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STOMATAL MORPHO-ANATOMICAL CHARACTERIZATION OF THE NATIVE *COELOGYNE* IN LIWA BOTANICAL GARDEN, LAMPUNG, INDONESIA

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SUMMARY

Coelogyne is one of the orchid genera that grows in the Liwa Botanical Garden, Lampung, Indonesia. The subsequent study aimed to characterize the *Coelogyne* different species samples based on the morpho-anatomical characteristics of the stomata. Six leaf samples of the different species, as collected, had the paradermal sections examined microscopically to observe their stomata. The key stomatal traits studied included their aperture width, stomatal length, width, density, and index, and the number of stomata. The results indicated that overall, the epidermal cell width was 9.25 μm , stomata length was 19.65 μm , stomata width was 17.09 μm , stomata density was 17.67 mm^2 , and stomatal index was 1.045%. The phenetic analysis based on the dendrogram divided the *Coelogyne* different species samples into two clusters (A and B), with similarity indices of 1.60 and 0.90, respectively. Meanwhile, the PCA values (2.4 and 0.093) emerged as greater than 0.02, which shows the contribution value of each group. The presented results provide a sound genetic base for the identification and conservation of different *Coelogyne* species at the Liwa Botanical Garden, Indonesia, and the potential applicative value of stomatal characteristics in ex situ conservation and taxonomic classification of *Coelogyne*.

Keywords: *Coelogyne*, leaf anatomy, orchid conservation, PCA, phenetic analysis, stomatal morphology

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Key findings: The different *Coelogyne* species samples showed varied morpho-anatomical characteristics. The most influential characters were the stomata density, stomatal opening width, and stomatal index. The phenetic analysis divided the *Coelogyne* species samples into two clusters (A and B), with similarity indices of 1.60 and 0.90 and PCA values of 2.4 and 0.093, respectively, emerging greater than 0.02.

INTRODUCTION

Coelogyne is one of the epiphytic orchid genera characterized by growing in clumps and having broad, elliptical leaves with bright green coloration, which exists in the Liwa Botanical Garden, Lampung, Indonesia (Esti *et al.*, 2023). *Coelogyne* has around 200 species worldwide, spread throughout the tropical Asia region, including India, Indochina, Southeast Asia, and the Pacific Islands, with the largest centers of diversity in Borneo (Serawak, Kalimantan, Sabah, Brunei), Sumatra, and the Himalayas (Mahfut, 2020; 2021). In Indonesia, *Coelogyne* species has an estimate of less than 100 (Wahyudiningsih *et al.*, 2018), with a classification of a threatened species, according to the IUCN Red List. *Coelogyne* species face increasing threats in their natural habitats, which underscores the need for conservation efforts. Stomata are an important feature for species identification, as the morpho-anatomical characteristics of stomata provide valuable information on species differentiation. Therefore, stomatal morpho-anatomical analysis is crucial for the development and conservation of *Coelogyne* in the future (Besi *et al.*, 2023).

The species kinship detection can take place through both phenotypic and genotypic approaches. Phenotypic kinship assessment can proceed through observations of plant morpho-anatomical characters, such as variations in the shape and size of epidermal cells and stomata on leaves (Asadudin *et al.*, 2024; Putera *et al.*, 2024), and observations of morphological features, including the morphology of stems (Mahfut *et al.*, 2025b), leaves (Putra *et al.*, 2024), and flowers (Mahfut *et al.*, 2025e), as well as knowledge about species relationships. The study of

genotypic kinship can be dependent on molecular observations using the plant's DNA (Mahfut *et al.*, 2024b; 2025a). The examinations based on morpho-anatomical characteristics play an important role in the analysis of genetic diversity and kinship. The stomata morpho-anatomical diversity interacts with the environment where it grows, through which the selection can be successful for the best accessions in ornamental plants, and later, being developed as new cultivars for cultivation (Asadudin *et al.*, 2025).

