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Morphological Characterization of Matoa, the "Permata Papua" Fruit (*Pometia pinnata*) in Central Java

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Abstract
This research aims to obtain the morphological characteristics of the Matoa (*Pometia pinnata* JR Forst & G Forst) plant. This research was conducted in 5 districts (Surakarta, Karanganyar, Klaten, Sukoharjo, and Pati) in Central Java from April to October 2021. The morphological character is based on direct observation through primary and secondary data recording, and documenting parts of an adult matoa plant with purposive random sampling. Data on the morphological characterization of matoa were analyzed using a descriptive analysis method with the assistance of the Ntsys v2.02i program. The results showed a morphological diversity of matoa plant accessions. Fifty matoa accessions exhibit morphological diversity in plant height, canopy diameter, stem circumference, branching type, leaf colour, number of leaflets, compound leaf length, compound leaf petiole length, leaflet width, fruit density, fruit length, fruit weight, seed weight, and fruit skin colour.

Keywords: Dendogram; Fruit Colour; Flower Density; Leaf Shape

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Introduction

Permata papua is the name given to the matoa fruit, which is considered a treasure of Papua land and a species of fruit tree native to Indonesia. Although known as a native fruit of Papua, this plant is also distributed throughout Indonesia, from lowlands to 1,400 metres above sea level (1). Matoa can also be found on Sumatra, Java, Kalimantan, and Sulawesi islands under names such as jagir, sapen, leungsir, pakam, and others. Matoa belongs to the rambutan family (Sapindaceae), giving its flesh a taste similar to rambutan, combined with the flavours of longan and lychee, and an aroma reminiscent of durian. Matoa is classified based on its fruit skin and flesh texture. Based on the fruit skin, matoa is divided into yellow-skinned matoa, green-skinned matoa, and red-skinned matoa (2). Based on the texture of the fruit flesh, matoa is divided into coconut matoa and papeda matoa (3). The matoa plant has been designated as a priority fruit crop based on the Decree of the Minister of Agriculture of the Republic of Indonesia No. 160/SR.120/3/2006. However, until now, information on the morphological characteristics of matoa and its distribution is still incomplete, particularly in Java, specifically in Central Java. The unstructured characterisation of matoa warrants further research as one of the steps to support mapping matoa plant characteristics.

The data obtained will serve as the initial step and information source for plant breeding programmes, and with the support of molecular marker and cytological data of matoa plants, to complete the information. Additionally, the research findings can serve as a reference for utilizing matoa in various fields, including agriculture, industry, and other sectors. This morphological study aims to determine the morphological characteristics and diversity of matoa fruit in Central Java.

Material and Methods

This study was conducted in 5 districts (Surakarta, Karanganyar, Klaten, Sukoharjo, and Pati) in Central Java from April to October 2021. The materials used in this study were 50 Matoa accessions (Pometia pinnata). The 50 matoa accessions were named PP1 to PP50. PP1-PP22 were located in Karanganyar, PP23-PP32 in Pati, PP33-37 in Klaten, PP38-PP42 in

Sukoharjo, and PP43-PP50 in Surakarta. The tools used were: a haga meter/clinometer, caliper, camera, roll meter, Munsell colour chart, scales, 2x2 m red cloth, ruler, and writing instruments. The morphological characterisation of matoa was conducted using a descriptive exploratory survey method on 50 mature matoa tree accessions in Solo, Karanganyar, Klaten, Sukoharjo, and Pati. Morphological characteristics were aligned with IPGRI (International Plant Genetic Resources Institute) standards, referencing the description for rambutan (4) and an additional description from (5). Data was analysed using the Numerical Taxonomy and Multivariate Analysis System (NTSYS) v2.02i. Data in the form of scores were converted into binary (0-1) for analysis using the similarity matrix method (SimQual) with the SM similarity coefficient. The accession data were then grouped using the Unweighted Pair Group Method Arithmetic Average (UPGMA) calculated through SAHN to illustrate the dendrogram of matoa morphological diversity based on similarity (6).

