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MORPHOLOGICAL SIMILARITY AMONG WILD ORCHID ACCESSIONS IN BENGKULU, INDONESIA

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SUMMARY

The Bengkulu Province in Indonesia is a natural habitat for various orchid species; however, its biodiversity currently faces threats from human activities and natural disasters. Precise identification and classification of these orchid species are essential for their future conservation. Hence, the presented study sought to characterize the 35 wild orchid accessions from Bengkulu's forests and construct a phylogenetic tree based on morphological data. The accessions' collection ensued through germplasm exploration conducted in Bengkulu Province. Then, growing the collected accessions ex situ pursued evaluating their morphological characteristics. Evidently, the 597 sub-characters observed were polymorphic (99.66%) and monomorphic (0.34%) in nature. Using the unweighted pair group method with arithmetic mean (UPGMA) at a 40% similarity coefficient, the existing accessions could result into 11 groups, with the highest similarity coefficient (72%) observed in *Flickingeria trilamellata* and *Flickingeria* sp. The relevant findings can serve as the reference for mitigating wild orchids in Bengkulu Province from extinction.

Keywords: Wild orchid, landraces, morphological traits, phylogenetic tree, similarity matrix, cluster analysis

Key findings: The wild orchids need preservation to save them from extinction. Natural orchids are an important genetic source to benefit the development of commercial orchids.

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INTRODUCTION

Orchids are typically the largest, most diverse, and unique flowering plants. More than 25,000 orchid species grow wild worldwide, and around 125,000 cultivars have succeeded in breeding and registration as hybrid orchids (Fatt and Astley, 2012). Most of the orchid species survive as epiphytes, and a few are lithophytes and terrestrial; however, none of them was distinctly parasitic (Ganefianti *et al.*, 2023).

Orchids showed remarkable diversity in morphological appearances and are readily visible through roots, stems, leaves, flowers, fruits, and seeds. Similarly, orchids have a wide range of adaptability, growing in almost all terrestrial ecosystems, except poles and deserts. From a horticultural viewpoint, orchids are premier ornamental plants of highest commercial values, which can generate a multimillion-dollar business (Da-Costa, 2016). Although, plant breeders have developed numerous orchid hybrids, the diverse markets have led to the establishment of both legal and illegal trades (Hinsley *et al.*, 2015; Phelps, 2015).

Orchids' illegal trade plays a critical role in its declining wild population through time (Vermeulen and Lamb, 2011; Subedi *et al.*, 2013; Fay, 2015; Phelps and Webb, 2015). Besides market-oriented exploitation, the reduced populations of wild orchids, to a greater extent, resulted from deforestation, land use variations, and other natural causes. Moreover, the agriculture expansion can severely damage the forest ecosystem by changing forest structure, ecosystem function, and the natural habitat of wildlife, including orchids (Budiharta *et al.*, 2011; Beltrán-Nambo *et al.*, 2012).

Around 300 wild orchid species have reached collection and identification through an expedition carried out in 1997 native to the Bengkulu Province by the team from the Indonesia Institute of Science (Mahyar *et al.*, 1997). Indonesia also provides a natural habitat for about 5,000 wild orchid species, and most of them grow in the Bengkulu Province, Indonesia (Jatmika, 2013). Wild

orchids' natural habitat has decreased due to various causes, including less sustainability of in-situ conservation in some areas. However, the mitigation of wild orchid diversity using ex-situ conservation can be a practical alternative (Ganefianti *et al.*, 2023).

Moreover, the detailed information on plant characteristics and the phylogenetic system of wild orchids could provide the existing species scientific background to help alleviate the loss of diversity. Similarly, by grouping the species would enable establishing species boundaries, as well as, the relationships between species. The presented study characterized 35 accessions of wild orchids collected from Bengkulu Province and developed a phylogenetic tree based on their degree of morphological similarity.

MATERIALS AND METHODS

For wild orchids, the pertinent study commenced at the ex-situ conservation facility of the Sungai Serut, Bengkulu, Indonesia. Thirty-five wild orchid accessions sustained ratings for varied characteristics (Table 1). The morphological characters included roots, stems, leaves, flowers, and fruits, rated from two fully grown plants (Seidenfaden and Wood, 1992; Comber, 2001; Ornamental Plant Research Institute, 2007). The qualitative data served to identify types of morphism for the observed features. The quantitative data's conversion to binary codes received a score of one (1) for observable and zero (0) for unobservable traits.

The data sets' arrangement in a matrix incurred further analysis. Using the NTSYS-PC version 2.02i (Rohlf, 2000) ran the SIMQUAL routine to generate the Dice similarity coefficient and the SAHN routine to construct the unweighted pair group method with arithmetic mean (UPGMA) clustering and the dendrogram. Cophenetic correlation (*r*) application measured the 'goodness of fit' of the similarity between cluster outputs, where $r > 0.9$ scored as a very good fit, $0.7 < r < 0.9$ = a good fit, and $r < 0.7$ is less fit.

Table 1. The accession names and their natural habitat.

