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MORPHOLOGICAL CHARACTERIZATION AND KINSHIP ANALYSIS OF THE *DENDROBIUM* FROM LIWA BOTANICAL GARDEN

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SUMMARY

Dendrobium is a genus of orchids comprising more than 1,000 species, renowned for its aesthetic appeal and commercial value. Species identification can take place by observing morphological characterization to determine the relationship among the species. This study builds upon previous research by conducting a comprehensive morphological characterization of the *Dendrobium* collection at the Liwa Botanical Garden. The morphological characterization proceeded using 25 leaf and flower traits, followed by an analysis of character variations and species grouping using the principal component analysis (PCA) and unweighted pair-group method with arithmetic averaging (UPGMA). The eight *Dendrobium* leaf samples (D1 to D8) showed some similarities and differences in their morphological traits. PCA analysis divided the samples into two main groups; Group I has a contribution of 82.448%, while Group II has 12.505%. UPGMA analysis produced a dendrogram showing two main clusters, A and B, and subclusters based on the same morphological characters. Cluster A comprised D7, D8, D6, and D5, while cluster B consisted of D2, D4, D3, and D1. Morphological grouping enunciated the relationship among the studied *Dendrobium* samples, and the highest similarity index indicated close kinship. *Dendrobium* species with morphological characterization can aid as an effort to preserve orchid germplasm in the Liwa Botanical Garden.

Keywords: *Dendrobium*, kinship analysis, morphological characterization, PCA, UPGMA

Key findings: Identification based on morphological traits, such as leaves and flowers, allows an accurate differentiation among the species. Morphological characterization of *Dendrobium* species is essential for supporting the breeding program and conservation of orchid germplasm in the Liwa Botanical Garden.

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INTRODUCTION

Dendrobium is one of the genera of the family Orchidaceae, comprising more than 1,000 species (Zhao *et al*., 2024). *Dendrobium* is highly valuable for its aesthetic and commercial importance, characterized by diverse flower shapes and colors (Hartati *et al*., 2022). In Sumatra, particularly in Lampung Province, the Liwa Botanical Garden harbors the largest flora area with the highest diversity of *Dendrobium* species (Mahfut *et al.,* 2025a). This ex-situ conservation area in West Lampung Regency plays a significant role in preserving the orchid germplasm (Mahfut *et al.,* 2021).

In addition to plant protection against diseases (Septiana *et al*., 2024; Anbiya *et al*., 2024), orchid species identification remains a major challenge in the conservation efforts of *Dendrobium* at the Liwa Botanical Garden (Putra *et al*., 2024). Reports declared bacteria (Mahfut *et al.,* 2020), fungi (Mahfut *et al.,* 2021b), and viruses (Mahfut, 2020; 2021) have been infecting and causing damage, reducing the aesthetic value of orchids (Mahfut *et al.,* 2025e). Meanwhile, the challenge of species identification lies in the limited availability of vegetative and generative organs during observation (Zhao *et al*., 2024). Hartati *et al*. (2022) explained orchid species identification can proceed through morphological (Mahfut *et al.,* 2024a), anatomical and molecular characterization (Mahfut *et al.,* 2024b; 2024c).

Morphological characterization of orchids includes phenotypic observations of the shape of pseudobulbs, leaves, flowers, and their colors, and the whole structure of the plants. The results of morphological characterization can reveal orchid species identification (Mahfut *et al*., 2025b) through phenetic analysis based on morphological variation among accessions (Mahfut *et al*., 2025d). Phenetic analysis commonly takes place through cluster analysis and PCA, followed by the calculation of the Gower's General Similarity value that produces the similarity matrix among the accessions. The data similarity matrix can continue using the agglomerative hierarchical clustering method, applying the UPGMA method, and displaying it in the form of a dendrogram (Sari *et al.,* 2025).

The similarity values of the accessions indicate the kinship relationship among the tested accessions. Morphological traits have been widely functional to assess species relationships, particularly when supported by environmental context and phenetic analysis, as demonstrated in the study of *Nepenthes* by Asadudin *et al*. (2025). Based on the dendrogram results obtained through morphological characters of the *Dendrobium*, it is well known that each *Dendrobium* has a close kinship relationship with other *Dendrobiums*. This was possible because these attributes have more variations than other traits (Asadudin *et al*., 2024; Putera *et al*., 2024).

