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Biodiversity and Relationships in Species Annonaceae Using the Phenetic Method in the Purwodadi Botanical Garden

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Abstract: This study aims to analyze the morphological diversity and phylogenetic relationships of six species from the Annonaceae family at the Purwodadi Botanical Garden using a phenetic approach. The background of this research is based on the importance of character-based identification to support taxonomy, conservation, and plant classification within the Annonaceae family, which is known for its high diversity. The research began with field exploration and specimen identification, followed by morphological characterization focusing on stem, leaf, petiole, and flower traits. Data acquisition was conducted by direct observation and measurement using tools such as calipers, rulers, and color tables. The morphological data were analyzed using Hierarchical Cluster Analysis and Principal Component Analysis (PCA) with SPSS 25.00 software to determine phylogenetic relationships among the species. The results revealed two major clusters: the first includes *Mitrephora polyprena*, *Stelechocarpus burahol*, *Orophea enneandra*, and *Polyalthia bullata*, with a similarity index of 73.2%, and the second consists of *Annona muricata* and *Miliusa horsfieldii*, with 59.3% similarity. PCA results indicated that leaf width, leaf length, petiole length, leaf color, and stem surface were the most influential morphological traits. These findings demonstrate that the phenetic approach is effective for analyzing phylogenetic relationships and can contribute to conservation strategies and biodiversity management.

Keywords: Annonaceae; Biodiversity; Botanical; Phenetics.

Introduction

Indonesia is one of the two countries with the richest biodiversity in the world. Indonesia's plant diversity reaches 30,000-35,000 species and ranks fifth in the world (Fajri et al., 2024; Lembang et al., 2023). Biodiversity is the variety and variability of living things and the ecological complexes in which organisms exist (Budiarti et al., 2023; Hamidah et al., 2024). *The World Wildlife Fund* defines biodiversity as the diversity of life on earth, including millions of species of plants, animals and microorganisms, including the genes they contain, as well as the complex ecosystems that are formed to become a living environment (Fuentes-Pardo & Ruzzante, 2017; Saliu et al., 2023; Shroff & Cortés, 2020). Biodiversity is divided into three levels, namely ecosystem biodiversity, species biodiversity, and biodiversity genetic. Ecosystem biodiversity is a collective response by species to diverse environments (Hu et al., 2020; Lawrence & Fraser, 2020). Species biodiversity describes the ecological and evolutionary adaptation of species to a particular environment (Cavender-Bares et al., 2022; Pigot et al., 2020). Genetic diversity allows species to adapt to changing conditions and maintain reproductive power and resistance to pests and disease (Elisha & Felix, 2020; Fuentes-Pardo & Ruzzante, 2017; Heydari et al., 2020).

Annonaceae is one of the important tribes/families in the lowland rainforests of Malaysia. In Sulawesi, about 53 types of trees from the Annonaceae tribe are reported which belong to 20 genera (Keßler et al., 2002), and 12 genera (Rugayah et al., 2020). The plant has a

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shrub or liana habit. Very flowery varies in terms of structure and shape, it is generally a multiple of 3. There are three petals, generally 6 petals arranged in two circles. The fruit is referred to as *carpedia* generally numerous and varied, both as *monocarpidia/apocarp*, or *syncarp/pseudocarp.* To find out the diversity of species, this text will provide a key to the introduction of the genus, description of the genus and other information for each species (Farjon, 2021; Govaerts et al., 2021; Hansen et al., 2020).

The research that has been carried out on the Annonaceae family mostly contains active ingredients in the species or particular species in general. Research on plants from the Annonaceae family using a phenetic approach has not yet been discovered, therefore it is necessary to conduct research on the diversity of several species from the Annonaceae family using a phenetic approach. This study introduces a novel application of the phenetic method to analyze species diversity and relationships within Annonaceae, especially in the Purwodadi Botanical Gardens. By incorporating morphological-based phenetic analysis, this research contributes a fresh perspective to the understanding of taxonomic relationships within this family, which has not been systematically documented in prior studies. This approach is expected to enrich the data on the morphological variation of Annonaceae species and provide an alternative method for conservation prioritization.