No.	Accession name	Habitat
1	<i>Acriopsis liliifolia</i>	Epiphytic
2	<i>Arundina graminifolia</i>	Terrestrial
3	<i>Bulbophyllum claptonense</i>	Epiphytic
4	<i>Bulbophyllum sp.</i> ,	Epiphytic
5	<i>Coelogyne asperata</i>	Epiphytic and Terrestrial
6	<i>Coelogyne pulverula</i>	Epiphytic
7	<i>Cylindrolobus mucronatus</i>	Epiphytic
8	<i>Cymbidium bicolor</i>	Epiphytic
9	<i>Cymbidium chloranthum</i>	Epiphytic
10	<i>Dendrobium aphyllum</i>	Epiphytic
11	<i>Dendrobium linguella</i>	Epiphytic
12	<i>Dendrobium sanguinolentum</i>	Epiphytic
13	<i>Dendrobium sp.1</i>	Epiphytic
14	<i>Dendrobium sp.2</i>	Epiphytic
15	<i>Dendrobium sp.3</i>	Epiphytic
16	<i>Encyclia sp.</i>	Epiphytic
17	<i>Eria palmifolia</i>	Epiphytic
18	<i>Eria sp.</i> ,	Epiphytic
19	<i>Eulophia graminea</i>	Epiphytic
20	<i>Eulophia spectabilis</i>	Epiphytic
21	<i>Flickingeria sp</i>	Epiphytic
22	<i>Flickingeria trilamellata</i>	Epiphytic
23	<i>Grammatophyllum stapeliiflorum</i>	Epiphytic
24	<i>Liparis sp.</i>	Epiphytic
25	<i>Micropera callosa</i>	Epiphytic
26	<i>Papilionanthe hookeriana</i>	Semi-aquatic
27	<i>Phaius tankervilleae</i>	Terrestrial
28	<i>Phalaenopsis tetraspis</i>	Epiphytic
29	<i>Pomatocalpa latifolia</i>	Epiphytic
30	<i>Porphyrodesme sp.</i>	Epiphytic
31	<i>Robiquetia spathulata</i>	Epiphytic
32	<i>Spathoglottis plicata</i>	Terrestrial
33	<i>Thrixspermum sp.</i>	Epiphytic
34	<i>Vanda helvola</i>	Epiphytic
35	<i>Vanda leucostele</i>	Epiphytic

RESULTS AND DISCUSSION

Morphological characterization

Based on the 68 morphological characteristics, the study identified 597 sub-characters among 35 newly characterized wild orchid accessions (Table 2). The sub-characters resulted in 595 polymorphic sub-characters (99.66%) and two monomorphic sub-characters (0.34%). The

large proportion of polymorphism for almost all the observed characters demonstrated varied performances for the accessions. Although, the morphological markers could have gained influences from the environment and the plant's developmental stage. However, these markers still play a vital role in characterizing the distinctiveness of the different accessions. Past studies revealed the variation in morphological traits also implied varied

Table 2. The morphological characters' identification of 35 Bengkulu orchid species.

No.	Characters	Number of sub-characters	Number of polymorphic sub-characters	Number of monomorphic sub-characters
1	Stem growth type	2	2	0
2	Plant size	3	3	0
3	Plant height	3	3	0
4	Stem size	3	3	0
5	Peduncle position on stem	4	4	0
6	Stem erectness	4	4	0
7	Stem color	29	29	0
8	Leaves arrangement	3	3	0
9	Pedicel erectness	4	4	0
10	Stem shape	4	4	0
11	Stem diameter	3	3	0
12	Tiller number	3	3	0
13	Root tip color	26	26	0
14	Root base color	23	23	0
15	Root type	3	3	0
16	Root hair	2	2	0
17	Root cross-section shape	1	0	1
18	Leaf cross-section	6	6	0
19	Leaf tip symmetry	2	2	0
20	Leaf shape	5	5	0
21	Leaf tip shape	7	7	0
22	Leaf edge shape	1	0	1
23	Leaf surface texture	4	4	0
24	Mature leaf color	17	17	0
25	Young leaf color	16	16	0
26	Leaf vein color	4	4	0
27	Leaf size	4	4	0
28	Leaf length	4	4	0
29	Leaf width	4	4	0
30	Inflorescence type	4	4	0
31	Flower resupination	2	2	0
32	Flower shape	5	5	0
33	Dorsal sepal shape	8	8	0
34	Lateral sepal shape	7	7	0
35	Sepal tip shape	5	5	0
36	Petal shape	8	8	0
37	Petal tip shape	4	4	0
38	Keel	3	3	0
39	Spur	2	2	0
40	Pollinia number	3	3	0
41	Spike color	29	29	0
42	Dorsal sepal color	28	28	0
43	Dorsal sepal pattern	17	17	0
44	Lateral sepal color	28	28	0
45	Lateral sepal pattern	17	17	0
46	Petal color	26	26	0
47	Petal pattern	13	13	0
48	Flower base color	30	30	0
49	Callus color	23	23	0
50	Lip mid lobe color	29	29	0

Table 2. (cont'd.)

No.	Characters	Number of sub-characters	Number of polymorphic sub-characters	Number of monomorphic sub-characters
51	Lip sidelobe	2	2	0
52	Lip sidelobe color	27	27	0
53	Lip mid-lobe shape	20	20	0
54	Flower color number	3	3	0
55	Petal twist	2	2	0
56	Flower size	3	3	0
57	Flower length	4	4	0
58	Flower width	4	4	0
59	Inflorescence length	4	4	0
60	Peduncle length	4	4	0
61	Peduncle diameter	4	4	0
62	Pedice number per peduncle	3	3	0
63	Flower number per pedice	4	4	0
64	Flower freshness	3	3	0
65	Mature fruit color	11	11	0
66	Fruit length	4	4	0
67	Fruit diameter	3	3	0
68	Fruit shape	7	7	0
Total		597	595	2
Percentage		100%	99.66%	0.34%

patterns in molecular (DNA) fragments (Khasim and Ramesh, 2010; Wahba *et al.*, 2014; Ferdiani *et al.*, 2015).

Overall, the two monomorphic sub-characters' detection surfaced among all accessions, namely, round root cross-section shape and entire leaf edge. However, previous studies indicated these two sub-characters were polymorphic, and the root cross-section could be either round or oblong (Oliveira and Sajo, 1999). Mujaffar *et al.* (2013) mentioned the leaf edge could be complete or undulated. Being monomorphic, expect no new variation for these sub-characters by crossing these accessions.