Previous research on stomata morpho-anatomy has taken place in various anatomical features. Field observations of nine morpho-anatomical characters on both upper and lower surfaces of the leaves showed four out of five *Dendrobium* accessions native to the Liwa Botanical Garden had stomata only on the lower surface. Meanwhile, one accession exhibited stomata on both surfaces (Wahyuningsih *et al.*, 2026). The observed stomatal types are predominantly tetracytic, characterized by four neighboring cells surrounding each stoma. The stomata are kidney-shaped, which display irregular, pentagonal, and hexagonal epidermal cells. These findings are relevant to this study, as understanding stomatal morpho-anatomy in different orchid species provides insights into genetic and environmental factors, crucial for the conservation and identification of *Coelogyne* species in the Liwa Botanical Garden.

Stomata characterization has been successful in its conduct in various orchid species and mutant plants, such as in *Dendrobium* accessions native to the Liwa Botanical Garden (Mahfut, 2023). Likewise, it succeeded in 24 mutant varieties of GMP6 (Asadudin *et al.*, 2024), 24 mutant varieties of

RGM-869 (Putera *et al.*, 2024), and 21 mutant cultivars of GMP6 (Mahfut *et al.*, 2024a). These studies revealed notable variations in stomatal traits, including stomatal size and type, such as grass-type stomata (dumbbell-shaped) observed in the GMP mutants. Mutant cultivars exhibited larger stomatal dimensions than their parental genotypes, and phenetic analysis based on the similarity index (0.20) indicated an increasingly close relationship between mutants and parental genotypes. Principal component analysis also highlighted a significant variation through axis I and axis II. These successful studies on stomatal morpho-anatomy identification in both local orchid species, such as *Dendrobium*, and mutant plants offer valuable methods and insights that can be applicable directly to the study of *Coelogyne*. Hence, it enhances our understanding of its morpho-anatomical diversity and supports its conservation efforts.

Conservation efforts at the Liwa Botanical Garden have focused on protecting native orchids from disease infections (Mahfut *et al.*, 2020; 2021a; 2021b; 2021c; 2025c; Septiana *et al.*, 2024; Anbiya *et al.*, 2024) as well as identifying native orchids through detailed morpho-anatomical characterization of stomata. These studies emphasized the importance of stomatal morpho-anatomy as a key factor in plant taxonomy and systematics. The morpho-anatomical traits include leaf stomatal features, such as epidermal cell width, stomatal length and width, stomatal count and density, and stomatal index. Given the enormous difficulties in accurately identifying orchid species based on morphology alone, this type of research is crucial and can help in species identification. This study sought to characterize the stomatal morpho-anatomical traits of native *Coelogyne* species from the Liwa Botanical Garden and analyze their phenetic relationships to support species identification and conservation efforts. Stomata are vital indicators in plant taxonomy and adaptation studies. Variations in stomatal traits often gain influences from abiotic factors that can shape genetic and phenotypic relationships among plant species (Mahfut, 2023).

MATERIALS AND METHODS

Plant material

The *Coelogyne* survey and sample collection commenced in the greenhouse of the Liwa Botanical Garden, Lampung, Indonesia. The collection of six different *Coelogyne* species leaf samples (C1, C2, C3, C4, C5, and C6) followed the methodology described by Mahfut (2023).

Morpho-anatomical characterization

Observations of the stomatal characteristics of leaves continued by making a paradermal section under a light microscope (Setiawan *et al.*, 2020). Leaf samples underwent initial cleaning with 70% alcohol. Then, the lower surface of the leaf sustained coating with a thin layer of nail polish and entailed drying. Once dried, gently pressing transparent adhesive tape onto the nail polish layer helped lift the epidermal imprint before its transfer to a glass slide. The preparation received staining with safranin dye to make it easier to observe the stomata structure. Microscopic observations ensued toward the specimen (Tuasamu, 2018). The stomatal characters observed included both quantitative traits, such as epidermal cell width, stomatal length and width, the number of stomata, and stomatal density and index, and qualitative traits, such as stomata type. Each measurement reached three replications.