This study is a continuation of previous research that performed morphological characterization of *Dendrobium* at Liwa Botanical Garden but only on five accessions (Mahfut *et al*., 2021a). Prior studies have revealed the morphological characterization of 11 leaf characters, showing a high variation. The phenetic relationship based on the Gower similarity value and the UPGMA method indicates the *Dendrobium* species classification in Liwa Botanical Garden can be in two main groups, with a similarity index value of 0.813. Based on the PCA values, it is evident that the characters with the greatest influence on grouping are the ratio of leaf length to width, leaf cross-section, and leaf arrangement.

The subsequent study aimed to carry out the morphological characterization of the entire *Dendrobium* at the Liwa Botanical Garden using the principal component analysis (PCA) and the unweighted pair-group method with arithmetic averaging (UPGMA). The findings of this study play a crucial role in the conservation of *Dendrobium* germplasm and in selecting various orchid accessions with superior traits to serve as parental genotypes in crossbreeding programs in Indonesia.

MATERIALS AND METHODS

Genetic material

Leaf samples collected from eight *Dendrobium* accessions received codes as D1, D2, D3, D4, D5, D6, D7, and D8. All the collected leaf samples from native orchids in Lampung originated from the Liwa Botanical Garden, Lampung, Indonesia, located at approximately 5.3444° S latitude and 104.0172° E longitude. This geographic location places it within the western part of the island of Sumatra, an area known for its rich biodiversity and unique tropical climate. Three leaves per accession as collected had the greenhouse as the specific location of sampling.

Dendrobium morphology

The study employed a quantitative observation to record morphological traits across different plant parts. The observed leaf morphological traits were the properties of the leaves that appeared macroscopically. Morphological characters, such as leaf and flower properties, followed the methods of Mahfut *et al*. (2021a) and Hartati *et al*. (2022). These include leaf shape traits (tip shape, blade shape, arrangement, edge shape, surface texture, symmetry, and seat) and spurs. The flower features comprised shape, dorsal sepal shape, petal tip shape, petal shape, labellum groove position, flowering position, number of pollinia, dorsal sepal pattern, lateral sepal pattern, and petal pattern. Others included flower scent, habitus, growth type, pseudobulb type, leaf width, and leaf length. The measurement of leaf length and width entailed three repetitions.

Data analysis

The recorded data on the morphological observations underwent descriptive analysis and binary scoring following Mahfut *et al*. (2025b) using the MVSP (Multivariate Statistical Package) v.3.1 software to generate a phenetic dendrogram and conduct PCA. The dendrogram construction utilized the UPGMA to determine the kinship among various species of *Dendrobium* at the Liwa Botanical Garden. Phenetic analysis aimed to identify the variations owned by *Dendrobium* species using the main component of PCA. The similarity matrix assessment with the dendrogram also used the phenetic correlation coefficient.

RESULTS AND DISCUSSION

Dendrobium species leaf samples, totaling eight (designated D1–D8), came from the Liwa Botanical Garden. The samples shared similarities in several characters, including leaf features, such as shape, tip shape, arrangement, edge shape, surface texture, and symmetry, as well as spurs, the number of pollinia, habitus, growth type, and pseudobulb type. However, considerable differences in various leaf samples were evident for the leaf blade and stalk. Similarly, differences resulted in the flower shape, dorsal sepal shape, petal tip shape, petal shape, labellum groove position, flowering position, dorsal sepal pattern, lateral sepal pattern, petal pattern, flower fragrance, and leaf size. Hence, accurate identification of closely related *Dendrobium* species requires detailed observations on their morphological characters, accounting for both shared traits and distinct differences, analyzed through cluster structures (Wahyuningsih *et al*., 2025). Morphological characterization of *Dendrobium* species structures can reveal genetic diversity, with significant phenotypic variances reflecting genotypic variations (Nguyen *et al*., 2020). Complete observations of the morphological characters took place by measuring all the parameters in *Dendrobium* leaves (Table 1).

Numerous characters observed may make it difficult to determine *Dendrobium*. Information related to variations is critical because it is a determining factor in managing species grouping. Furthermore, the use of the PCA method determined the qualitative and quantitative traits that influence grouping among the species, as shown in Figure 1 and Table 2. The principal component analysis grouped the *Dendrobium* into two clusters that obtained eigenvalues to reveal the percentage

Table 1. Morphological characteristics of the eight *Dendrobium* leaf samples at the Liwa Botanical Garden.