However, the abundance of the Annonaceae family in nature is under threat. This is caused by large-scale exploitation of forest products, conversion of agricultural and plantation land into housing and mining (Baird, 2020; Hairiah & Ashari, 2013; Kumar et al., 2022). Thus, the loss and reduction of biodiversity will affect the balance of nature and eliminate the potential resources contained therein (Dasgupta & Levin, 2023; Folberth et al., 2020). With growing threats to natural biodiversity, efforts to catalog, understand, and conserve plant groups such as Annonaceae have become increasingly urgent. This research is significant in supporting ex-situ conservation and guiding in-situ conservation decisions through a clearer understanding of species relatedness and substitutability in restoration and sustainable use contexts.

Even though Indonesia itself has abundant natural wealth, the natural wealth in Indonesia has not yet been studied and utilized properly by the Indonesian people, this can be seen from the many foreign researchers who research and write about the rich flora in Indonesia (Panigrahi & Mishra, 1984). One example is research on the Annonaceae family in Java which is still limited. Most of the Annonaceae are conserved *ex-situ*, such as the Bogor Botanical Gardens (Handayani, 2018) and the Purwodadi Botanical Gardens. In addition, inventories of Annonaceae on the island of Java were no longer reported after the work of Backer and van de Brink in 1963 (Nikmah et al., 2019). Taxonomic and biosystematic studies that assume the position of each species are urgently needed to determine Biodiversity is especially beneficial for human life and also supports conservation efforts in Indonesia, especially East Java (Huhn et al., 2020; Madduppa et al., 2022).

Previous research on Annonaceae includes the diversity and inventory of certain species or the Annonaceae family as a whole outside Java Island by Rugayah et al. (2020) examining the diversity and inventory of the Annonaceae family on Wawonii Island, South Sulawesi and Turner (2012) examining the diversity of the Annonaceae family in Borneo, especially climber species. Apart from that, there is research on the diversity of Annonaceae based on the morphology represented in the Bogor Botanical Gardens which was carried out by Handayani (2018). Research by Yulianti et al. (2024) on 28 types of Annonaceae from East Java at the Purwodadi Botanical Gardens aimed to identify the kinship relationships of Annonaceae types using molecular analysis.

Compared to these studies, the present research is distinct in its specific use of a phenetic (morphology-based) approach to determine species diversity and relationships within the Annonaceae family at Purwodadi Botanical Gardens. While previous works focused primarily on molecular techniques or broad floristic inventories, this study emphasizes observable morphological traits and their analysis using phenetic clustering techniques. This approach not only complements molecular studies but is also more accessible for rapid assessments in field or conservation contexts. Research studies regarding the diversity and kinship relationships of several species of the Annonaceae family in Indonesia are still rare, therefore it is necessary to conduct research on the diversity of several species of the Annonaceae family, especially in the Purwodadi Botanical Gardens using a phenetic approach. By looking at the relationship, if there is a rarity in the existence of a species, it can be replaced with another species that is closely related to that species in phytochemical science.

Method

Time and Place of Research

This research will be carried out at the Purwodadi Botanical Gardens to explore and collect specimens of the genus from the Annonaceae family, as well as to observe the characteristics of Annonaceae species in January-June 2022.

Research tools and materials

The tools used in this research include a tape measure, ruler, caliper, magnifying glass, plant scissors, plastic bags, label paper, camera, plant morphology book, and color table (Cooper, 2021; Maaroof et al., 2025). The materials used in the research are plants that represent species *Annona muricata, Polyalthia bullata, Orophea enneandra, Stelechocarpus burahol, Miliusa horsfieldii,* And *Mitrephora polyprena.*