Accessions' grouping based on morphological traits

Based on the Dice coefficient of the similarity matrix, the UPGMA clustering produced a dendrogram for 35 accessions with the goodness of fit correlation matrix ($r = 0.85$) (Figure 1). The similarity coefficient close to 1.0 indicates the highest similarity among the accessions. However, a cutoff point produced 11 major clusters at a 0.4 similarity coefficient.

Cluster I consisted of six accessions from five genera, with a 0.4 similarity coefficient, i.e., *Liparis latifolia*, *Encyclia sp.*, *Coelogyne pulverula*, *Grammatophyllum stapeliiflorum*, *Cymbidium chloranthum*, and *Cymbidium bicolor* (Figure 2). Based on the RBCL nucleotide sequence data, Cameron *et al.* (2009) found accessions *Cymbidium* and *Grammatophyllum* bore the same grouping in the cluster of subtribe Cyrtopodiinae (tribe Cymbidieae). The subtribe Cyrtopodiinae usually has common features, including pseudobulbs in terrestrial and lithophytic herbs (Stem, 2014). Dividing Cluster I reached three clades. The first clade comprised *Liparis latifolia* and *Encyclia sp.*, with a similarity coefficient of 0.48. Both accessions possessed similarities in plant size, stem, peduncle position on stem, basal root color, leaf cross-section shape, tip shape, edge shape, and surface texture, and flower resupination.

The dendrogram grouped the landraces *Cymbidium chloranthum* and *Cymbidium bicolor* with a similarity coefficient of 5.1, with linear leaf shape, less symmetrical leaf tip, entire leaf edge, and inflorescence flower. The labellum was ovoid, with linear dorsal petal,

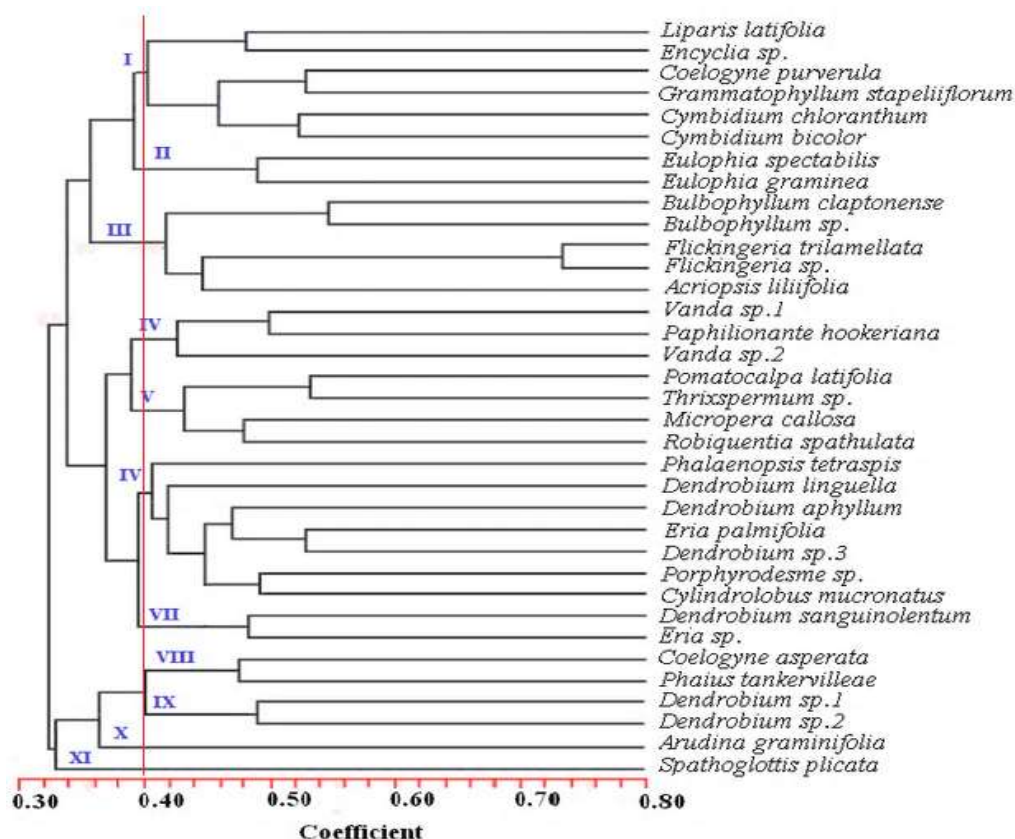


Figure 1. Dendrogram of the morphological similarity of 35 accessions of Bengkulu wild orchids based on the UPGMA cluster analysis of Dice similarity coefficients.

lateral sepal, and petal (dorsal sepal, lateral sepal, and ribbon-shaped petal). Based on molecular markers, Siripiyasing *et al.* (2012) grouped both accessions in the same clade at a similarity coefficient of 5.7. The remaining clade of cluster I contained *Coelogyne pulverula* and *Grammatophyllum stapeliiflorum*. These accessions had a similarity index of 5.2, with typical plant size, bulb, leaf growth, root type, peduncle position on stem, and the pedicel erectness.