Results and Discussion

General conditions of the region

The accession with the lowest elevation is accession PP23-32 at 5 m above sea level, while the highest is accession PP1 at 1,870 m above sea level. According to (7), altitude is categorised into three levels: lowlands (0 to 400 masl), midlands (400 to 700 masl), and highlands (>700 masl).

Table 1. Coordinates and Altitude of Matoa Growing Locations

Accession	Coordinat	Region	asml
PP1	7°39'59"S 111°11'04"E	Karanganyar	1870
PP2	7°39'44"S 111°08'54"E	Karanganyar	1300
PP3	7°39'41.4"S 111°07'33.6"E	Karanganyar	1260
PP4	7°39'45"S 111°07'08"E	Karanganyar	921
PP5	7°39'39"S 111°06'56"E	Karanganyar	865
PP6	7°39'28"S 111°06'40"E	Karanganyar	810
PP7	7°37'29"S 111°05'09"E	Karanganyar	700
PP8	7°39'56"S 111°05'15"E	Karanganyar	665
PP9	7°36'51"S 111°04'12"E	Karanganyar	560
PP10	7°36'55"S 111°03'30"E	Karanganyar	515
PP11	7°37'00"S 111°02'51"E	Karanganyar	470
PP12	7°38'42"S 111°03'08"E	Karanganyar	444
PP13	7°37'10"S 111°01'59"E	Karanganyar	398
PP14	7°37'51"S 111°02'11"E	Karanganyar	363
PP15	7°37'50"S 111°02'11"E	Karanganyar	363
PP16	7°37'06"S 111°00'46"E	Karanganyar	318
PP17	7°37'05"S 111°00'44"E	Karanganyar	315
PP18	7°36'42"S 110°59'30"E	Karanganyar	239
PP19	7°36'44"S 110°58'24"E	Karanganyar	204
PP20	7°36'27"S 110°58'18"E	Karanganyar	199
PP21	7°35'53"S 110°57'20"E	Karanganyar	171

Table 2. Coordinates and Altitude of Matoa Growing Locations

Accession	Coordinat	Region	asml
PP22	7°34'43"S 110°53'52"E	Karanganyar	113
PP23	6°34'40"S 111°01'52"E	Pati	5
PP24	6°35'02"S 111°01'48"E	Pati	5
PP25	6°35'02"S 111°01'48"E	Pati	5
PP26	6°34'42"S 111°01'51"E	Pati	5
PP27	6°34'13"S 111°02'06"E	Pati	5
PP28	6°34'11"S 111°02'01"E	Pati	5
PP29	6°34'11"S 111°02'00"E	Pati	5
PP30	6°34'09"S 111°02'07"E	Pati	5
PP31	6°34'09"S 111°02'07.9"E	Pati	5
PP32	6°35'00"S 111°01'47"E	Pati	5
PP33	7°37'16"S 110°45'24"E	Klaten	120
PP34	7°36'46"S 110°44'12"E	Klaten	120
PP35	7°36'46"S 110°44'12"E	Klaten	120
PP36	7°36'45"S 110°44'12"E	Klaten	120
PP37	7°36'35"S 110°44'16"E	Klaten	120
PP38	7°35'56"S 110°44'53"E	Sukoharjo	118
PP39	7°35'57"S 110°45'23"E	Sukoharjo	115
PP40	7°35'57"S 110°45'23"E	Sukoharjo	111
PP41	7°36'08"S 110°45'52"E	Sukoharjo	111
PP42	7°36'09"S 110°45'57"E	Sukoharjo	110
PP43	7°33'10"S 110°51'51"E	Surakarta	92
PP44	7°33'13"S 110°51'51"E	Surakarta	95
PP45	7°33'02"S 110°51'48"E	Surakarta	97
PP46	7°33'16"S 110°51'46"E	Surakarta	101
PP47	7°33'23"S 110°51'43"E	Surakarta	103
PP48	7°33'20"S 110°51'38"E	Surakarta	105
PP49	7°33'12"S 110°51'40"E	Surakarta	106
PP50	7°33'24"S 110°51'39"E	Surakarta	107