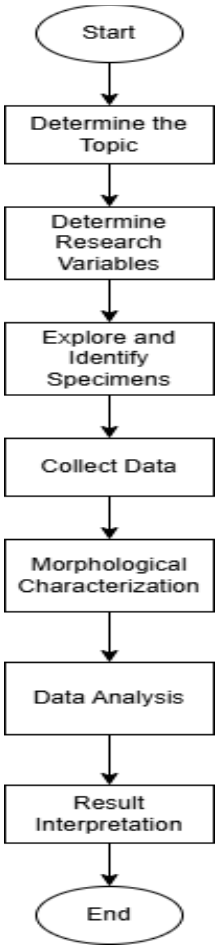

Figure 1. Methodology

The method used in this study follows a phenetic approach to analyze morphological diversity and determine kinship relationships among selected Annonaceae species. The research stages include: determining the topic; identifying research variables; exploring and identifying specimens in the field; collecting morphological data; conducting morphological characterization; and performing data analysis using descriptive statistics and cluster analysis (e.g., UPGMA) based on morphological characters (Anjani et al., 2022). The phenetic approach groups taxa based on overall similarity and is especially useful for analyzing variation within and among species using observable morphological traits (Martina et al., 2021; Martínez-Domínguez et al., 2024; Ningrum & Chasani, 2021).

Result and Discussion

Grouping analysis to determine the similarity relationship between several species from the Annonaceae family was carried out based on 35 morphological characters (Appendix 1) using the SPSS 25.00 program. The 35 morphological characters used as a basis for grouping consist of 1 stature character, 6 stem characters, 17 leaf characters, and 11 flower characters. Descriptive data is assessed numerically by providing scoring that describes differences, while quantitative data is obtained from direct measurements. Grouping of several species from the Annonaceae family was carried out using Classify *Hierarchial Cluster* and PCA analysis (*Principal Component Analysis*) as a complement. Analysis *Classify Hierarchial Cluster* carried out based on measuring similarities between operational taxonomic units (ONE) by method *agglomerative* based on average linkage (Table 2) using coefficients *simple matching* for binary data. Results of calculating the similarity coefficient index *simple matching* (Table 1) was obtained from data that has been scored (Appendix 3) and processed with the SPSS 25.00 program.

Table 1. Results of calculating the similarity index with coefficients *simple matching*

Case	Coefficient *Simple Matching*					
	NOTE	MTP	PLB	MLH	OPE	S.E.B
NOTE	1.000	0.253	0.148	0.593	0.326	0.405
MTP	0.253	1.000	0.705	0.504	0.754	0.738
PLB	0.148	0.705	1.000	0.585	0.826	0.723
MLH	0.593	0.504	0.585	1.000	0.651	0.517
OPE	0.326	0.754	0.826	0.651	1.000	0.771
S.E. B	0.405	0.738	0.723	0.517	0.771	1.000

Information: ANM: Species *Annona muricata*; MLH: Species *Miliusa horsfieldii*; MTP: Species *Mitrephora polyprena*; OPEN: Species *Orophea enneandra*; PLB: Species *Polyalthia bullata*; BEE: Species *Stelechocarpus burahol*

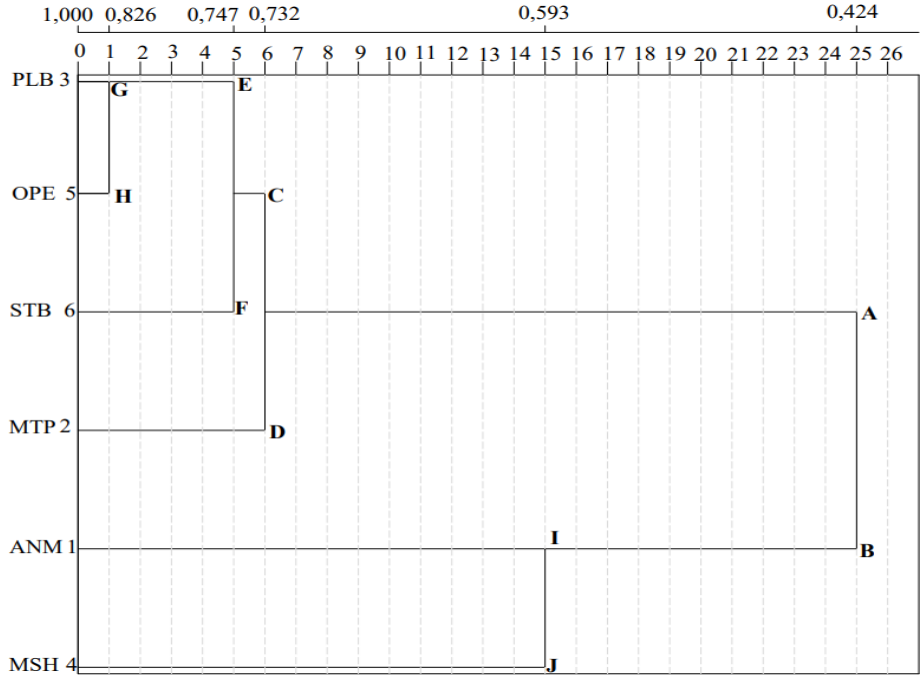

Figure 2. Dendrogram of phenetic relationships between 6 species from the Annonaceae family studied using morphological characterization analysis