Cluster II included the two accessions *Eulophia graminea* and *Eulophia spectabilis*, belonging to the genus *Eulophia*, with a similarity coefficient of 0.4 (Figures 1 and 2). Both species appeared terrestrial, however, differed by their natural habitats. The *E. graminea* was primarily prevalent along the coastline, while the *E. spectabilis* resides at medium altitudes. The stem developed into a pseudobulb, leaf linear, conduplicate leaves'

cross-section, with an erect panicle-shaped stalk. The sepals and petals have the same shape with different colors. The dorsal and lateral sepals were linear, and the petals were oval. Shu *et al.* (2009a, b) reported accessions *E. graminea* and *E. spectabilis* had the same morphological characteristics, i.e., growing above the ground, panicle-shaped stalks with 4–9 flower buds, linear-shaped sepals, and oblong/oval-shaped petals.

Genus *Bulbophyllum* (*B. claptonense* and *Bulbophyllum sp.*), *Flickingeria* (*F. trilamellata* and *Flickingeria sp.*), and *Acriopsis* (*A. liliifolia*) belonged in Cluster III, with similarity coefficient of 0.42 (Figures 1 and 2). These three genera also revealed similarities in the overall plant size. The genera have aerial/attached roots, stems with a one-bulb segment, flower stalk growth type at the base of the stem, and leaf growth type at the stem tip. Meanwhile, *Flickingeria* has a single