Description: Permata Papua (PP)

Habitus

According to observation, plant height shows high diversity. Accession PP43 was the shortest at 4.3 m, while the tallest accession was PP8 at 14.5 m; the average plant height is 8.3 m. The smallest crown diameter was observed in accession PP2, with a diameter of 2.5 mm. At the same time, the largest is accession PP8, with a diameter of 8 m, and the average crown diameter is 4.8 m. The variation in plant height and crown diameter in the observation results was influenced by age, genetics, and environmental factors. Genotype influences plant height growth. Also, they confirmed by (8) that plant height and photosynthesis rate of matoa can be enhanced by applying chitosan at specific times.

Canopy Shape

High crown diameter diversity is inversely proportional to crown shape diversity among 50 accessions, where only irregular (picturesque) shapes were found in all 50 Matoa tree accessions. The tree crown is the canopy of all leaves, branches, flowers, and fruits. The irregular crown shape of most accessions is likely due to the ease with which branches or twigs form on matoa plants. (9) explain that the planting distance between plants influences crown shape.

Figure 1. Irregular/Picturesque Shape

Stem Circumference

Based on observation, the smallest trunk circumference was found in accession

PP18 (25.2 cm), and the largest in accession PP27 (214 cm), and the average trunk circumference is 84.7 cm. The increase in stem circumference is due to the activity of the cambium. (10) state that cambium activity is influenced by environmental factors such as temperature and rainfall.

Shape and Texture of the Stem Surface

Fifty matoa plant accessions showed that matoa stems are spherical and have a rough surface texture. (11) state that matoa has a brown, cylindrical stem with a rough surface. The rough surface of the stem is due to the presence of lenticels. (12) explains that lenticels are areas on the bark containing loosely arranged cells. The hardening of the cambium is another reason for the rough surface of the stem.

Figure 2. Stem surface of matoa

Branching Type

Two types of branching were observed, namely monopodial and sympodial. Monopodial branching is a type of branching where the main stem is clearly visible, long, and larger than its branches. According to (2), matoa exhibits sympodial branching growth. Sympodial branching means the main stem is difficult to identify due to rapid branch growth.

(a) (b)

Figure 3. (a) Sympodial branching (b) Monopodial branching

Number of Leaflets per Compound Leaf, Length of Compound Leaf, and Length of Compound Leaf Stalk

Based on observation, the number of leaflets per compound leaf is lowest in accession PP8, with 11 leaflets. The highest number is found in accession PP45, with 25 leaflets per compound leaf, and the average number of leaflets per compound leaf is 19.3. Matoa has pinnate compound leaves with an even number of leaflets. Accessions PP8, PP15, PP18, PP23, PP26, PP29, PP34, PP35, PP40, and PP47 are unique because they have an odd number of leaflets—the most extended compound leaf length belongs to accession PP8 at 136 cm. The shortest compound leaf length is found in accession PP1, measuring 39 cm, and the average is 94.2 cm. (13) explain that compound leaves exposed to high light intensity exhibit smaller average growth than shaded compound leaves. This indicates phototropism, where leaves elongate to obtain better sunlight exposure. The most extended compound leaf stalk length was found in accession PP8, measuring 105.5 cm; the average is 64.5 cm. The shortest compound leaf stalk length was found in accession PP1, measuring 1 cm. (14) stated that the petiole (petiolus communis) is where the leaflets attach.

(a) (b)

Figure 4. (a) Compound leaves with an even number of leaflets, (b) Compound leaves with an odd number of leaflets.