Information:
ANM: Species *Annona muricata*; MLH: Species *Miliusa horsfieldii*; MTP: Species *Mitrephora polyprena*; OPEN: Species *Orophea enneandra*; PLB: Species *Polyalthia bullata*; BEE: Species *Stelechocarpus burahol*

Table 2. Grouping of morphological characteristics based on character *average linkage*

Level	Group Combination		Similarity Coefficient
	Group 1	Group 2	
1	3	5	826
2	3	6	747
3	2	3	732
4	1	4	593
5	1	2	424

Description: The numbers listed in column group 1 and group 2 indicate the code for ONE being compared
The numbers listed in the similarity coefficient column indicate the magnitude of the phenetic similarity of the two groups ONE which is compared and causes the 2nd ONE those compared are grouped

Based on dendrogram to Figure 1, with a similarity value of 42.4%, two groups are obtained, marked as group A and group B. Group A with a similarity value of 42.4% is separated into group C and group D, which consists of species. *Mitrephora polyprena*. Then, with a similarity value of 73.2%, group C separated again into groups E and F with a similarity value of 74.7%. Group E consists of species *Polyalthia bullata* and group F consists of species *Stelechocarpus burahol*. Group G and group H have a similarity value of 82.6%, group G consists of species *Polyalthia bullata* and group H consists of species *Orophea enneandra*. Group I and group J have a similarity value of 59.3%, group I consists of species *Annona muricata*, while group J consists of species *Miliusa horsfieldii*. The closeness between species of the family *Annonaceae* can be seen from the coefficient value *agglomerative*, i.e., species *Annona muricata* closer to the species *Miliusa horsfieldii* with a value of 0.593, while species *Mitrephora polyprena* closer to the species *Stelechocarpus burahol*, *Orophea enneandra*, And *Polyalthia bullata* with a value of 0.732. The relationship between several species of the Annonaceae family in terms of morphological characters and dendrograms produces species *Mitrephora polyprena* close kinship with *Stelechocarpus burahol, Orophea enneandra and Polyalthia bullata,* whereas *Annona muricata* closer to the species *Miliusa horsfieldii*.

The dendrogram in Figure 1 separates several species based on the similarity of the morphological characters of each sample until we obtain groups of species that are truly separated or grouped with other groups of species. The formation of groups between existing species is in accordance with the level of similarity in morphological characters which is expressed in the similarity coefficient values listed in Table 1. The similarity coefficient shows the ratio between shared characters and the total characters being compared. Thus, the more characters they have in common, the greater the similarity scale value, the closer the kinship relationship. This kinship relationship is shown by the many things they have in common

(Tjitrosoepomo, 1998). So, it is very clear that groups consisting of various species that were formed first to form two branches (groups A and B) have the smallest similarity value of 42.4%, while groups formed in groups of one species have the highest similarity value of 100% because they have the same morphology.

After analysis *Classify Hierarchial Cluster* which produces a dendrogram, then continues with PCA analysis (*Principal Component Analysis*). PCA analysis is useful for determining morphological characters that have a major influence and separating OTUs (Gil & Cubero, 1993). The role of each morphological character will separate the 18 OTUs in this study. The PCA results are expressed by displaying a number of main differentiating components along with the value of each character in their components.

Morphological character components that cause OTU grouping of several species in the Annonaceae family are shown in Table 3.