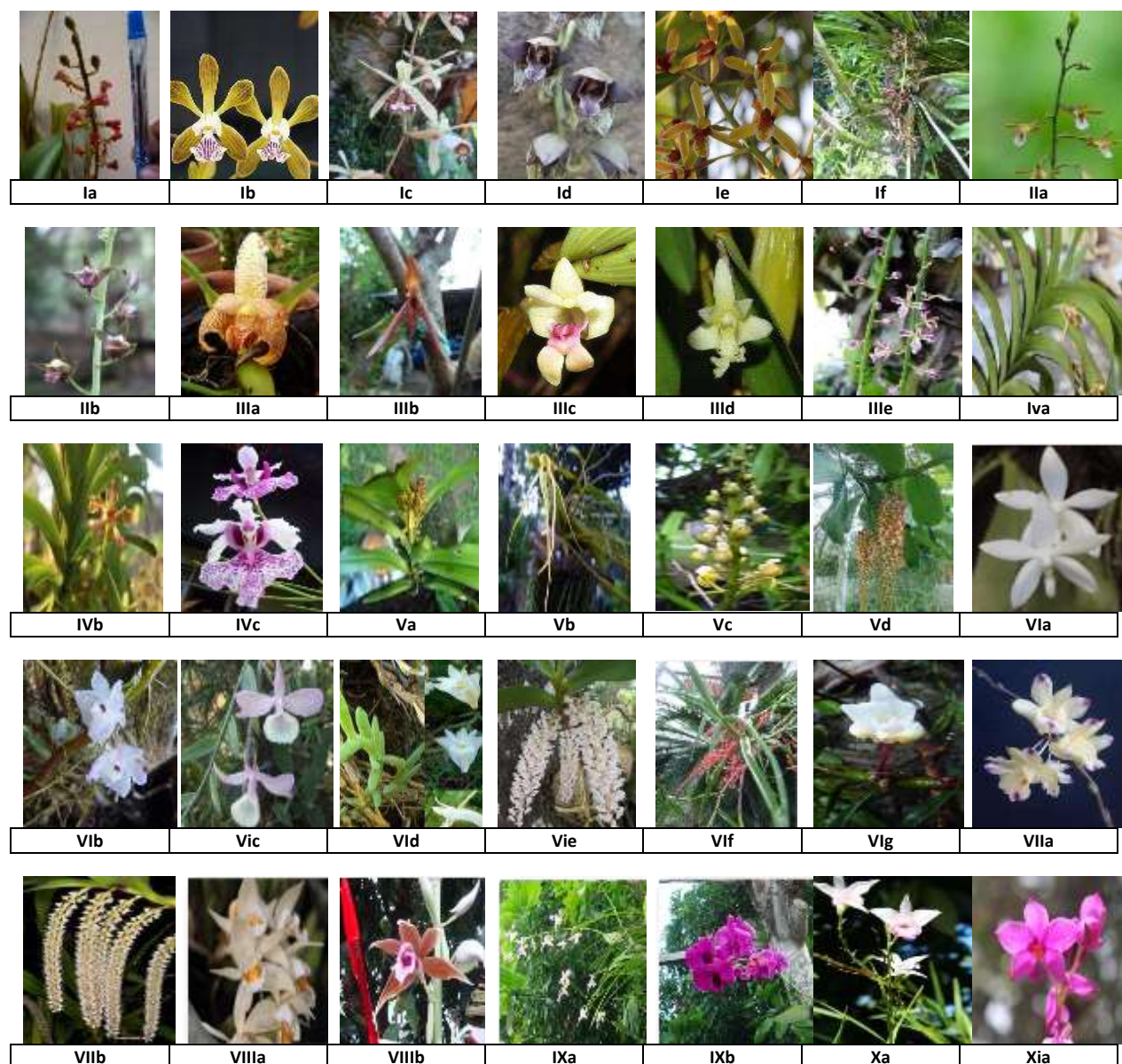


Figure 2. Bengkulu natural orchid diversity in group I. Ia. *Liparis latifolia*, Ib. *Encyclia* sp., Ic. *Coelogyne pulverula*, Id. *Grammatophyllum stapeliiflorum*, Ie. *C. chloranthum*, If. *C. bicolor*. Group II. IIa: *Eulophia graminea* and IIb. *Eulophia spectabilis*. Group III. IIIa. *B. claptonense* and IIIb. *Bulbophyllum* sp., IIIc. *Flickingeria trilamellata* and IIId. *Flickingeria* sp., and IIIe. *Acriopsis* (*A. liliifolia*). Group IV: Iva: *Vanda* sp.1 and IVb. *Vanda* sp.2, and IVc. *Papilionanthe hookeriana*. Group V: Va. *Pomatocalpa latifolia*, Vb. *Thrixspermum* sp., Vc. *Micropera callosa*, and Vd. *Robiquetia spathulata*. Group VI: VIa. *Phalaenopsis tetraspis*, VIb. *Dendrobium linguella*, Vic *D. aphyllum*, and Vid. *Dendrobium* sp.3, Vie. *Eria palmifolia*, VIf. *Porphyrodesme* sp., and VIg. *Cylindrolobus mucronatus*. Group VII: VIIa. *Dendrobium sanguinolentum* and VIIb. *Eria* sp. Group VIII: VIIa. *Coelogyne asperata* and VIIb. *Phaius tankervilleae*. Group IX: IXa. *Dendrobium* sp.1 and IXb. *Dendrobium* sp.2. Group X: *Arundina graminifolia* and XI. *S. Plicata*.

flowering, i.e., one flower on each stalk. The accessions *B. claptonense* and *Bulbophyllum* sp. had a morphological similarity of 54%. The plants were small and of sympodial type. Flower stalk growth at the base of the stem, leaf growth at the tip of the stem, and the stem create one bulb, with attached root and pointed leaf tip. Furthermore, they have single inflorescent flower, starflower, sepal and petal lanceolate, sepal tip and petal taper, simple lip callus type, with no flower spur.

Hsu and Chung (2008) characterized two new species of *Bulbophyllum* in Taiwan by having attached roots, stems in the form of bulbs, one segment oval/ovoid, semi-erect, stalks growing at the base of the stem, single leaf at the end of the stem, oblong leaf shape, and blunt leaf tips. The accessions *Flickingeria trilamellata* and *Flickingeria* sp. revealed a relatively high level of similarity (72%). The two orchids of these species look slightly different by stem and leaf morphology. However, they were highly similar in shape and color, i.e., short flower stalks, single-flowered, non-resupinate, dorsal sepals, laterally ovate/oval, and oval-shaped petals. The sepal tips, pointed petals, and flowers do not have spurs. Overall, the genus *Flickingeria* characteristics include branches on each bulb, growing creeping/dangling, a single leaf on each bulb, ribbon, and oval leaf shape. Short flower stalks and the flower blooming period was only one day (Shu *et al.*, 2009c, d).

Group IV had a similarity of 43%, comprising three orchid species belonging to two genera, namely, *Vanda* (*Vanda* sp.1 and *Vanda* sp.2) and *Papilionanthe* (*P. hookeriana*). However, the *Vanda* sp.1 and *P. hookeriana* have a similarity of 62% (Figures 1 and 2). The likeness of these two orchids was in the root, stem, and leaf morphology. However, the *P. hookeriana* has a smaller size. Both orchids have soil and aerial roots that were silver. The orchid stems have a round cross-section. The leaf growth alternates on the stem, the cross-section of the leaf shapes as a pencil because the leaf shape of these two orchids appears like a dark green pencil at the first glance. It resembles like a stem, the stalk growth was on the side of the stem, and the flower stalk was of a bunch type. Li *et al.* (2016) stated orchid

species *P. hookeriana* and *P. teres* belonged to one cluster; although, both still belonged to the *Vanda* tribe.

Group V consisted of four species belonging to different genera, i.e., *Pomatocalpa latifolia*, *Thrixspermum* sp., *Micropera callosa*, and *Robiquetia spathulata* (Figure 2). The morphological characteristics (including roots, stems, and leaves) of these four orchid species have the similarity coefficient of 43%. These four orchids have medium plant size, hard woody stems, and a flower stalk growth type in leaf axils, attached aerial roots with no root hairs, round root cross-section, alternating leaf growth, and conduplicate leaf cross-section. Lok *et al.* (2010) and Shu *et al.* (2009b, c) stated the general characteristics of the genera *Pomatocalpa*, *Thrixspermum*, and *Robiquetia* were notable with linear leaves, flower stalks in leaf axils, non-resupinate flowers, small flower size, and the number of pollinia is two. *P. latifolia* and *Thrixspermum* sp. have a similarity of 52%. Additionally, these two orchid species have some other resemblances, i.e., semi-erect stems, dorsal sepals, lateral sepals, and flower petals were in linear/ribbon form. At a similarity coefficient of 47%, the species were *M. callosa* and *R. spathulata*. These species have more likeness, including creeping stems, small flowers, oblong lateral sepals, blunt sepal tips, and side plates on the labellum. Hidayat *et al.* (2012) reported the phylogeny of *Aeridinae* (Orchidaceae) based on DNA sequences stated the *Pelatantheria*, *Thrixspermum*, *Trichoglottis*, *Acampa*, and *Pomatocalpa* groups belonged to the third group, with a similarity of 68%.

In group VI, there are seven orchid species belonging to five different genera, with a similarity coefficient of 41% (Figures 1 and 2). The five genera and their seven species were *Phalaenopsis* (*Phalaenopsis tetraspis*), *Dendrobium* (*D. linguella*, *D. aphyllum*, and *Dendrobium* sp.3), *Eria* (*E. palmifolia*), *Porphyrodesme* (*Porphyrodesme* sp.), and *Cylindrolobus* (*C. mucronatus*). *E. palmifolia* and *Dendrobium* sp.3 had a similarity of 52%, while the species *Dendrobium aphyllum* and *D. linguella* had a similarity of 45% with the two accessions *E. palmifolia* and *Dendrobium* sp.3,

and both were sympodial. The attached and aerial roots also showed no root hairs, and the root cross-section was round. The stem was pseudobulb with segments, leaf growth alternates, the leaves were lanceolate, leaf tips were pointed and symmetrical, and the leaf edges were intact. De (2020) reported in *Dendrobium aphyllum* the leaf morphology was lanceolate, and the leaf surface texture was bald.