Statistical analysis

Quantitative and qualitative data on the stomatal characteristics underwent descriptive analysis to assess variations (Cambaba *et al.*, 2021). The study used the multivariate statistical package (MVSP) software version 3.2 to construct a phenetic dendrogram and perform the principal component analysis (PCA). The generation of the dendrogram utilized the Jaccard index, and for similarity index and genetic distance analysis, the study applied the unweighted pair-group method with arithmetic mean (UPGMA). Stomatal

density and stomatal index calculations employed the methodology of Tambaru (2015). All microscopic observations transpired at 400× magnification.

RESULTS AND DISCUSSION

Stomata characterization

Microscopic observations of the six *Coelogyne* samples (C1, C2, C3, C4, C5, and C6) had an anomocytic stomata type (Figure 1). This type is characteristic of guard cells surrounded by indistinct subsidiary cells that are morphologically similar to adjacent epidermal cells. Anomocytic stomata are common among monocotyledons, including orchids, and seem to facilitate physiological adaptation to fluctuating environmental conditions (Mahfut *et al.*, 2024c). Supporting these observations, Asadudin *et al.* (2024) and Putra *et al.* (2024) demonstrated that anomocytic stomata play a crucial role in optimizing gas exchange and

transpiration in epiphytic orchids, particularly in habitats with variable humidity and climatic conditions (Aritonang *et al.*, 2024; Nuraini *et al.*, 2024; Simamora *et al.*, 2024). These findings align with this study's results, indicating the stomatal morpho-anatomy of *Coelogyne* to its ecological adaptability in the tropical climate of the Liwa Botanical Garden.

The six *Coelogyne* species revealed varying values in stomatal characters (Table 1). On average, the largest epidermal cell width resulted in sample C1 (23.62 μm). Stomatal aperture width ranged from 0.95 to 3.58 μm , with an average of 2.09 μm , and the highest value appeared in the *Coelogyne* sample C2, while the lowest was evident in the sample C5. Stomatal length ranged from 16.50 to 23.62 μm , with an average of 19.65 μm . The *Coelogyne* sample C1 exhibited the ultimate value, with sample C6 recorded with the lowest value. Overall, the stomatal width ranged from 12.09 to 20.39 μm , with an average value of 17.09 μm .

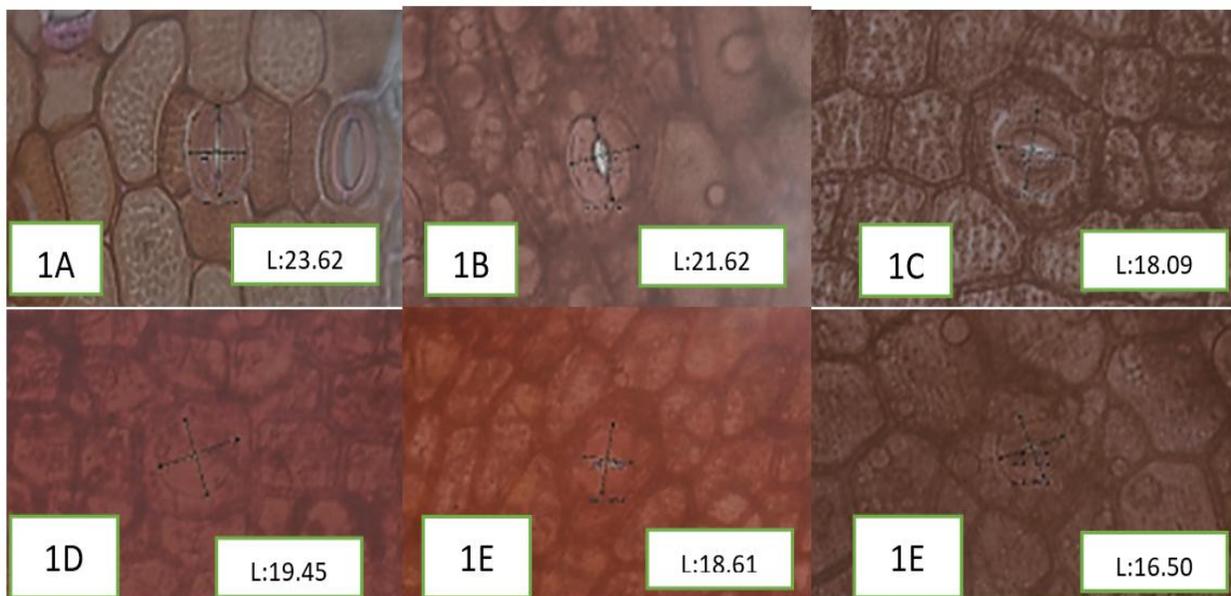


Figure 1. Stomatal structure of the *Coelogyne* six samples: 1A - D16, 1B - D23, 1C - D24, 1D - D25, 1E - D26, and 1F - D27.