Table 3. The value of the main components of the species character *Annona muricata, Miliusa horsfieldii, Mitrephora polyprena, Stelechocarpus burahol, Orophea enneandra, and Polyalthia bullata* from the Annonaceae family by PCA analysis

Character	Component				
	1	2	3	4	5
Habitus	0.587	0.613	-0.342	0.383	-0.127
Stem length	0.631	0.675	0.117	0.362	0.043
Stem surface	0.522	-0.124	0.800	-0.224	-0.146
Existence trunk surface engraving	-0.792	0.411	0.377	0.246	0.019
Bar color	-0.475	0.150	-0.200	-0.249	0.806
Leaf base	0.693	-0.681	-0.189	-0.111	0.091
Upper surface of the leaf	0.158	0.420	0.134	0.881	0.072
The lower surface of the leaf	0.533	0.732	0.310	0.039	-0.288
Wake up leaves	0.343	-0.674	0.543	0.363	-0.027
Leaf length	0.954	-0.247	0.018	0.080	0.150
Leaf width	0.988	-0.064	-0.002	0.071	0.119
Leaf color	0.792	-0.411	-0.377	-0.246	-0.019
The surface of the petiole	0.190	0.895	0.171	-0.155	0.332
Panjang petiolus	0.934	-0.170	0.155	0.189	0.197
Varna petiolus	-0.259	0.274	0.730	-0.542	0.174
Existence of leaf aroma	-0.557	-0.448	0.139	0.597	0.337
Flower sex	0.418	-0.876	0.090	0.085	0.209
Types of flowers according to quantity	-0.658	-0.256	-0.305	0.111	-0.629
Sitting flowers	0.794	0.357	0.077	-0.380	-0.303

Note: The value in red is a character value that has a value ≥ 0.750, which means the character has a very strong influence in the grouping of 6 species from the Annonaceae family.The values in bold are character values that have a value of 0.500 ≤

In Table 3 which shows the components of the PCA matrix, there are 5 main character components that play a major role in separating 6 groups of species from the Annonaceae family. Component 1 is the character that plays the most important role in separating species groups. Meanwhile, component 2 is the first supporting character component of component 1, component 3 is the second supporting character component of component 1, component 4 is the third supporting character component of component 1, and component 5 is the fourth supporting character component of component 1. The red values in the table are character values that have a value of ≥ 0.750, which means the character has a very strong influence in grouping 6 species from the Annonaceae family. Meanwhile, the character value is 0.500 ≤ Characters that have a big influence (have a value ≥ 0.750) on component 1 include the presence of carvings on the stem surface, leaf length, leaf width, leaf color, petiole length, flower seat. The characters that have a big influence on component 2 are the surface of the petiolus and the sex of the flower. The character that has a big influence on component 3 is the stem surface. The character that has a big influence on component 4 is the upper surface of the leaf. The character that has a big influence on component 5 is stem color.

Discussion

Morphological diversity of several species in the Annonaceae family

Biodiversity is the result of variations that include living things at various levels of biological organization. In Indonesia, especially in the Purwodadi Botanical Gardens, there are six species from the Annonaceae family, namely *Annona muricata, Miliusa horsfieldii, Mitrephora polyprena, Stelechocarpus burahol, Orophea enneandra, and Polyalthia bullata*. Research on morphological characters in the Annonaceae family is

very necessary to recognize the diversity among the six species in the Annonaceae family, namely by creating descriptions and identification keys. Apart from recognizing the diversity of the six species in the Annonaceae family, the differences and similarities in the appearance of external morphology in a plant can be used to determine how closely related they are. Penelitian yang telah dilakukan terhadap famili Annonaceae sebagian besar mengandung bahan aktif pada spesies tertentu atau spesies secara umum. Penelitian terhadap tumbuhan dari famili Annonaceae dengan menggunakan pendekatan fenetik belum ditemukan, oleh karena itu perlu dilakukan penelitian tentang keanekaragaman beberapa spesies dari famili Annonaceae dengan menggunakan pendekatan fenetik. By looking at the relationship, if there is a scarcity of a species, it can be replaced with another species that is closely related to that species in terms of morphological diversity.

Research by Lestari (2019) on 28 types of Annonaceae from East Java at the Purwodadi Botanical Gardens aimed to identify the kinship relationships of Annonaceae types using molecular analysis. Research studies regarding the diversity and kinship relationships of several species of the Annonaceae family in Indonesia are still rare, therefore it is necessary to carry out research on the diversity of several species of the Annonaceae family, especially in the Purwodadi Botanical Gardens using a phenetic approach. The results of the analysis using descriptions state that there are differences and similarities between the six species of the Annonaceae family studied. The morphological differences and similarities between the species of the Annonaceae family studied can be seen in Appendix 1. Morphological similarities possessed by an organism have a relative similarity value because the characteristics they possess do not have a significant similarity value, so it is very important to recognize an organism.