Characters	D1	D2	D3	D4	D5	D6	D7	D8
Leaf shape	Lancet	Lancet	Lancet	Lancet	Lancet	Lancet	Lancet	Lancet
Leaf tip shape	Taper	Taper	Taper	Taper	Taper	Taper	Taper	Taper
Leaf blade shape	Pointed	Sharp	Pointed	Sharp	Sharp	Sharp	Sharp	Sharp
Leaf arrangement	Double	Double	Double	Double	Double	Double	Double	Double
Leaf edge shape	Curse	Curse	Curse	Curse	Curse	Curse	Curse	Curse
Leaf surface texture	Bare	Bare	Bare	Bare	Bare	Bare	Bare	Bare
Leaf symmetry	Symmetry	Symmetry	Symmetry	Symmetry	Symmetry	Symmetry	Symmetry	Symmetry
Leaf sitting	Intermittent	Intermittent	Intermittent	Intermittent	Meeting	Meeting	Meeting	Meeting
Spurs	None	None	None	None	None	None	None	None
Flower shape	None	None	None	None	None	Star	Star	Star
Dorsal sepal shape	None	None	None	None	None	Javelin Eye	Javelin Eye	Javelin Eye
Petal tip shape	None	None	None	None	None	Oval	Oval	Oval
Petal shape	None	None	None	None	None	No petals	No petals	No petals
Location of the	None	None	None	None	None	None	None	None
Flowering position	None	None	None	None	None	Leaf axil	Leaf axil	Leaf axil
Number of pollinia	None	None	None	None	None	None	None	None
Dorsal sepal pattern	None	None	None	None	Patterned and striped	Patterned and striped	Patterned and striped	Patterned and striped
Lateral sepal pattern	None	None	None	None	Edged and striped	Edged and striped	Edged and striped	Edged and striped
Petal pattern	None	None	None	None	Striped	Striped	Striped	Striped
The scent of flowers	None	None	None	None	No scent	No scent	No scent	No scent
Habitus	Epiphyte	Epiphyte	Epiphyte	Epiphyte	Epiphyte	Epiphyte	Epiphyte	Epiphyte
Growth type	Monopodial	Monopodial	Monopodial	Monopodial	Monopodial	Monopodial	Monopodial	Monopodial
Pseudobulb type	None	None	None	None	None	None	None	None
Leaf width	0.6±1	0.5±0.8	0.8±1.2	0.8±1.3	0.2±0.4	0.4±0.8	0.4±0.7	0.4±0.8
Leaf length	5.3	3.4	5.4	5.5	1.8	2.2	1.5	4.6

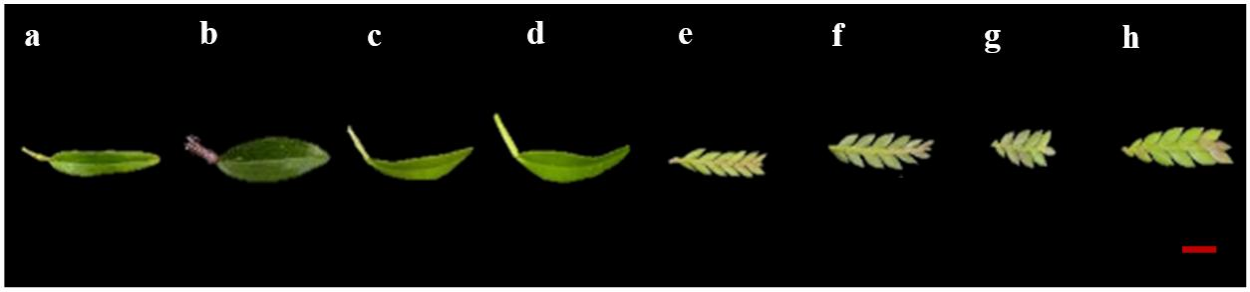

Figure 1. *Dendrobium* leaf samples collection at the Liwa Botanical Garden, a) D1, b) D2, c) D3, d) D4, e) D5, f) D6, g) D7, and h) D8.