Moreover, both accessions have almost the same flower shape in white, the sepals, and petals tips were sharp, the callus was simple with no spurs and side pieces, and the polynias are two. At a similarity level of 48%, two accessions of orchid species *Porphyrodesme* sp. and *C. mucronatus* had almost the same stem and leaf morphology. Both species have small stem sizes, flower stalk growth in leaf axils, dangling plants, alternating leaves, reddish-brown root tip, yellowish-gray root base, sticky and aerial roots with no hairs, and round root cross-section. Leaf cross-section was double, leaf tip symmetrical, needle leaf shape, leaf tip shape, and leaf edge sticking out. Non-resupinate starflower, sepal and petal tips pointed, no spurs, lip side lobe, lip side lobe side pieces, with two polynias. Agrawala and Ormerod (2014) reported the finding of a new *Cylindrolobus* species in India. According to Besi et al. (2019), *C. mucronatus* is an epiphytic orchid discovered in the Malaysian Peninsula.

Dendrogram represented Group VII by two orchid species *Dendrobium sanguinolentum* and *Eria* sp., belonging to two different genera, with a similarity level of 47% (Figures 1 and 2). In addition to the relationship with different genera, the morphology of both orchid species was different. However, the similarities include the type of sympodial growth, medium plant size, semi-erect stem, alternating leaves, semi-erect flower stalk, and stems in the form of segmented bulbs. More than two tillers appear, attached roots, round transverse slices, lanceolate leaves, pointed leaf tips, symmetrical, intact margins, bald leaf texture, and green shade. Flowers were in bunches and non-resupinate, oval dorsal and lateral sepals,

sepals with sharp tips, lip side lobe, side pieces, and no flower spurs. Zed et al. (2020) also reported species *D. sanguinolentum* was predominant in the protected forest of Gunung Raya, Temajuk village, Sambas Regency, Kalimantan, Indonesia.

Group VIII contained two terrestrial orchid species *Coelogyne asperata* and *Phaius tankervilleae*, belonging to different genera, with a similarity level of 47% (Figure 2). The similarities occurred in sympodial growth type, large plant size, erect stem, symmetrical leaf tips, long oblong leaf shape, curving leaf edges, intact leaf surface texture, considerable leaf size, type of flower bunches, non-resupinate flowers, starflower shape, lateral lanceolate sepal shape, simple flower lip callus type with side pieces, large wide-open flowers, and oval fat fruit. Deswiniyanti and Lestari (2017) disclosed orchid species *C. asperata* is native to Kalimantan, Indonesia. Orchid species *P. montanus*, *P. tankervilleae*, and *P. amboinensis* have also exhibited a strong resemblance (80%) with each other (Hartati et al., 2021; Sukma et al., 2021).

Two accessions of orchid species belonging to the genus *Dendrobium* (*Dendrobium* sp.1 and *Dendrobium* sp.2) clustered in group IX, with a similarity level of 63% (Figures 1 and 2). The stem and leaf morphological traits were very similar in these two species. Although, their flowers are different. According to Widiastoety et al. (2010), the genus *Dendrobium* was the largest globally, hence, with great diversity, especially in flower shapes, colors, and patterns. Both species were sympodial and large. They have semi-erect stems, with alternating leaf, segmented pseudobulb, with more than two tillers. Root attached and aerial, round root cross-section with no root hairs. Leaf cross-section is conduplicate and lanceolate. Pointed leaf tips were not symmetrical, leaf edge intact, irregular leaf surface texture, with a light green shoot. Flowers were in a bunch and resupinate type, and callus protrusion type lamellate. Flower lips/plates, flowers have spurs, two pollinia numbers, and no petal patterns; flower has a lip side lobe, with two open colors extensively. Lokho and Kumar (2012) characterized *Dendrobium* as a fleshy

pseudobulb. The leaves grow alternately on the pseudobulb internodes, and the leaf shape was generally lanceolate and oblong.

Only one terrestrial orchid species is in group X, namely, *Arundina graminifolia* (Figure 2). This orchid was often called a bamboo orchid because of the stems and leaves' morphology resembling a bamboo. *A. graminifolia* has a height of up to 1.6 m and has ground roots, leaves grow alternately on the stem, and leaf shape was linear, with pointed leaf tips and sharp edges. The flower stalk grows at the tip of the stem, in panicle non-resupinate with pink starflowers. Dorsal and lateral sepal lanceolate, sepal tip mucronate/shallow, petal oval, and center flank shape with lobed edges. Musa *et al.* (2013) also mentioned in his findings the species *A. graminifolia* characteristics were terrestrial, linear leaves, and labellum margin wavy.

Group XI comprised one species, *S. plicata*. The species *S. plicata* occupied a separate cluster fork from other accessions, especially the accessions of soil orchids, i.e., *E. graminea*, *E. spectabilis*, *P. tankervilleae*, and *A. graminifolia* (Figure 2). *S. plicata* has a sympodial growth type, corm-shaped stem, long oval-shaped leaves, and folded leaf cross-section. The stalk's growth type was at the base of the stem, the flower shape was round (sepals and petals overlap), the sepals were oblong, and the petals were oval with a pointed tip. The general characteristics of species *S. plicata* include sympodial growth type, cormus stem shape, long leaves, and tapered leaf tips with sharp edges. Flowers appear at the base of the stem, and the flowering type was racemose (Kartikaningrum and Effendi, 2005; Aziz *et al.*, 2016). The said morphological characterization was essential for orchid conservation both in-situ, ex-situ, and via in vitro (Ganefianti *et al.*, 2023). Natural orchids can benefit as a source of germplasm for the development of commercial orchids with unique characteristics (Prayoga *et al.*, 2022; Sophia *et al.*, 2024).