Length and Width of Leaflets

Based on observation, the most extended leaflet length in accession PP15 is 50 cm, while the shortest length is in accession PP1 with a width of 15 cm, and the average of the 50 accessions is 37.7 cm. The largest leaflet width is accession PP2, with a width of 17 cm, while the shortest is accession PP1, only 6 cm, and the average is 12.5 cm. According to (15), the leaf width decreases as the intensity of light the plant receives increases.

Shape of Young Leaves

Observations of leaflet shapes in 50 Matoa plant accessions showed little diversity. Only two leaflet shapes were found, namely elliptical and oblong. Plant accessions with elliptical or oblong shapes were PP1, PP2, PP3, PP6, PP7, PP8, PP13, PP14, PP16, PP19, PP20, PP21, PP22, PP23, PP24, PP33, PP34, PP37, PP38, PP39, PP40, PP41, PP42, PP43, PP44, PP45, PP46, PP47, and PP48. Leaves with an oblong or elongated shape include accessions PP1, PP4, PP5, PP9, PP10, PP11, PP12, PP15, PP17, PP18, PP25, PP26, PP27, PP28, PP29, PP30, PP31, PP32, PP35, PP49, and PP50.

(a) (b)

Figure 5. (a) Ellips Leaf Shape, (b) Oblongus Leaf Shape

Shape of Leaf Tip

Observations of the leaf tip shape in 50 Matoa plant accessions showed low diversity. Only two leaf tip shapes were observed, namely acutus and acuminatus. Plant accessions with acutus or pointed leaf tips were represented by accessions PP2, PP3, PP6, PP7, PP8, PP12, PP14, PP16, PP19, PP37, PP38, PP39, PP40, PP41, PP42, PP43, PP44, PP45, PP46, PP47, and PP48. Leaflets with an acuminate or pointed tip are represented by accessions PP1, PP4, PP5, PP9, PP10, PP11, PP13, PP15, PP17, PP18, PP20, PP21, PP22, PP23, PP24, PP25, PP26, PP27, PP28, PP29, PP30, PP31, PP32, PP33, PP34, PP35, PP36, PP49, and PP50. The leaf tip is said to be acuminate when the leaf margin narrows gradually until it meets at a single point, producing a long, pointed tip. (16) explain that the leaf tip is said to be acute when the leaf tip forms an acute angle (less than 900), but not as long as acuminate.

(a) (b)

Figure 6. (a) Acute leaf tip shape, (b) Acuminate leaf tip shape

Shape of Leaf Base

Observations of the base of the leaflets in 50 Matoa plant accessions showed no diversity. All matoa plant accessions exhibited obtuse or blunt leaf base shapes. (5) explains that a leaf base is considered obtuse when the leaf margin immediately converges at a point on the leaf vein and forms a blunt angle (greater than 90°).

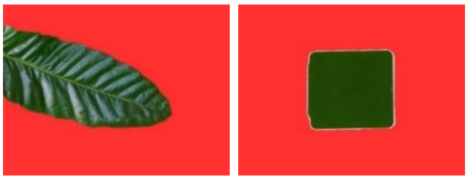
Figure 7. Obtuse leaf base shape

Leaf Edge Shape

Observations of the leaf margin shape in 50 Matoa plant accessions showed no diversity. All 50 Matoa plant accessions exhibited leaf margins that were either repandus or wavy. Wavy leaf margins occur when both the sinus and angle are blunt. Wavy leaf margins function as water collectors from leaf transpiration. (17) state that transpiration is the process of water loss through evaporation in plants, most of which originates from the leaves.

Colour of Leaf Surface

According to observations of the surface colour of young leaves, two leaf surface colours were identified: light yellowish green 7.5GY 5/8 and dark yellowish green 5GY 3/6. (18) explain that the amount of chlorophyll in leaves can be influenced by various factors, such as genetic and environmental factors (the higher the shade level, the higher the chlorophyll content).