Table 2. Characters that play a primary role in the grouping of 19 *Dendrobium.*

Character	PC1	PC 2
Leaf shape	0.44	-0.279
Leaf tip hape	0.157	-0.099
Leaf cross section	0.248	-0.157
Leaf arrangement	0.248	-0.157
Leaf edge shape	0.157	-0.099
Leaf surface texture	0.157	-0.099
Leaf symmetry	0.157	-0.099
Leaf sitting	0.19	-0.238
Pseudobulb type	0.364	-0.231
Spurs	0.248	-0.157
Flower shape	0.099	0.138
Dorsal sepal shape	0.278	0.388
Petal tip shape	0.278	0.388
Petal shape	0.157	0.219
Location of labellum curve	0.039	0.057
Flowering position	0.157	0.219
Number of pollinia	0	0
Dorsal sepal pattern	0.099	0.138
Lateral sepal pattern	0.198	0.277
Petal pattern	0.198	0.277
Flower aroma	0.157	0.219
Leaf length	0.043	-0.182
Leaf width	0.029	-0.123
Growth type	0	0
Habitus	0.157	-0.099
Eigenvalues	2.767	0.42
Percentage	82.448	12.505
Cum. percentage	82.448	94.953

of contribution values to the various groupings. Two main components resulted in the grouping, namely, component I and component II. The component I comprised designation of characters, such as leaf shape, leaf cross section, leaf arrangement, pseudobulb type, spurs, dorsal sepal shape, and petal tip shape, with an eigenvalue of 2.767 and a percent variation of 82.448%. Defining component II were the traits leaf shape, leaf seat, pseudobulb type, dorsal sepal shape, petal tip shape, petal shape, flowering position, lateral sepal pattern, petal pattern, flowering position, lateral sepal pattern, coral petal, and flower aroma. It had an eigenvalue of 0.42 and a percent variation of 12.505%.

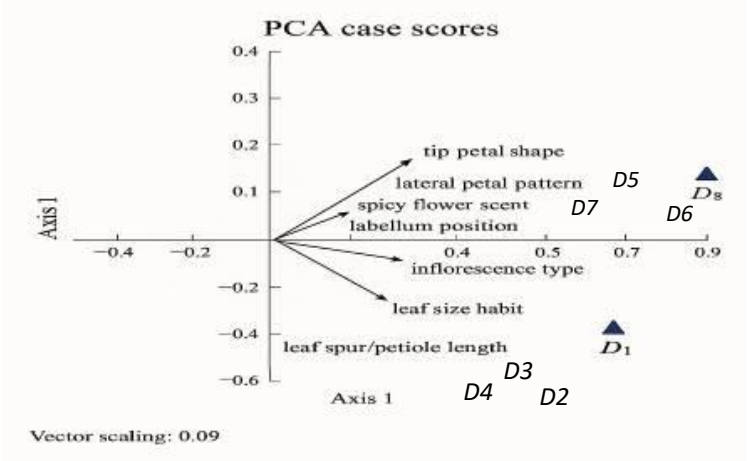

Figure 2. Phenotypic kinship relationship among the *Dendrobium* leaf samples at the Liwa Botanical Garden.

The eigenvalue reflects each character's influence based on the magnitude of its formed projection. Beyond the cluster grouping pattern, observed similarities among specific characters play a vital role in distinguishing *Dendrobium* species accessions by comparing cluster and principal component analyses (Mahfut *et al*., 2025a; 2025d).

In the PCA, leaf shape appears in both components, with varying degrees of influence (Figure 2). For component I, leaf shape is a major contributing factor, with an eigenvalue of 2.767 (82.448% variation), indicating its significant role in distinguishing *Dendrobium* species. In component II, it was also present but with a lesser influence, reflected by an eigenvalue of 0.42 (12.505% variation). The higher contribution of leaf shape in component I suggests it is a key morphological trait for species differentiation, while its role in component II is secondary. This finding aligns with previous studies on the role of morphological traits in plant species differentiation (Nuraini *et al*., 2024; Simamora *et al*., 2024).

The recognition of genetic diversity through observations based on morphological characters is one of the efforts to obtain basic information to determine the characters with the highest diversity (Putra *et al.,* 2024). Studies have shown PCA can be effective to determine the magnitude of a character affecting diversity, and therefore, it can be a characteristic for a variety (Dai *et al*., 2024). Previous research has demonstrated PCA is a valuable tool for summarizing some variations among the plant species (Elhaik*,* 2022). The PCA can also be applicable and helpful to identify the important characteristics with the highest variability values, which are key for classification purposes (Zhang *et al.,* 2024). These findings underscore the relevance of PCA in assessing morphological diversity and identifying the most significant characteristics.