Table 1. Average value of stomata characters in the *Coelogyne* species six samples at the Liwa Botanical Garden, Lampung, Indonesia.

No.	<i>Coelogyne</i> sample code	Stomata aperture width (µm)	Stomata length (µm)	Stomata width (µm)	Number of stomata	Stomata density (mm)	Stomata index (%)
1.	C1	1.41	23.62	15.04	12.67	25.34	0.182
2.	C2	3.58	21.62	17.59	9.00	18.00	0.172
3.	C3	1.12	18.09	20.39	8.00	16.00	0.172
4.	C4	1.10	19.45	20.31	6.00	12.00	0.171
5.	C5	0.95	18.61	12.09	6.33	12.67	0.171
6.	C6	1.09	16.50	17.14	11.00	22.00	0.177
Means		9.25	19.65	17.09	8.83	17.67	1.045

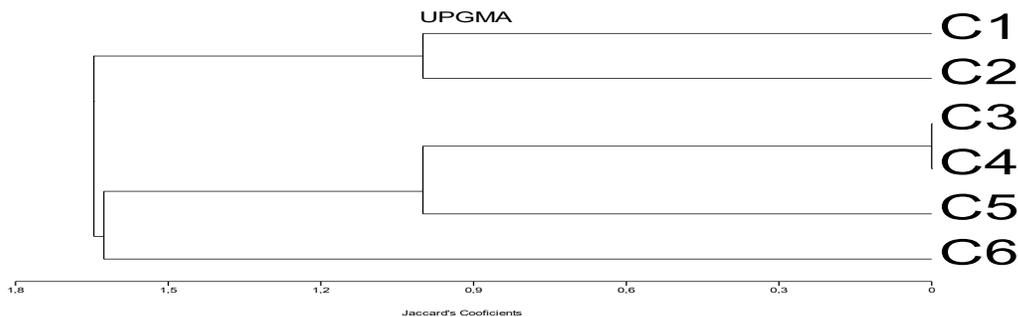


Figure 2. Dendrogram of the kinship tree for the *Coelogyne* six samples based on stomatal morpho-anatomical characters.

The presented results agreed with past findings, which reported stomatal morphometric variations in orchids influence the transpiration efficiency and environmental adaptation (Cambaba *et al.*, 2021). For instance, sample C1, which exhibited the highest stomatal length of 23.62 µm, may indicate higher transpiration efficiency, as larger stomata often showed an association with greater gas exchange and water loss. Conversely, sample C5, with the smallest stomatal aperture width, could represent an ecological adaptation to a high-humidity environment, where reduced stomatal size helps minimize water loss. These findings are relevant to the habitat conditions of *Coelogyne*, as similar adaptations have been notable in epiphytic plants (Mahfut *et al.*, 2024a; 2025d). However, it is important to compare these measurements with other species to determine whether these values are unusually high or low or if they represent typical traits of tropical epiphytes. Therefore, in the concerned study,

the observed stomatal characteristics may serve as crucial indicators for understanding the physiological adaptations of *Coelogyne* in the Liwa Botanical Garden.

