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Assessment of genetic parameters and heritability of *Dendrobium* species section *Spatulata* native to Indonesia

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Abstract: Being one of the most abundant genera of orchids, *Dendrobium* presents a valuable genetic resource for hybridization programs. Morphological characterization and assessment of genetic parameters plays a crucial role in establishing genetic connections among orchid species within the same genus. The study aims to discern the morphological traits of five Indonesian *Dendrobium* species, intending to evaluate their potential as candidates for crossbreeding programs. The materials used in this study were *D. antennatum, D. discolor, D. stratiotes, D. lineale, D. gouldii,* and *D. sylvanum*. This research examines 21 quantitative traits and 21 qualitative morphological traits of the studied *Dendrobium*. The findings reveal variations in characters related to flowers, leaves, and pseudobulbs. The analysis of genetic parameters indicates the presence of genetic diversity in traits such as flower stalk length, length of inflorescence, flower series length, flower length, flower width, dorsal sepal width, lateral sepal width, petal length, petal width, labellum length, labellum width, and the number of florets. All observed traits demonstrate high heritability. So, the characters that have high genetic variability and heritability are valuable in selection criteria for plant breeding.

1. Introduction

Indonesia possesses abundant biodiversity, encompassing a variety of orchids. Out of the approximately 30,000 orchid species worldwide, around 5,000 are present in Indonesia, distributed across diverse regions, with certain species being endemic to the country (Puspitaningtyas, 2020). *Dendrobium* as the most plentiful genus of orchids globally, boasting approximately 1,600 species and holding the title of the largest genus within the Orchidaceae family. The collective number of hybrids, derived from both natural variations and crossbreeding, exceeds 20,000 and encompasses single and multi-genera varieties (Hartati *et al*., 2021). Indonesia also known for hosting a significant variety of *Dendrobium*

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orchids, contributing to the overall diversity of orchid species in the region (Rahayu and Yusri, 2022).

Schuiteman (2012) has identified 20 sections of *Dendrobium*, and one of these is the *Spatulata* section. The *Spatulata* species within the section display significant diversity in flower characters, encompassing variations in colors, labellum shapes and colors, horn shapes and colors, as well as the duration of flower bloom shelf life. Therefore, it is essential to assess the genetic variation of these species to offer fundamental genetic insights and facilitate genetic enhancements within the *Spatulata* orchid section (Purwantoro *et al.*, 2023). To discern the variations among species, it is essential to employ a characterization method. Utilizing morphological features such as leaves, stems, tubers, fruits, and roots for characterization is anticipated to facilitate the identification and understanding of the specific utility of these characterized plants (De *et al*., 2015). Observing morphological characters is visually straightforward, allowing for a swift assessment of their diversity in comparison to other traits. Furthermore, employing morphological characterization proves valuable in evaluating the relationships among orchids, which is crucial for conservation initiatives and enhances the practicality of plant genetic resources (Vo *et al*., 2015). While the assessment of genetic relationships through morphological characters can be significantly affected by environmental factors, it remains essential to thoroughly characterize these traits. This thorough characterization is necessary to ease the utilization of germplasm by breeders (Aloysius *et al*., 2017).

The characterization of plants plays a crucial role in evaluating the genetic proximity between orchid species within the same genus, influencing the effectiveness of plant crossbreeding. A more intimate genetic connection enhances the likelihood of successful crosses. This characterization serves not only to craft plant descriptions but also to ascertain the genetic relationships among different species (Mursyidin *et al*., 2021). In genetics studies of quantitative traits, the primary role of heritability lies in its predictive function, indicating the dependability of phenotypic value as a predictor of breeding value (Ponzi *et al*., 2018). Genetic variability in plant breeding refers to the range of genetic differences or variations that exist among individuals within a population of plants. It is a key concept in plant breeding because this variability is the raw material that plant breeders work with to develop new and improved crop varieties (Yani *et al*., 2018). By assessing genetic variability, plant breeders can identify traits that exhibit variation within a population. This information is crucial for selecting traits that are desirable and heritable, meaning they can be passed on to future generations (Wirasti and Purwantoro, 2018). Traits with high heritability are more likely to respond positively to selection, making them prime candidates for improvement through breeding (George *et al*., 2020). The objective of this research is to characterize the *Dendrobium* section *Spatulata* orchid from Indonesia and investigate its genetic diversity and heritability as part of a plant breeding initiative.