The *Dendrobium* species sample grouping using UPGMA appears Figure 3, with the similarity index displayed in Table 3. The dendrogram analysis based on morphological characterization showed the two different groups, namely, group A and group B. Group A comprised cluster I and cluster II. Cluster I consists solely of accession D7. Cluster II contained the accessions D8, D6, and D5, with the same similarity index of 1, which means these accessions have very similar morphological characters. This suggests these accessions exhibit very similar traits; however, the reason for D7's separation remains

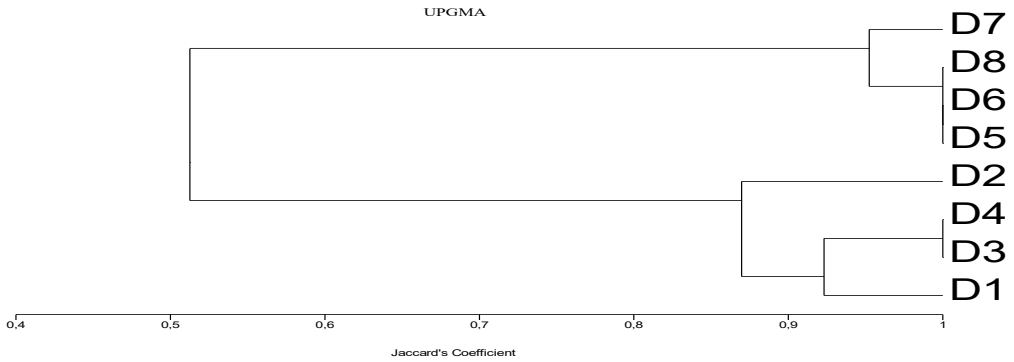

Figure 3. Dendrogram of phenetic kinship among the *Dendrobium* sample leaves at the Liwa Botanical Garden.

Table 3. Similarity index of the morphological traits in eight *Dendrobium* samples at the Liwa Botanical Garden.

Leaf samples	D1	D2	D3	D4	D5	D6	D7	D8
D1	1							
D2	0.972	1						
D3	0.972	0.946	1					
D4	0.972	0.946	1	1				
D5	0.273	0.342	0.203	0.203	1			
D6	0.273	0.342	0.203	0.203	1	1		
D7	0.221	0.298	0.143	0.143	0.933	0.933	1	
D8	0.273	0.342	0.203	0.203	1	1	0.933	1

unclear. Mahfut *et al*. (2024c) explained environmental influences, such as ecological or geographical factors or genetic differentiation, may have led to distinct morphological traits in D7. Group B also consisted of clusters I and II. Cluster I included accession D2, while cluster II further comprised two groups—the first group (IIa) consisting of accessions D4 and D3, and the second group (IIb) recognized only to have accession D1. The isolation of D1 in subcluster IIb could refer to unique environmental conditions, or it might reflect underlying genetic or ecological factors that distinguish it from other accessions in group B (Wahyuningsih *et al.*, 2026). Further investigation into these factors could provide more insights into the reasons for such clustering and isolation.

The dendrogram enunciated the percentage of closeness between *Dendrobium* species, grouped according to a similarity found in the identified morphological character data. This phenomenon can be ascribable to the significant morphological variations observed in the *Dendrobium* species features. These findings align with previous research indicating the highest variability provides a considerable basis for breeding and conservation programs (He *et al*., 2021).

The differences formed through cluster analysis will cause the formation of subclusters, which showed the diversity of characteristics possessed by *Dendrobium* species (Hartati *et al.,* 2022). Grouping based on morphological traits data is the initial step used to determine the relationship among the species, and the same attained authentication by the dendrogram with several genotype groups. The *Dendrobium* species found in the same group displayed close kinship and the highest success rate through crossbreeding (Sukmawati *et al*., 2021;Aritonang *et al*., 2024), indicating closely related species tend

to have higher compatibility in breeding programs.

In the phenetic kinship analysis, the characters used must be owned by all the studied species samples. The traits based on the vegetative organs can effectively differentiate the species. However, the species found in the same environmental and habitat conditions could exhibit phenotypic similarities, leading to shared grouping within the dendrogram (Mahfut *et al*., 2024c; 2025c). Therefore, the phenetic characterization proved valuable in the classification of various *Dendrobium* species (Bhattacharjee *et al*., 2023).