Phenetic analysis

Based on the dendrogram analysis of stomata morpho-anatomical characters, two main clusters were distinct, namely, clusters A and B (Figure 2). Cluster A consists of two *Coelogyne* samples, C2 and C1, which exhibited the highest degree of similarity based on stomatal length and width. However, other parameters, such as stomatal density, stomatal index, and epidermal cell width, may also contribute to the clustering pattern, and further analysis could clarify their impact on the grouping. Cluster B positioning was at the similarity level of 1.60 line, which further divided into two subclusters—subcluster I comprised samples C3 and C4, and subcluster II only contained the *Coelogyne* sample C6. The separation of

sample C6 from the other samples could refer to its lower stomatal length, as it exhibited the smallest value for this parameter, which might explain why it moved away from the other samples. This dendrogram grouping pattern revealed obvious differentiation among the *Coelogyne* species samples, and sample C4 has a very close kinship with *Coelogyne* sample C3. Samples within the same cluster, such as C3 and C4, demonstrated closer kinship based on the similarity of their stomatal characters, while samples in different clusters, such as C6 and the others, exhibited a more distant kinship. The similarity index ranges from 0 to 1, indicating that the closer the index is to 1, the more similar the species.

According to morpho-anatomical features, the plant samples emerged with relatively the same similarity indices and close kinship relationships (Asadudin *et al.*, 2024; Putera *et al.*, 2024). The analysis of kinship relationships aims to group the plant populations based on their morpho-anatomical traits. Relationships based on the same characteristics served to determine whether the plant species studied have a close or distant relatedness. In cluster analysis, variables such as stomatal length, stomatal width, and stomatal density likely contributed the most to the grouping pattern. The closer the kinship relationship between species, the lower the genetic distance and the greater the similarity coefficient value (Sukmawati *et al.*, 2021).

These findings were consistent with previous studies by Mahfut *et al.* (2024a; 2025c), who reported grouping based on stomatal morphological characters can reflect genetic kinship among the plant species. Additionally, Sari *et al.*'s (2025) findings revealed that variations in stomatal size and shape serve as vital indicators in phylogenetic and taxonomic analyses of crop plants. Therefore, in the presented study, the dendrogram provided preliminary evidence of kinship relationships among the *Coelogyne* samples based on stomatal morpho-anatomical characteristics.

Principal component analysis

Based on the cluster analysis, it showed the division of *Coelogyne* species samples into two clusters (Figure 3). Cluster I comprised the samples C2, C1, and C6, which exhibited similarities in epidermal cell width, stomata density, and stomata index. Although C6 displayed a previous separation in the dendrogram, its inclusion in Cluster I with C1 and C2 may be due to the similar values it shared with these samples in stomatal density and epidermal cell width (Table 1). Cluster II consisted of the *Coelogyne* samples C3, C4, and C5. Sakurai and Miklavcic (2022) mentioned the length and direction of the arrow indicated the stomatal character that mostly affected the grouping. The arrow pointing to a particular group indicates the most influential stomatal character, and the arrow length was directly proportional to the stomatal characters.

From the significant results, the characteristics that influence the separation of *Coelogyne* samples between cluster analysis and PCA analysis have similarities apart from the cluster grouping pattern (I and II). However, the results of both analyses are consistent, as they both successfully separate species with similar morpho-anatomical characteristics. The match between the two methods indicates that both cluster analysis and PCA can be effectively helpful in determining the cluster structures in taxonomy. The key characters that contribute to the separation of *Coelogyne* samples are available in Table 2, which includes relevant morphological and anatomical traits.

The findings further revealed that in cluster I, the characters that play a positive role were the epidermal cell width, stomatal index, stomatal density, and stomatal area, with an eigenvalue of 0.604 (54.9%). However, in cluster II, the characters with a vital role were the epidermal cell width and stomatal area, with an eigenvalue of 0.377 (34.3%) (Table 3). In this analysis, the eigenvalues showed the percentage value of

Table 2. Similarity index (%) of stomatal morpho-anatomical characters in the *Coelogyne* six samples at the Liwa Botanical Garden, Lampung, Indonesia.

