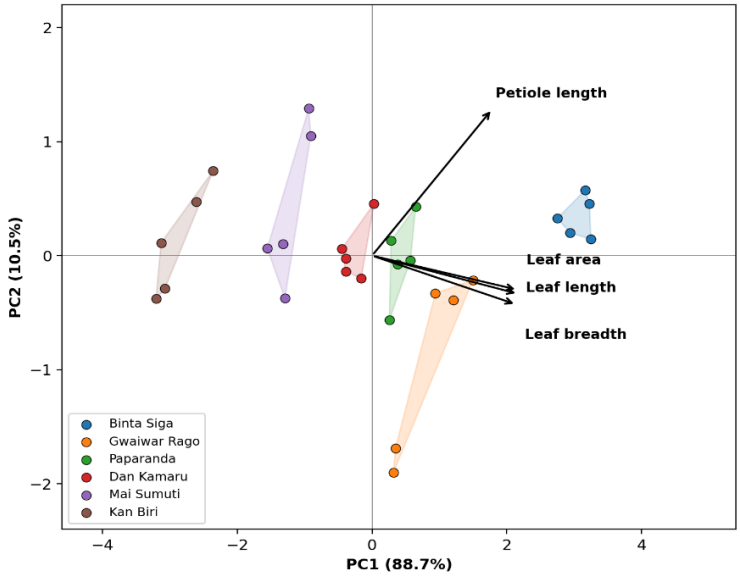


Figure 3: Principal Component Biplot of Four-Leaf Morphometric Traits for 30 Trees of Six Locally Recognized Mango Types. Arrows Show Trait Loadings; Shaded Polygons Enclose the Five Trees of Each Type

Table 6: Pearson Correlation Coefficients Among Four Leaf Morphometric Traits (*n* = 30 Trees)

Trait	Leaf length	Leaf breadth	Petiole length	Leaf area
Leaf length	1.000	0.973	0.717	0.989
Leaf breadth	0.973	1.000	0.678	0.991
Petiole length	0.717	0.678	1.000	0.712
Leaf area	0.989	0.991	0.712	1.000

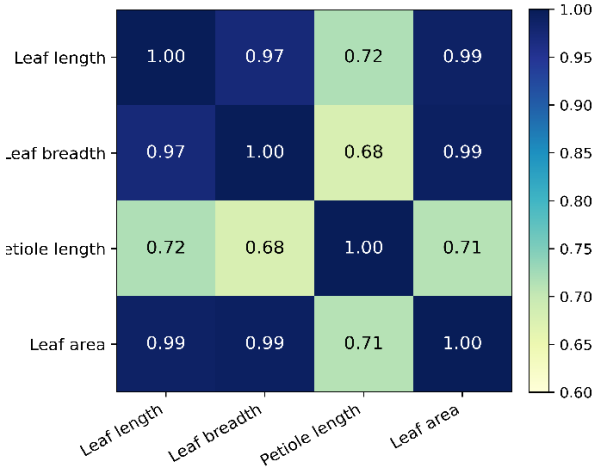


Figure 4: Heatmap of Pearson Correlation Coefficients Among Four Leaf Morphometric Traits (*n* = 30 Trees)

Hierarchical clustering (Ward's method on standardized traits) gave a consistent picture (Figure 5). At the six-cluster level, only three of the six farmer-recognized types (Binta Siga, Kan Biri and Mai Sumuti) formed pure clusters containing all five of their trees. Paparanda and Dan Kamaru trees fell together in a single cluster of ten, and the five Gwaiwar Rago trees split into groups of two and three. Thus, leaf traits alone do not fully recover all six types.

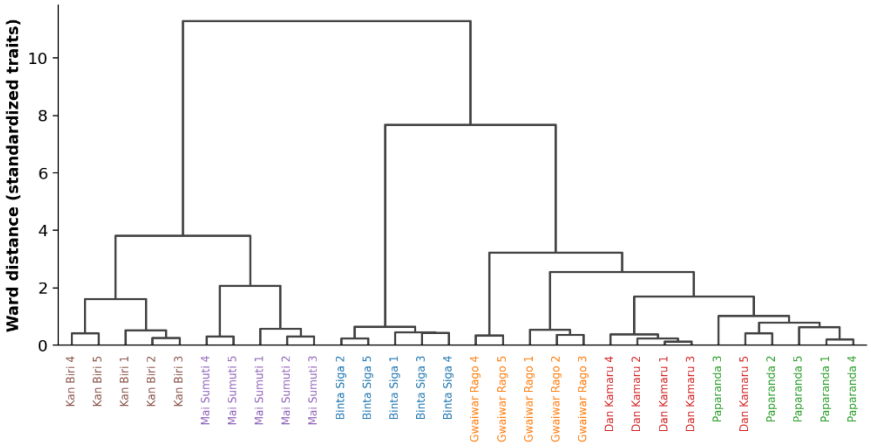


Figure 5: Dendrogram (Ward's Method, Standardized Traits) of 30 Trees of Six Locally Recognized Mango Types. Label Colours Indicate the Farmer-Recognized Type

Taken together, the univariate tests, the PCA and the clustering show a coherent pattern: Binta Siga had the largest leaves, Kan Biri the smallest, and the other four types were arranged between them mostly according to leaf size. This consistency strengthens the descriptive evidence that the farmer-recognized groups differ phenotypically under the conditions sampled. However, it does not establish that the groups are genetically distinct. Mango morphology can be affected by environmental conditions, soil, water availability, tree age and management, and previous Nigerian work has documented environmental contributions to phenotypic expression (Esan et al., 2024). The farmer-associated names recorded in the study should therefore be retained as local recognition categories until further characterization confirms their horticultural or genetic identities.

CONCLUSION

Six mango types recognized locally by farmers in Hausawa Village showed significant differences in leaf length, leaf breadth, petiole length and estimated leaf area, with very large effect sizes for the blade traits ($\eta^2_p = 0.985–0.992$) and a large effect for petiole length ($\eta^2_p = 0.714$). Binta Siga recorded the highest mean values for all four traits, whereas Kan Biri recorded the lowest. Leaf breadth and estimated leaf area showed significant differences in all pairwise comparisons, while limited overlap occurred between Dan Kamaru and Paparanda for leaf length and between Gwaiwar Rago and Paparanda for petiole length. The results demonstrate substantial phenotypic variation in the sampled mango materials and provide baseline quantitative information for mango diversity documentation in Hausawa Village. The findings should, however, be interpreted as morphological or phenotypic differences rather than confirmed genetic differentiation.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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