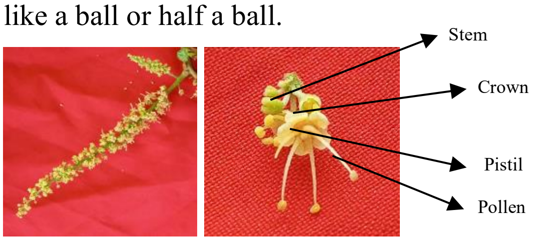
(a) (b)

(a) (c)

Figure 8. (a) Colour of upper leaf surface, (b) *Munsell* color *chart* 5GY 3/6; (c) *Munsell color chart* 7.5GY 5/8

Flower Morphology

Only a few accessions were flowering, namely accessions PP13, PP17, PP23, PP34, PP35, PP38, and PP45. Matoa is a perfect flower and also hermaphroditic. (19) explain that perfect flowers have pistils, stamens, a corolla, sepals, and a stalk. The matoa flower has a yellowish corolla, greenish-yellow sepals, pink anthers, and yellow pistils. The matoa flower on a single main stem branch has a cluster or capitulum shape, appearing to cluster like a ball or half a ball.



(a) (b)

Figure 9. (a) Matoa flower bud, (b) Matoa flower section

The matoa plant has flowers that are grouped into an unlimited compound inflorescence (inflorescentia racemosa) and form a conical structure. The flower density in the panicles of the seven matoa plant accessions showed low diversity. Only two flower density scores were found: low and medium. Low flower density was defined as 1–15 flower stalks per panicle, while medium flower density was defined as 16–30 flower stalks per panicle. PP13, PP17, PP23, PP34, PP38, and PP45 have moderate flower density, while sparse flower density is only found in accession PP35.

(a) (b)

Figure 10. (a) Medium flower density, (b) Rare flower density

Fruit Morphology

Based on the morphological observation of matoa fruit, only a few accessions bore fruit, namely accessions PP4, PP5, PP10, PP11, PP12, PP14, PP16, PP17, PP19, PP20, PP21, and PP22.

Fruit Density

Based on the fruit density observation, three types of fruit density were found: sparse fruit, moderate fruit density, with 15–30 fruits, and high fruit density, with over 30 fruits. Accessions with low fruit density include PP12, PP16, PP17, and PP20. Moderate fruit density, with 15–30 fruits, is found in accessions PP4 and PP10. High fruit density, with over 30 fruits, is observed in accessions PP5, PP11, PP14, PP19, PP21, and PP22. The varying number of fruits per matoa stem is due to differences in genetic and environmental factors. (20) explain that applying growth regulators and nutrient content in the soil can influence the generative phase.

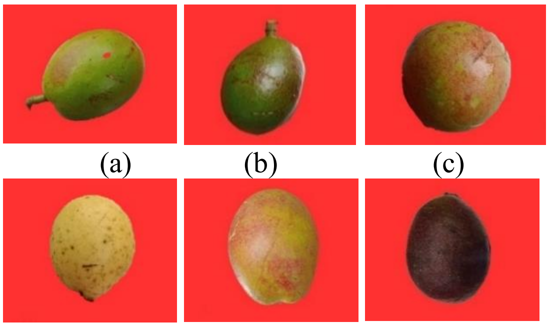
(a) (b) (c)

Figure 11. (a) Rare fruit density, (b) Medium fruit density, (c) Compact fruit density

Skin Fruit Colour

Based on observations of fruit skin colour in 12 Matoa plant accessions that bear fruit, there is high diversity in fruit colour. Greenish-yellow fruit skin colour with brown patterns was found in accessions PP4, PP5, PP12, PP14, PP16, PP19, and PP21. Greenish-red fruit skin colour was found in accession PP10. Purple fruit skin colour was found in accession PP11. Greenish-purple fruit skin colour was found in accession PP17. The yellow fruit skin colour is found in accession PP20.