<i>Coelogyne</i> samples	C1	C2	C3	C4	C5	C6
C1	1.00					
C2	0.75	1.00				
C3	0.25	0.33	1.00			
C4	0.25	0.33	1.00	1.00		
C5	0	0	0	0	1.00	
C6	0.50	0.25	0	0	0	1.00

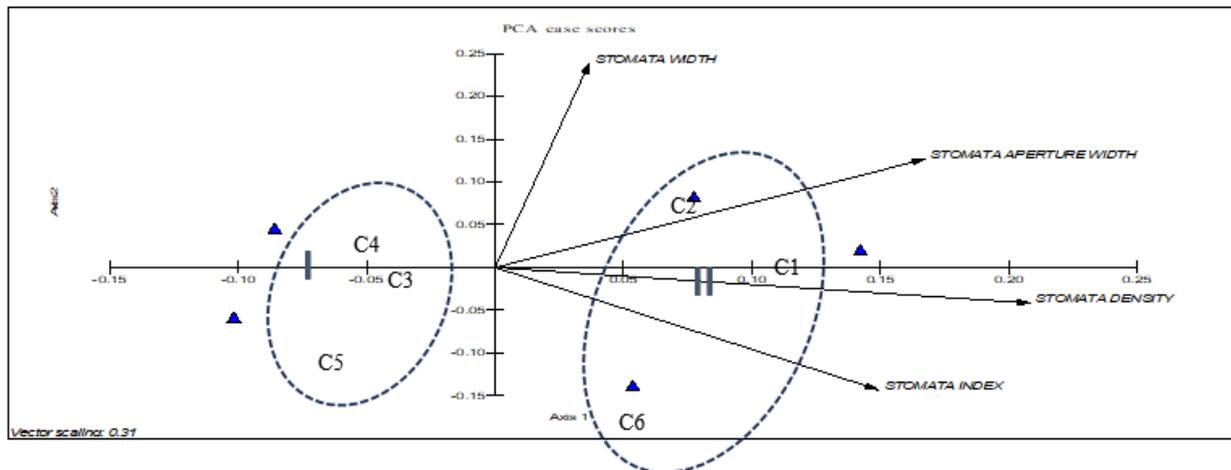


Figure 3. Results of PCA analysis on the *Coelogyne* six samples based on stomatal morpho-anatomical characters.

Table 3. Characters that play a vital role in the grouping of *Coelogyne* species samples.

<i>Coelogyne</i> characters	PC 1	PC 2
Stomata aperture width	0.543	0.411
Stomata index	0.484	-0.463
Stomata density	0.676	-0.135
Stomata area	0.119	0.774
Eigenvalues	0.604	0.377
Percentage (%)	54.919	34.296
Percentage Cum.	54.919	89.215

the contribution in each grouping. An eigenvalue (>0.02) indicates the most influential character in cluster grouping (Elhaik, 2022). The eigenvalue value implies the level of influence of each character, which can be visible from the length of the projection formed. The consistency between the dendrogram and PCA results further supports the use of stomatal characters as reliable taxonomic markers in *Coelogyne*.

CONCLUSIONS

Characterization of different *Coelogyne* species samples revealed various morpho-anatomical characteristics concerning stomata. Overall, the results disclosed average values for epidermal cell width (9.25 μm), stomata length (19.65 μm), stomata width (17.09 μm), stomata density (17.67 mm), and stomata index (1.045%). The phenetic analysis divided

Coelogyne samples into two clusters (A and B), with similarity indices of 1.60 and 0.90, and PCA values (2.4 and 0.093) greater than 0.02 indicate the contribution value of each grouping. The valuable findings provide essential data for conservation practices, such as species prioritization, genetic diversity assessment, and the development of conservation strategies for *Coelogyne* at the Liwa Botanical Garden, Lampung, Indonesia.