Relationship between six species of the Annonaceae family

Relationships in plant systematics can be interpreted as a pattern of relationships or total similarities between groups of plants based on certain traits or characteristics of each group of plants (Stuessy & Lack, 2011). Observing the diversity of morphological characters of a plant with the naked eye, without measurements, will only produce external appearances which can lead to different interpretations between researchers (subjectivity). So, analysis is really needed with the help of mathematical calculations, namely by determining the possible diversity coefficient to eliminate subjectivity (Hamidah et al., 2020). From the results of analysis using the phenetic method using the SPSS 25.00 program, a dendrogram was obtained which can describe the close relationship between species of the Annonaceae family. Results dendrogram Figure 2 shows that there are species that are grouped or separated based on the similarity index value (Table 1) and coefficient *agglomerative* (Table 2). Coefficient *agglomerative* used for estimate the level of differences between species or populations in selected characters (Nilasari et al., 2013).

From the dendrogram it can be seen that species *Annona muricata and Miliusa horsfieldii* form group B with coefficient values *agglomerative* of 0.593. Meanwhile, species *Mitrephora polyprena, Stelechocarpus burahol, Orophea enneandra, and Polyalthia bullata* form group A with coefficient values *agglomerative* of 0.732. Group A and group B separate each other by coefficient value *agglomerative* of 0.424. Species grouping *Annona muricata and Miliusa horsfieldii* separates from the other 4 species because it has 1 character that is different from the other four species, namely the character of the stem surface. This means species *Annona muricata* And *Miliusa horsfieldii* are more distantly related to the other 4 species.

In the dendrogram, it can be seen that the species *Mitrephora polyprena* form groups with species *Stelechocarpus burahol, Orophea enneandra, and Polyalthia bullata* with coefficient values *agglomerative* of 0.732. This means species *Mitrephora polyprena*, *Stelechocarpus burahol, Orophea enneandra, and Polyalthia bullata* have a closer relationship when compared to species *Annona muricata and Miliusa horsfieldii*. However, the dendrogram also shows that the species *Polyalthia bullata* And *Orophea enneandra* form another group separate from *Stelechocarpus burahol* nor *Mitrephora polyprena*. This is due to species *Polyalthia bullata* having more similarities in morphological characters that are shared with *Orophea enneandra* when compared with *Stelechocarpus burahol and Mitrephora polyprena*. In other words, species *Polyalthia bullata* have a fairly close taxonomic distance to the species *Orophea enneandra* when compared by species *Stelechocarpus burahol and Mitrephora polyprena*.

Morphological characters that influence the grouping of six species in the Annonaceae family

There are 35 morphological characters in this study, 15 characters are general characters shared by the four samples, while the other 20 characters are special characters shared between species of the Annonaceae family. The existence of these 20 special characters causes diversity between 6 species in the Annonaceae family; 20 special characters were analyzed using PCA. The results of the PCA analysis showed that the highest and highest character component values were found in leaf characters. From table 4.3, it can be seen that the

characters in component 1, namely the characters that play the main role in separating groups of six species from the Annonaceae family and which have a value of ≥ 0.750, total 6 characters, namely 1 stem character, 3 leaf characters, 1 petiolus character, and 1 flower character. The character of the stem is the existence of carvings on the stem surface, the character of the leaves is the length of the leaf, the width of the leaf, and the color of the leaf, the character of the petiolus is the length of the petiolus, as well as the character of the flower, namely the flower sitting. Component 2 shows the characters that play the most role in separating groups of species from the Annonaceae family and has a value of ≥ 750 totaling 2, namely 1 petiolus character and 1 flower character. The character of the petiolus is the surface of the petiolus, while the flower includes the sex of the flower.