CONCLUSIONS

The 68 morphological characters were evident in 35 accessions of orchid species, which also produced 595 polymorphic (99.66%) and two monomorphic (0.34%) sub-characters. The similarity coefficient between Bengkulu natural orchid species ranges from 0.30 to 0.80. Overall, the 11 groups of 35 accessions of orchid species have a 40% similarity coefficient. Species *Flickingeria trilamellata* and *Flickingeria* sp. have the highest similarity coefficient (72%). The value of the goodness of fit correlation matrix (r) of morphological markers was $r = 0.84$. The promising results can help in organizing the groups of orchid species based on morphological characterization.

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REFERENCES

- Agrawala DK, Ormerod P (2014). A new species of *Eria* (Orchidaceae) from India under the section *Cylindrolobus*. *Taiwania*. 59(3): 206-209.
- Aziz SA, Azmi TKK, Sukma D, Qonitah FZ (2016). Morphological characters of triploids and tetraploids produced by colchicine on buds and flowers of *Phalaenopsis amabilis*. *SABRAO J. Breed. Genet.* 48(3): 352-358.
- Beltrán-Nambo MA, Larrocea PO, Garciglia RS, Ospina JTO, Trujillo MM, Carreón-Abud Y (2012). Distribution and abundance of terrestrial orchids of the genus *Bletia* in sites with different degrees of disturbance in the Cupatitzio Natural Reserve, Mexico. *Int. J. Biodivers. Conserv.* 4(8): 316-325.
- Besi EE, Nikong D, Mustafa M, Go R (2019). Orchid diversity in anthropogenic-induced degraded tropical rainforest, an extrapolation towards conservation. *Lankesteriana* 19(2): 107-124.

- Budiharta S, Widyatmoko D, Wiriadinata H, Partomihardjo T, Uji T, Keim AP, Wilson KA (2011). The processes that threaten Indonesian plants. *Oryx* 45(02): 172-179.
- Cameron KM, Chase MW, Whitten WM, Kores PJ, Jarrell DC, Albert VA, Yukawa T, Hills HG, Goldman DH (2009). A phylogenetic analysis of the Orchidaceae: Evidence from *RBCL* nucleotide sequences. *Am. J. Bot.* 86(2): 208-224.
- Comber JB (2001). Orchids of Sumatra. The Royal Botanic Gardens. England.
- Da-Costa E (2016). Global E-Commerce Strategies for Small Businesses. Mit Press, Massachusetts.
- De LC (2020). Morphological diversity in orchids. *Int. J. Bot. Stud.* 5(5): 229-238.
- Deswiniyanti NW, Lestari NKD (2017). Persilangan Interspesifik Anggrek Hitam (*Coelogyne pandurata*) Dengan Anggrek Mutiara (*Coelogyne asperata*). *Metamorfosa: J. Biol. Sci.* 4(1):102.
- Fatt CT, Astley D (2012). The Essential Guide to Growing Orchids in the Tropics. Marshall Cavendish International (Asia) Ltd., Singapore.
- Fay MF (2015). Undocumented trade in species of Orchidaceae. Convention on International Trade in Endangered Species of Wild Fauna and Flora. Twenty-second meeting of the Plants Committee Tbilisi (Georgia), October 19-23, 2015. PC22 Inf. 6.
- Ferdiani DI, Devi FL, Koentjana JP, Milasari AF, Nur'aini I, Semiarti E (2015). Molecular characterization of natural orchids in South slopes of Mount Merapi, Sleman regency, Yogyakarta. In *AIP Conference Proceedings*. 1677(1). AIP Publishing.
- Ganefianti DW, Romeida A, Herawati R, Sundari EP (2023). Anggrek Alam Bengkulu. Badan Penerbitan Fakultas Pertanian.
- Hartati S, Samanhudi S, Manurung IR, Cahyono O (2021). Morphological characteristics of *Phaius* spp. orchids from Indonesia. *Biodiversitas* 22(4): 1991-1995.
- Hidayat T, Weston PH, Yukawa T, Rice R (2012). Phylogeny of subtribe Aeridinae (Orchidaceae) inferred from DNA sequences data: Advanced analyses including Australasian genera. *J. Teknol.* 59: 87-95.
- Hinsley A, Verissimo D, Roberts DL (2015). Heterogeneity in consumer preferences for orchids in international trade and the potential for market research methods to study the demand for wildlife. *Biol. Conserv.* 190: 80-86.
- Hsu TC, Chung SW (2008). Two new *Bulbophyllum* species in Taiwan: *B. brevipedunculatum* and *B. ciliisepalum*. *Taiwania* 53(1): 23-29.
- Jatmika YN (2013). Tanaman-tanaman hias ajaib untuk kecantikan dan kesehatan. PT. Buku Biru, Yogyakarta.
- Kartikaningrum S, Effendie K (2005). Keragaman genetik plasma nutfah anggrek *Spathoglottis*. *J. Hort.* 15(4): 260-269.
- Khasim SM, Ramesh G (2010). Molecular and morphological studies in *Vanda tessellata*, an Epiphytic Orchid from the Eastern Ghats of India. In *International Orchid Symposium* 878, pp. 63-70.
- Li MH, Zhang GQ, Lan SR, Liu ZJ (2016). China Phylogeny Consortium, A molecular phylogeny of Chinese orchids. *J. Syst. Evol.* 54(4): 349-362.
- Lok AFSL, Ang WF, Tan HTW (2010). The status and distribution in Singapore of *Pomatocalpa diffusum* Breda. *Nat. Singap.* 3: 147-152.
- Lokho A, Kumar Y (2012). Reproductive phenology and morphological analysis of Indian *Dendrobium* Sw. (Orchidaceae) from the northeast region. *Int. J. Sci. Res.* 2(9): 1-14.
- Mahyar UW, Sumaadmadja G, Sulaeman E, Waluyo EB, Sunaryo (1997). Anggrek alam Bengkulu. Proyek Penelitian, Pengembangan, dan Pendayagunaan Potensi Wilayah. Puslitbang Biologi – LIPI, Bogor.
- Mujaffar S, Mishra S, Deoda VS, Moinuddin S, Mustakim S (2013). Orchid species diversity of East Nimar, Madhya Pradesh, India. *Int. J. Plant Anim. Environ. Sci.* 3(4): 222-230.
- Musa FF, Syamsuardi, Arbain A (2013). Keanekaragaman jenis Orchidaceae (Anggrek-anggrekan) di kawasan hutan lindung Gunung Talang Sumatera Barat. *J. Biol. U.A.* 2(2): 153-160.
- Oliveira VDC, Sajo MDG (1999). Root anatomy of nine Orchidaceae species. *Braz. Arch. Biol. Technol.* 42(4): <https://doi.org/10.1590/S1516-89131999000400005>.
- Ornamental Plant Research Institute (2007). Panduan Karakterisasi Tanaman Hias Anggrek. Departemen Pertanian.
- Phelps J (2015). A Blooming Trade: Illegal Trade of Ornamental Orchids in mainland Southeast Asia (Thailand, Lao PDR, Myanmar). TRAFFIC. Petaling Jaya, Selangor, Malaysia.
- Phelps J, Webb EL (2015). Invisible wildlife trades: Southeast Asia's undocumented illegal trade in wild ornamental plants. *Biol. Conserv.* 186: 296-305.