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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 annum* L.). The 3rd Universitas Lampung International Conference on Science, Technology and Environment (ULICoSTE) 2022. *AIP Conf. Proc.* 2970: 050034.
- Aritonang LL, Mahfut, Ahyar AN (2024). Acclimatization of five commercial 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>.
- Besi EE, Mustafa M, Yong CSY, Go R (2023). Deforestation Impacts on diversity of orchids with inference on the conservation initiatives: Malaysia case study. *Bot. Rev.* 89:386-420. <https://doi.org/10.1007/s12229-023-09292-y>.
- Cambaba S, Kasi PD, Asriani I (2021). Comparison of the anatomical structure of stomata of several mangrove plant species. *Cokroaminoto J. Biol. Sci.* 3(1): 1-6. <https://doi.org/10.36987/cjbs.v3i1.123>.
- Elhaik E (2022). Principal Component Analyses (PCA)-based findings in population genetic studies are highly biased and must be reevaluated. *Sci. Rep.* 12:14683. <https://doi.org/10.1038/s41598-022-14395-4>.
- Esti M, Yupi I, Yohanes P (2023). Diversity of orchid species in Liwa Botanic Gardens and their utilization by the community. *AIP Conf. Proc.* 2606:050004. <https://doi.org/10.1063/5.0119074>.
- 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 (2023). Identification of native dendrobium based on morphological and anatomical characters in Liwa Botanical Garden. In *Tropical Plant Species and Technological Interventions for Improvement*, Muhammad Sarwar Khan (Ed.), Intech Open Publisher: United Kingdom, 284. <https://doi.org/10.5772/intechopen.102446>.
- 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, Angeiny A, Wahyuningsih S, Handayani TT, Sukimin (2020). Identification of disease and efforts to protect native orchid plants against bacterial infection in Liwa Botanical Garden. *J. Phys. Conf. Ser.* 1641 (012098): 1-8. <https://doi.org/10.1088/1742-6596/1641/1/012098>.
- 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. <http://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, Minarni IY, Wahyuningsih S, Handayani TT (2021a). Physiological analysis of orchid chlorophyll against *Odontoglossum ringspot virus* infection. *Jordan J. Biol. Sci.* 14(5): 1025–1029. <https://doi.org/10.54319/jjbs/140522>.
- 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 annum* 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, Syahira H, Wahyuningsih S, Handayani TT, Sukimin (2021c). Identification of virus infection on native orchids in Liwa Botanical Garden. *J. Phys. Conf. Ser.* 1751(012063): 1–7. <https://doi.org/10.1088/1742-6596/1751/1/012063>.
- 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>.
- Nuraini S, Mahfut, Bangsawan R (2024). Germination of bud chips 5 varieties of commercial sugarcane (*Saccharum officinarum* L.) at PT. GunungMadu Plantation. The 3rd Universitas Lampung International Conference on Science, Technology and Environment (ULICoSTE) 2022. *AIP Conf. Proc.* 2970: 050037.
- Putera AY, Mawardi I, Ananda M, Sephanti DI, Rajagukguk OPU, Pubianty DP, Mahfut, Ahyar AN, Bangsawan R, Susiyanti E (2024). The effect of colchicine on anatomic stomata characteristics 24 mutants RGM 01-1869 varieties at 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 M (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>.
- Sakurai G, Miklavcic SJ (2022). A whole leaf comparative study of stomatal conductance models. *Front. Plant Sci.* 13: 766975. <https://doi.org/10.3389/fpls.2022.766975>.
- 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>.
- Setiawan E, Miftahudin M, Chikmawati T (2020). Variation of leaf anatomical structure of several species of *Alpinia* Roxb. in Malesia. *Al-Kauniah - J. Biol.* 22(2):121-130. <https://doi.org/10.15408/kauniah.v22i2.17446>.
- 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>.
- Tambaru E (2015). Identification of morphological and anatomical characteristics of *Flacourtia inermis* Roxb. in the Unhas Tamalanrea Makassar campus area. *J. Nat. Environ. Sci.* 6(11): 35-41. <https://doi.org/10.24815/jipi.v1i2.9693>.
- Tuasamu Y (2018). Characterization of leaf morphology and stomata anatomy in several species of citrus plants (*Citrus* sp.). *J. Agrikan.* 11(2):85-90. <https://doi.org/10.29239/j.agrikan.11.2.85-90>.
- Wahyudiningsih T, Jagau Y, Ravenska N (2018). Conservation of *Coelogyne pandurata* Lindl. in Central Kalimantan: Morphological characters, in vitro propagation, and local community-based conservation. *J. Environ. Sustain. Manag.* 2(2): 125-139. <https://doi.org/10.36813/jplb.2.2.125-139>.
- 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>.