Component 3 shows the character that plays the most role in separating the group of six species from the Annonaceae family and has a value of ≥ 750 totaling 1, namely 1 stem character. The character of the stem is the surface of the stem. Component 4 shows the characters that play the most role in separating groups of six species from the Annonaceae family and those with a value ≥ 750 are 1, namely 1 leaf character. The character of the leaf is the upper surface of the leaf. Component 5 shows the character that plays the most role in separating the group of six species from the Annonaceae family which has a value of ≥ 750 totaling 1, namely 1 stem character. The character of the bar is the color of the bar. From the results of the PCA analysis on component 1, it shows that the highest component value and has a value ≥ 750 is found in the leaf character, namely in the leaf width character with a value of 0.988 (Table 3). The highest value and the number of occurrences found in the leaf characters indicate that the leaf characters have the greatest influence on the grouping of the six species of the Annonaceae family. In table 3 can be seen from the value of the first component in leaf characters which has a value of ≥ 0.750, there are 4 characters. From the PCA results, the most influential leaf characters are leaf width (0.988), leaf edge (0.954), leaf top surface (0.881) and leaf color (0.792) with a similarity value of > 750.

These results are supported by research conducted by Nilasari et al. (2013), that leaf morphological characters can be used for identification and grouping of Mango plants (*Mangifera indica* L.). This finding is in line with the current study, reinforcing the idea that leaf morphology serves as a key determinant in phenetic grouping across different plant families. Moreover, the consistency of leaf traits such as width and surface texture as primary grouping variables highlight their taxonomic relevance not only in *Mangifera* but also within the Annonaceae family. This correlation strengthens the evidence that phenetic approaches using leaf morphology can be a reliable method for distinguishing closely related species in tropical plant taxa.

Apart from leaf characters, in table 4.3 you can also see the component values for stem characters with a value of ≥ 0.750, there are 3 characters. The flower characters that influence the grouping of the six species of the Annonaceae family are stem color (0.806), stem surface (0.800), and the existence of stem surface carvings (0.792). As for petiolus characters, in table 4.3 you can also see the component values for stem characters with a value of ≥ 0.750, there are 2 characters. The petiolus characters that influence the grouping of the six species of the Annonaceae family are petiolus length (0.934) and petiolus surface (0.876). As well as flower characters, in table 4.3 you can also see the component values of valuable stem characters ≥ 0.750 contains 2 characters. The flower characters that influence the grouping of the six species of the Annonaceae family are the sex characters of the flower (0.876) and the flower position (0.794).

Based on the results of research using morphological characters (phenotypic characters) as carried out in this study, it shows that morphological characters as taxonomic evidence is good for identifying and analyzing the diversity of plants in the Annonaceae family and can know the closeness of their kinship relationships. Form or morphological characters, in general, are the best data for delimiting a tax on. According to Hardiyanto et al. (2007), good taxon delimitation is done by using characters that are easily seen, and not by hidden characters. For this reason, morphological characters can be used as a source of taxonomic evidence.

Conclusion

Annonaceae family, particularly in stem, leaf, petiole, and flower characters. Cluster analysis based on morphological traits revealed two main groups: Group A (*Mitrephora polyprena*, *Stelechocarpus burahol*, *Orophea enneandra*, *Polyalthia bullata*) and Group B (*Annona muricata* and *Miliusa horsfieldii*), with similarity indices of 73.2% and 59.3% respectively. Leaf characteristics — especially leaf width, upper surface, margin, and color — were found to be the most influential in determining species grouping. This finding confirms that morphological characters, especially on leaves and stems, are very influential in grouping species in the Annonaceae family. Generalization of the results of this study opens the possibility that a similar approach can be applied for kinship analysis in other tropical plant families that have complex and diverse morphological

characteristics. These findings can also be used in the context of botany learning, especially in the introduction of plant taxonomy and strengthening understanding of morphological variations within a family. Practically, the results of this study can serve as a basis for the conservation and preservation of germplasm of Annonaceae species, especially those with high economic or ecological value. In addition, this morphology-based phenetic approach can be used as an initial method in rapid identification before more detailed molecular analysis is carried out. These findings suggest that morphological analysis is an effective approach for identifying and classifying species within the Annonaceae family. This approach is not only useful in taxonomic research but can also be applied in conservation strategies and botanical education. Further studies incorporating anatomical traits and broader species sampling from various regions in Indonesia are recommended to enhance the understanding of phylogenetic relationships within this family.

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The authors declare no conflict of interest.

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