Yellowish-red fruit skin colour is found in accession PP22. A total of 6 colour variations were observed in the matoa fruit skin during the observation. (21) explains that changes in fruit skin colour are influenced by fruit chlorophyll, which gradually decreases due to the fruit ripening process.



(a) (b) (c)

(d) (e) (f)

Figure 12. (a) greenish-yellow fruit colour, (b) purplish green fruit colour, (c) greenish red fruit colour, (d) yellow fruit colour, (e) yellowish red fruit colour, (f) purple fruit colour

Fruit length, fruit weight, and seed weight

Based on Table 1, the shortest matoa fruit length was found in accession PP20, measuring 2.14 cm, while the longest was found in accession PP4, measuring 4.75 cm. (22) stated that the variation in fruit length can be influenced by genetic and environmental factors such as sunlight, which is used for photosynthetic assimilation. The weight of matoa fruit in 12 fruiting accessions showed diversity. The smallest fruit weight was found in accession PP20, weighing 9.75 g, while the largest was in accession PP4, weighing 27.73 g. (23) explained that fruit weight is influenced by nutrient uptake in the soil, and that applying compost significantly affects fruit weight. Seed weight in matoa fruit shows diversity. Seed weight in matoa fruit shows diversity. The smallest seed weight is found in accession PP20 at 1.75 g, while the largest is in accession PP4 at 7.37 g. Several factors influence seed weight. According to (24), seeds will develop further by receiving nutrients during the generative phase, so that fertiliser application will increase seed weight during the generative phase.

Table 3. Fruit Length, Fruit Weight, and Seed Weight of Matoa Plants.

Aksesi	Fruit Length (cm)	Score	Fruit Weight (gr)	Score	Seed Weight (gr)	Score
PP4	4.75	5	27.73	5	7.37	6
PP5	3.97	4	22.31	4	5.78	5
PP10	2.87	2	16.46	3	2.83	3
PP11	3.26	3	19.73	4	3,19	3
PP12	3.85	4	15.51	3	3,78	3
PP14	2.74	2	13.95	2	1.95	2
PP16	3,64	3	16.11	3	2.6	2
PP17	4.34	4	23.15	4	5.54	4
PP19	4.05	4	16.02	3	3.4	3
PP20	2.14	1	9.75	2	1.75	2
PP21	4.66	5	24.01	5	5.81	5
PP22	3.79	4	22.44	4	3.4	3

Description: Permata Papua (PP)
Score 1 = $<\chi-2sd$, Score2 = $\chi-2sd$ sampai $\chi-1sd$, Score 3 = $\chi-1sd$ sampai χ, Score 4 = χ sampai $\chi+1sd$, Score 5 = $\chi+1sd$ sampai $\chi+2sd$, Score 6 = $>\chi+2sd$

Diversity and Classification of Matoa

Fifty matoa plant accessions showed similarities with a range of values from 0.71 to 0.97, resulting in a diversity value of 0.26 or 26%. Similarity values closer to 1 indicate a stronger genetic relationship, whereas values closer to 0 indicate a weaker one (25). Diversity occurs due to cultivation factors, age, and environment. (26) explain that environmental factors influencing changes in plant morphological characteristics include altitude, temperature, humidity, climate, soil type, and soil conditions. The 26% diversity indicates that the environmental influence on morphological diversity in matoa in Central Java is insignificant.

The groups formed from the clustering analysis consist of 5 groups, namely groups A, B, C, D, and E, with group B having three subgroups, B1, B2, and B3.