2. Materials and Methods

Experimental location

The research was carried out in Banjarsari village, Sumbang District, Banyumas Regency, Central Java Province, Indonesia 7.3576° S, 109.2445° E. The research was carried out from March to June 2023.

Experimental materials

The characterization was conducted on the following *Dendrobium* orchids: *D. antennatum, D. discolor, D. stratiotes, D. lineale, D. gouldii*, and *D. sylvanum.* These plants were sourced from farmers and orchid collectors in Indonesia, and they represent mature specimens in the flowering stage. A total of three plants per species were analyzed. The tools used are digital calipers, rulers, digital single-lens reflex (DSLR) cameras, and writing instruments.

Cultivation methods

Dendrobium was cultivated in a screen house with 50% shade. Air temperature at daytime temperature around 27-32°C and nighttime temperature around 22-25°C, and humidity levels between 50-80%. Plants are watered once a day or according to plant needs. If the media humidity is still high, the plants can be watered every two days. The medium used for cultivation is charcoal. Fertilization is carried out once a week with NPK 20:20:20 fertilizer with follicular application. Regularly inspect *Dendrobium* orchids for pests. Additionally, monitor the orchids for signs of fungal or bacterial diseases and take necessary precautions to prevent spread.

Characterization procedure

The characterization procedure is based on the

Orchid Characterization Guidelines published by the Indonesian Ornamental Plant Research Institute which was adapted from the *Dendrobium* Characterization Guidelines by the International Union for the Protection of New Varieties of Plants (UPOV). Variables observed and analyzed were nature of stem, leaf shape, apexes of leaf, apexes of dorsal sepal, apex of lateral sepal, apex of petal, petal curvature, lip shape, lip margin, dorsal sepal shape, lateral sepal shape, petal shape, dorsal sepal cross section, lateral sepal cross section, petal cross section, lip overlapping of basal part, lip shape of lateral lobe, lip shape of apical lobe, lip type of curving, lip shape of eye, color of anther cap; plant height (cm), pseudobulb diameter (cm), internode length (cm), leaf length (cm), leaf width (cm), leaf area (cm^2), peduncle-ovary length (cm), length of inflorescence (cm), length of flower arrangement (cm), leaf thickness (mm), flower length (cm), flower width (cm), dorsal sepal length (cm), dorsal sepal width (cm), lateral sepal length (cm), lateral sepal width (cm), petal length (cm), petal width (cm), labellum length (cm), labellum width (cm), number of flowers per spike. The tools used are digital calipers, rulers, digital single-lens reflex (DSLR) cameras, and writing instruments.

Statistical analysis

To evaluate the performance of observed traits, conducted a variance analysis. The estimation of genetic parameters such as Coefficient of Genetic Varibility (CGV), Coefficient of Phenotypic Variability (CPV) and Heritability followed Jambormias (2014) steps.

3. Results

Dendrobium species origin

*Dendrobium antennatum*is native to Papua (Indonesia) (Table 1, Fig. 1). These orchids thrive on tall tree branches within coastal forests, mangrove swamps, and rainforests, typically below 1200 meters in elevation.

Dendrobium discolor var. *Tanimbar* is native to the Tanimbar Islands. It thrives in warm to hot climates, growing both as an epiphyte and a lithophyte. It can be found in various habitats, including mangrove forests along the coast, behind sand dunes where it may experience salt spray, as well as on cliffs and rock faces up to an elevation of 550 meters.

Dendrobium stratiotes is native to the Moluccas (including Halmahera and Morotai), the Sunda Islands, and Sulawesi, this orchid thrives at lower elevations. It typically grows as a medium to large-sized epiphyte, preferring warm to hot conditions, often forming clustered groups.

Dendrobium lineale is native to Papua, this orchid species grows as a large to giant-sized plant, thriving in warm to hot climates as either an epiphyte or

Table 1 - *Dendrobium* species used in the study

Name of germplasm	Source of germplasm
Dendrobium antennatum	Papua
Dendrobium discolor var. Tanimbar	Tanimbar Island, Maluku
Dendrobium stratiotes	Western Papua, the Moluccas (Halmaheira and Morotai), the Sunda Islands and Sulawesi
Dendrobium lineale	Papua
Dendrobium gouldii	Papua
Dendrobium sylvanum	Papua, New Guinea