Dendrogram generation through clustering relied on the UPGMA method using the MVSP application. The dendrogram showed the considerable close relationship of *Dendrobium* species samples for morphological characters. The dendrogram has the same group type, although with different similarity coefficients. The dendrogram results revealed each genus and the species were morphologically diverse (Burzacka-Hinz *et al.,* 2025). The degree of similarity in their morphological characters reflected the kinship among the *Dendrobium* species. This level of morphological resemblance serves as a direct indicator of relationship among the various orchid species within the same genus. Consequently, numerous shared morphological traits among the *Dendrobium* species revealed a closer kinship, which can succeed in their validation by analyzing the extent to which their morphological characters were shared (Nadeem *et al.* 2020). However, morphological data alone may not fully reflect genetic relationships. Molecular techniques are crucial to validate and enhance these findings, providing a more accurate assessment of genetic diversity and kinship among *Dendrobium* species, particularly in Southeast Asia and Indonesia.

CONCLUSIONS

Morphological characterization of eight *Dendrobium* species samples, using PCA and UPGMA, yielded two primary clusters based on the similarity of their morphological characters. The clustering was an indication of phylogenetic relationship, highlighting the close genetic ties, with Components I and II contributing 82.448% and 12.505% variations, respectively. The resulting dendrogram clearly divided the *Dendrobium* species samples into two distinct groups, A and B. Group A comprised the accessions D7, D8, D6, and D5, while Group B contained the *Dendrobium* species accessions D2, D4, D3, and D1.

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REFERENCES

Anbiya L, Mahfut, Wahyuningsih S, Suratman (2024). Optimum temperature for detection of TrAP and Rep genes using SPG1/SPG2 primer design on red chili (*Capsicum annuum* L.). The 3rd University of Lampung International Conference on Science, Technology and Environment (ULICoSTE) 2022. *AIP Conf. Proc.* 2970: 050034. https://doi.org/10.1063/5.0208192.

Aritonang LL, Mahfut, Ahyar AN (2024). Acclimatization of five comercial varieties of sugarcane (*Saccharum officinarum* L.) at PT Gunung Madu Plantations, Lampung. The 3rd Universitas Lampung International Conference on Science, Technology and Environment (ULICoSTE) 2022. *AIP Conf. Proc.* 2970: 050004. https://doi.org/ 10.1063/5.0208181.

Asadudin D, Mahfut, Wahyuningsih S, Nurcahyani N, Lumbanraja FR, Irawan B (2025). Morphological characteristics of the pitcher plant (*Nepenthes* spp.) in Lampung, Indonesia. *SABRAO J. Breed. Genet.* 57(5): 2057-2068. http://doi.org/10.54910/ sabrao2025.57.5.26.

Asadudin D, Mulya IP, Nugraha MA, Hasanudin SNA, Mahfut, Susiyanti E, Ahyar AN (2024). Anatomic characterization of 24 mutant varieties of GMP6 in PT Gunung Madu Plantations. The 3rd Universitas Lampung International Conference on Science, Technology and Environment (ULICoSTE) 2022. *AIP Conf. Proc.* 2970: 050039. https://doi.org/10.1063/5.0208463.

Bhattacharjee B, Hossain ME, Ayesha MN, Islam SS (2023). Morphological diversity analysis of some existing and endangered *Dendrobium* orchid species in Bangladesh. *J. Biosci.* 30(2): 47–57. https://doi.org/10.3329/jbs.v30i2.68911.

Burzacka-Hinz A, Dude M, Olędrzyńska, N, Naczk AM, Szlachetko DL (2025). Evolution of morphological traits of *Dendrobium sensu lato* (Orchidaceae)—an attempt to resolve phylogenetic relationships in nominal and morphologically convergent sections. *BMC Plant Biol*. 25: 239. https://doi.org/10.1186/s12870-025-06263-w.

Dai Y, Huang D, He Y, Xiang Y, Li S (2024). Exploratory study on distinguishing *Dendrobium* stem and five species of *dendrobium* using heracles neo ultra fast gas phase electronic nose. *J. Sep. Sci*. 11(7): 1–13. https://doi.org/10.3390/separations11070211.

Elhaik E (2022). Principal component analyses (PCA)-based findings in population genetic studies are highly biased and must be reevaluated. *Sci Rep.* 12(1):14683. https://doi.org/10.1038/s41598-022-14395-4.

Hartati S, Samanhudi, Cahyono O (2022). Morphological characterization of five species of *Dendrobium* native to Indonesia for parent selection. *Biodiversitas* 23: 2648–2654. https://doi.org/10.13057/biodiv/d230548.