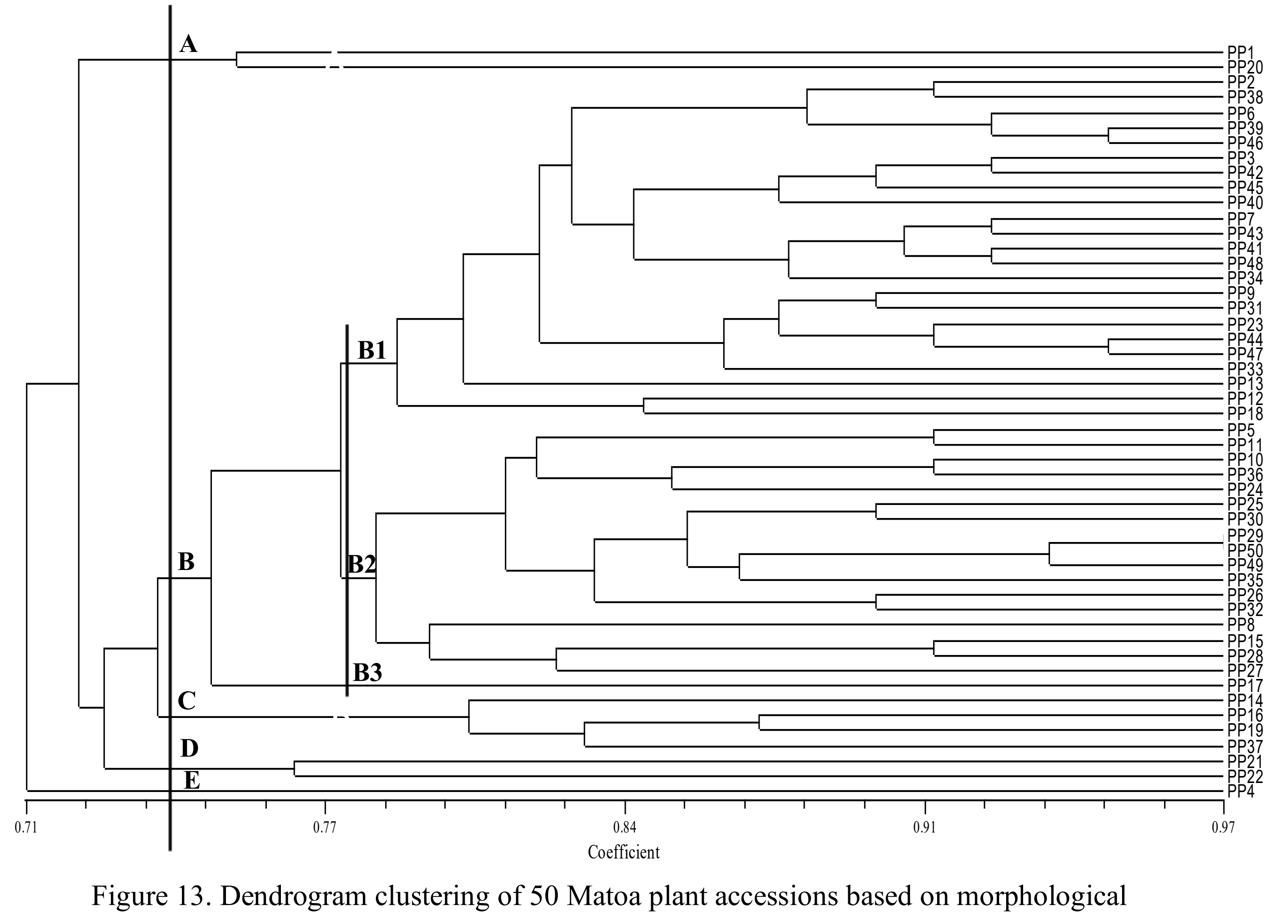


Figure 13. Dendrogram clustering of 50 Matoa plant accessions based on morphological characteristics with the SM coefficient

Conclusion

The evaluation of fifty (50) matoa plant accessions (*Pometia pinnata*) revealed considerable morphological diversity across various traits, including plant height, crown diameter, stem circumference, branching type, leaf characteristics, and fruit morphology. The overall diversity index of 0.26 (26%) indicates a moderate level of variation among the accessions, suggesting that these genetic resources hold potential for future selection and breeding programs aimed at improving desirable traits.

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