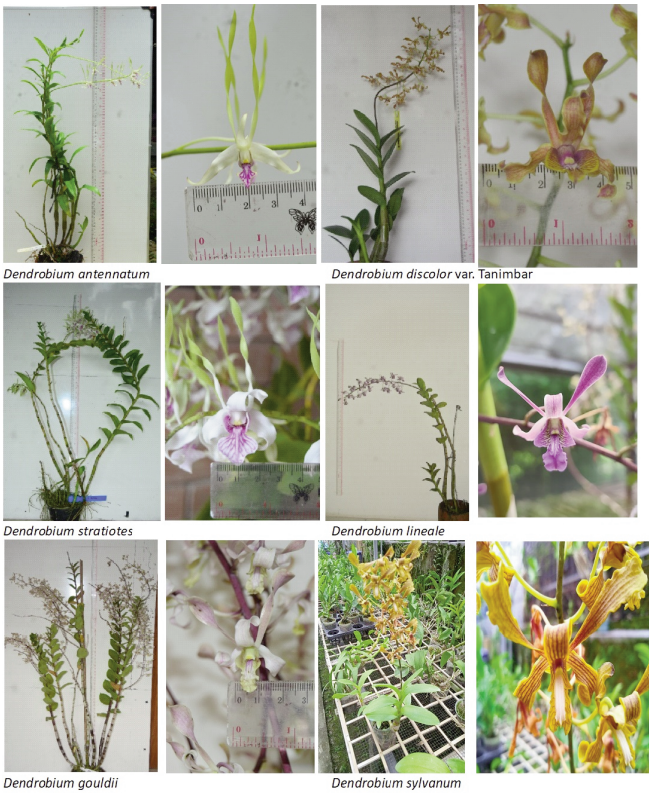

Fig. 1 - Six species of *Dendrobium* section *Spatulata* native to Indonesia studied.

lithophyte. It is typically found at elevations of up to 800 meters, often near streams and coastal areas.

Dendrobium gouldii is native to Papua. This orchid species grows as a large to giant-sized plant, thriving in warm to hot climates as either an epiphyte or lithophyte. It can be found in riverine forests, coastal forests, swamp forests, beaches, and plantations, typically at altitudes ranging from sea level to 700 meters.

Dendrobium sylvanum is native to Papua New Guinea in lowland areas, this orchid species grows as a large to giant-sized epiphyte, thriving in warm climates.

Morphological characters

Most diversity was found in the characters of leaves (leaf shape, apexes of leaf), pseudobulb (nature of stem), flowers (apexes of dorsal sepal, apex of lateral sepal, apex of petal, petal curvature, lip shape, lip margin, dorsal sepal cross-section, lateral sepal cross-section, petal cross-section, lip overlapping of basal part, lip shape of lateral lobe, lip shape of apical lobe, lip type of curving, and lip shape of eye) (Table 2).

Flowers

In this study, all the flower parts of *Dendrobium* that were observed had diverse characters, even though they were still in one section, namely the *Spatulata* section. The section *Spatulata* includes several species known for their characteristic flattened or spatula-shaped lip petals. This diversity shows differences in the shape of the petals, dorsal sepals, lateral sepals and labellum.

The Spatulata section's characters are the dorsal, lateral sepal and petal shapes were categorized as narrow elliptic. However, there is diversity in petal curvature, namely, *D. antennatum* and *D. statiotes* exhibit a spiral pattern. Conversely, in *D. discolor, D. gouldii,* and *D. sylvanum,* the curvature is deflexed, while in *D. lineale*, it remains straight.

The diversity in the labellum lies in the lip shape of the lateral lobe, namely in *D. antennatum, D. sylvanum*, and *D. lineale* it is triangular, while in *D. discolor* it is broadly trapezoidal, and in *D. gouldii* and *D. stratiotes* it is ovate. Variability is also found in the lip shape of the apical lobe, namely in *D. antennatum, D. stratiotes, D. discolor, D. gouldii* it is rhombic, while in *D. lineale* it is reniform, and in *D.*