He T, Ye C, Zeng Q, Fan X, Huang (2021). Genetic diversity and population structure of *Dendrobium* nobile in Southwest of China based on genotyping by sequencing. *Res Sq*. 1–16. https://doi.org/10.21203/rs.3.rs-1069533/v1.

Mahfut (2020). Identification and detection Odontoglossum ringspot virus on native orchids collection of nurseries in Java, Indonesia. *J. Phys. Conf. Ser*. 1641(012075): 1-6. https://doi.org/10.1088/1742-6596/1641/1/012075.

Mahfut (2021). Identification and efforts to control infection *Odontoglossum ringspot virus* (ORSV) on orchid. *IJESTY*. 1(1): 25-29. https://doi.org/10.52088/ijesty.v1i1.38.

Mahfut, Ananda M, Susiyanti E, Agustina R (2025a). Screening of sugarcane commercial GMP varieties tolerant to drought stress based on molecular detection of P5CS gene. *J. Multidiscip. Appl. Nat. Sci.* 5(1): 119–129. https://doi.org/10.47352/jmans.2774-3047.233.

Mahfut, Anggeiny A, Wahyuningsih S**,** Handayani TT, Sukimin (2020). Identification of disease and efforts to protect native orchid plants against bacteria infection in Liwa Botanical Garden. International Conference on Advanced Information Scientific Development (ICAISD) 2020. *J. Phys.: Conf. Ser*. 1641 (012098): 1–8. https://iopscience.iop.org/article/10.1088/1742-6596/1641/1/012098.

Mahfut, Handayani TT, Wahyuningsih S, Sukimin (2021a). Identification of *Dendrobium* (orchidaceae) in Liwa Botanical Garden based on leaf morphological characters. *J. Trop. Biodivers. Biotechnol*. 6(1): 1–6. https://doi.org/10.22146/jtbb.59423.

Mahfut, Kendari P, Bangsawan R, Susiyanti E (2024a). Agronomic characteristics of sugarcane cultivar GMP3 mutants induced through colchicine. *SABRAO J. Breed. Genet.* 56(3): 1083–1094. https://doi.org/10.54910/sabrao2024.56.3.16.

Mahfut, Kendari P, Susiyanti E, Ahyar AN, Bangsawan R (2024b). Molecular characterization of the sugarcane cultivar GMP3 mutants induced through colchicine using PCR-RAPD markers. *SABRAO J. Breed. Genet*. 56(3): 940–950. http://doi.org/10.54910/sabrao2024.56.3.4.

Mahfut, Panjaitan MVT, Wahyuningsih S, Handayani TT, Sukimin (2021b). Identification of disease and efforts to protect natural orchid plants against fungi infection in the Liwa Botanical Garden. *IJESTY*. 1(1): 30–35. https://doi.org/10.52088/ijesty.v1i1.39.

Mahfut, Riniarti M, Kurniawaty E (2025b). Morphology and phytochemical characterization of native *Dendrobium* used as a herbal medicine In Lampung, Indonesia. *SABRAO J. Breed. Genet.* 57(2): 587–598. http://doi.org/10.54910/sabrao2025.57.2.17.

Mahfut, Sari HE, Kendari P (2024c). Habitat identification and phenetic analysis of bryophyta in Lampung, Indonesia. The 3rd Universitas Lampung International Conference on Science, Technology and Environment (ULICoSTE) 2022. *AIP Conf. Proc*. 2970: 050014. https://doi.org/10.1063/5.0208187.

Mahfut, Sari M, Akin HM, Wahyuningsih S, Irawan B (2025c). Molecular characterization and effectiveness cross-protection of weak strains against super-infection malignant strains Cucumber mosaic virus (CMV) on cayenne pepper (*Capsicum annuum* L.) in Lampung, Indonesia. *J. Trop. Plant Pests Dis*. 25(1): 63–75. https://doi.org/10.23960/jhptt.12563-75.

Mahfut, Sari VDA, Widyawan A, Wahyuningsih S, Irawan B (2025d). Phenotypic stability of mutant sugarcane (*Saccharum officinarum* L.) tolerant to drought stress based on variations in morphological traits at the greenhouse scale. *Int. J. Agric. Technol.* 21(3): 959–972. https://doi.org/10.63369/ijat.2025.21.3.959-972.