- Prayoga GI, Henri, Mustikarini ED, Anggyansyah (2022). Diversity and morphological relationship of orchid species (Orchidaceae) in Bangka Island, Indonesia. *Biodiversitas* 23(10): 5323-5332.
- Rohlf FJ (2000). Statistical power comparisons among alternative morphometric methods. *Am. J. Phys. Anthropol.* 111:463-478.
- Seidenfaden G, Wood JJ (1992). The Orchids of Peninsular Malaysia and Singapore. Olsen & Olsen. Denmark.
- Shu JSH, Xinqi C, Wood JJ (2009a). 140. *Flickingeria* A. D. Hawkes, Orchid Weekly 2: 451. 1961. *Flora of China* 25: 397-400.
- Shu JSH, Xinqi C, Wood JJ (2009b). 168. *Thrixspermum* Loureiro, Fl. Cochinch. 2: 516, 519. 1790. *Flora of China* 25: 466-470.
- Shu JSH, Xinqi C, Wood JJ (2009c). 173. *Robiquetia* Gaudichaud, Voy. Uranie, Bot. 426. 1829. *Flora of China* 25: 475-476.
- Shu MGL, Xinqi C, Cribb PJ, Gale SW (2009d). 89. *Eulophia* R. Brown, Bot. Reg. 7: ad t. 573 [578]. 1821 [*Eulophus*], nom. cons. *Flora of China* 25: 253-258.
- Siripiyasing P, Kaenratana K, Mokkanul P, Tanee T, Sudmoon R, Chaveerach A (2012). DNA barcoding of the *Cymbidium* species (Orchidaceae) in Thailand. *Afr. J. Agric. Res.* 7(3): 393-404.
- Sophia, Sukma D, Purwoko BS, Dinarti D, Sukmadjaja D, Sanjaya IPW (2024). Flow cytometry analysis reveals nuclear DNA content variation in *Phalaenopsis* young leaf and root tip cells. *SABRAO J. Breed. Genet.* 56(4): 1410-1423. <http://doi.org/10.54910/sabrao2024.56.4.8>.
- Subedi A, Kunwar B, Choi Y, Dai Y, Van Andel T, Chaudhary RP, de-Boer HJ, Gravendeel B (2013). Collection and trade of wild-harvested orchids in Nepal. *J. Ethnobiol. Ethnomed.* 9(64): 1-10.
- Sukma D, Elina J, Raynalta E, Aisyah SI, Aziz SA, Sudarsono, Chan MT (2021). Analysis of the genetic diversity of *Phalaenopsis* orchids with single nucleotide polymorphisms and snap markers derived from the Pto gene. *SABRAO J. Breed. Genet.* 53(4): 620-631. <https://doi.org/10.54910/sabrao2021.53.4.6>.
- Vermeulen JJ, Lamb A (2011). Endangered even before formally described: *Bulbophyllum kubahense* n. sp., a beautiful and assumedly narrowly endemic orchid from Borneo. *Plant Syst. Evol.* 292(1-2): 51-53.
- Wahba LE, Hazlina N, Fadelah A, Ratnam W (2014). Genetic relatedness among *Dendrobium* (Orchidaceae) species and hybrids using morphological and AFLP markers. *HortSci.* 49(5): 524-530.
- Widiastoety D, Solvia N, Soedarjo M (2010). Potensi anggrek *Dendrobium* dalam meningkatkan variasi dan kualitas anggrek bunga potong. *J. Litbang. Pert.* 29(3): 101-106.
- Zed AN, Listiawati A, Rahmadiyah R (2020). Inventarisasi Anggrek Alam di Hutan Lindung Gunung Raya Desa Temajuk Kecamatan Paloh Kabupaten Sambas. *J. Sains Pert. Equator.* 9(2): 1-12.