Mahfut, Syarif A, Wahyuningsih S (2025e). Molecular phylogeny of rDNA-ITS on native dendrobium in Lampung. *J. Multidiscip. Appl. Nat. Sci.* 5(2): 553–563. https://doi.org/10.47352/jmans.2774-3047.263.

Nguyen NH, Vu HT, Le ND, Nguyen TD, Duong HX, Tran HD (2020). Molecular identification and evaluation of the genetic diversity of *Dendrobium* species collected in Southern Vietnam. *Biology (Basel)*. 9(4): 76. http://doi.org/10.3390/biology9040076.

Nuraini S, Mahfut, Bangsawan R (2024). Germination of bud chips 5 varieties of commercial sugarcane (*Saccharum officinarum* L.) at PT Gunung Madu Plantation. The 3rd Universitas Lampung International Conference on Science, Technology and Environment (ULICoSTE) 2022. *AIP Conf. Proc.* 2970: 050037. https://doi.org/10.1063/5.0208193.

Putera AY, Mawardi I, Ananda M, Sephanti DI, Rajagukguk OPU, Pubianty DP, Mahfut, Ahyar AN, Bangsawan R, Susiyanti E (2024). Anatomic stomata characteristics of 24 mutants of RGM 01-1869 varieties in PT Gunung Madu Plantations. The 3rd Universitas Lampung International Conference on Science, Technology and Environment (ULICoSTE) 2022. *AIP Conf. Proc.* 2970: 050038. https://doi.org/10.1063/5.0208535.

Putra AS, Syarif A, Mahfut, Sulistiyanti SR, Hasibuan MS (2024). Performance evaluation of fuzzy logic system for *Dendrobium* identification based on leaf morphology. *J. Appl. Data Sci*. 5(4): 1520–1529. https://doi.org/10.47738/jads.v5i4.224.

Sari HE, Mahfut, Widyawan A, Wahyuningsih S, Irawan B (2025). Sugarcane commercial cultivars with drought stress tolerance on in vitro and greenhouse scales. *SABRAO J. Breed. Genet*. 57(1): 137–148. http://doi.org/10.54910/sabrao2025.57.1.14.

Septiana AZ, Mahfut, Handayani TT, Suratman (2024). Survey of Tomato yellow leaf curl virus (TYLCV) infection on *Solanum lycopersicum* L. in Lampung, Indonesia. The 3rd Universitas Lampung International Conference on Science, Technology and Environment (ULICoSTE) 2022. *AIP Conf. Proc.* 2970: 050027. https://doi.org/10.1063/5.0208190.

Simamora S, Mahfut, Bangsawan R (2024). Germination test of commercial variety of sugarcane (*Saccharum officinarum* L.) in the end planting month using bud chips at PT Gunung Madu Plantations. The 3rd Universitas Lampung International Conference on Science, Technology and Environment (ULICoSTE) 2022. *AIP Conf. Proc.* 2970: 050029. https://doi.org/10.1063/5.0208191.

Sukmawati S, Badaruddin I, Dewi NK, Situmorang N, Mahfut, Mustapa E (2021). Analysis of organoleptic and coliform value in fresh mackerel (*Rastrelliger* Sp.) fish in TPI Sorong City. *J. Phys. Conf. Ser.* 1764(012035): 1–6. https://doi.org/10.1088/1742-6596/1764/1/012035.

Wahyuningsih S, Mahfut, Anbiya L (2026). Stomata characterization of native Dendrobium in Liwa Botanical Garden. *J. Multidiscip. Appl. Nat. Sci.*, 6(1). https://doi.org/10.47352/jmans.2774-3047.347.

Wahyuningsih S, Mahfut, Putri DS (2025). Genetic stability and phytochemical properties of *Dendrobium nobile* Lindl. as an antiviral using RAPD. *SABRAO J. Breed. Genet.* 57(3): 924–934. http://doi.org/10.54910/sabrao2025.57.3.5.

Zhang T, Liu Z, Ma Q, Hu D, Dai Y, Zhang X, Zhou Z (2024). Identification of *Dendrobium* using laser-induced breakdown spectroscopy in combination with a multivariate algorithm model. *Foods*. 13(11):1676. https://doi.org/10.3390/foods13111676.

Zhao L, Chen P, Li W, Zhang Z (2024). Characterization and phylogenetic analysis of the complete chloroplast genome sequence of *Dendrobium hainanense* (Orchidaceae). *Mitochondrial DNA B Resour.* (12):1679–1682. https://doi.org/10.1080/23802359.2024.2435899.