Table 2 - Qualitative characters of *Dendrobium* studied

No.	Characters	*D. antennatum*	*D. discolor*	*D. stratiotes*	*D. lineale*	*D. gouldii*	*D. sylvanum*
1	Nature of stem	Cane cylindric	Cane cylindric	Cane	Cane cylindric	Cane cylindric	Cane cylindric
2	Leaf shape	Lenceolate	Lanceolate	Lanceolate	Elliptic	Ovate	Lanceolate
3	Apexes of leaf	Acute	Obtuse	Acute	Acute	Acute	Obtuse
4	Apexes of dorsal sepal	Acuminate	Obtuse	Acuminate	Acute	Obtuse	Obtuse
5	Apex of lateral sepal	Acuminate	Obtuse	Acuminate	Acute	Obtuse	Obtuse
6	Apex of petal	Acuminate	Obtuse	Acuminate	Acute	Obtuse	Obtuse
7	Petal curvature	Spiral	Deflexed	Spiral	Straight	Deflexed	Deflexed
8	Lip shape	Ovate	Undulate	Ovate	Ovate	Oblong	Obovate
9	Lip margin	Entire	Undulate	Entire	Undulate	Undulate	Undulate
10	Dorsal sepal shape	Narrow elliptic	Narrow elliptic	Narrow elliptic	Narrow elliptic	Narrow elliptic	Narrow elliptic
11	Lateral sepal shape	Narrow elliptic	Narrow elliptic	Narrow elliptic	Narrow elliptic	Narrow elliptic	Narrow elliptic
12	Petal shape	Narrow elliptic	Narrow elliptic	Narrow elliptic	Narrow elliptic	Narrow elliptic	Narrow elliptic
13	Dorsal sepal cross section	Narrow elliptic	Moderately convex	Strongly concave	Strongly concave	Strongly concave	Moderately convex
14	Lateral sepal cross section	Narrow elliptic	Moderately convex	Strongly concave	Strongly concave	Strongly concave	Flat
15	Petal cross section	Narrow elliptic	Straight	Strongly concave	Strongly concave	Strongly concave	Moderately concave
16	Lip overlapping of basal part	Present	Absent	Present	Present	Absent	Absent
17	Lip shape of lateral lobe	Tringular	Broad trapezoid	Ovate	Tringular	Ovate	Triangular
18	Lip shape of apical lobe	Rhombic	Rhombic	Rhombic	Reniform	Rhombic	Elliptic
19	Lip type of curving	Type I	Type 1	Type 1	Type I	Type VI	Type IV
20	Lip shape of eye	Type I	Type 1	Type 1	Type I	Type II	Type I
21	Color of anther cap	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow

*sylvanum*it is elliptic (Table 2).

There was diversity in the quantitative flower parameters observed (Table 3). The length of the flowers in *D. sylvanum* is smaller compared to other species, measuring only 2.36 cm, but the width of the flowers reaches 5.00 cm. This indicates that the petals and sepals extend outward. This flower type is also similar to *D. gouldii*, characterized by a length of 3.43 cm and a width of 5.26 cm. *D. antennatum* and *D. stratiotes* have petal shapes resembling antlers, resulting in a longer length than width. Besides that, in *D. antennatum*, the length is 4.75 cm, and the width is 2.15 cm. For *D. discolor* and *D. lineale*, the proportions of flower length and width are more or less the same. The flower size of *Dendrobium* studied showed that *D. stratiotes* had the largest flower length, namely 9.33 cm compared to other species. This is related to the longer petals on *D stratiotes*, namely 6.23 cm. Besides that, in *D. discolor*, the length is 4.50 cm, and the width is 4.00 cm. In *D. lineale*, the length is 5.15 cm, and the width is 6.16 cm.

Leaves

Leaves characterization included leaf shape, apexes of leaf, leaf length (cm), leaf width (cm), and leaf area (cm^2). The variability in the leaf shape of *Dendrobium* was *D. antennatum, D. discolor, D. stratiotes,* and *D. sylvanum*, being lanceolate. In contrast, *D. lineale* has an elliptic shape, and *D. gouldii* has an ovate shape. Variability in the apexes of leaves in *D. antennatum, D. stratiotes, D. linelae, D. gouldii* is acute, *D. sylvanum* and *D. discolor* are obtuse. Variability in leaf length is not wide, namely around 10.93 - 13.67 cm. The narrowest leaf width is *D. antennatum*, which is 2.50 cm, while the widest is *D. discolor*, which is 4.13 cm. The difference in leaf width affects the leaf area, the largest leaf on *D. discolor* is 47.30 cm^2, while the smallest leaf is *D. antennatum*, namely 25.13 cm^2.

Pseudo bulb

There is variation in the height among the observed *Dendrobium* species. Specifically, in *D. stratiotes* and *D. gouldii*, the height exceeds 100 cm, reaching 108.50 cm and 156 cm, respectively. In contrast, *D. lineale* reaches a height of 90 cm, while *D. antennatum* and *D. discolo*r have heights of 51.33 cm and 57.33 cm. The lowest height is recorded in *D. sylvanum* at 34.60 cm. Additionally, the length of pseudo bulb internodes varies across different

Table 3 - Quantitative characters of *Dendrobium* species studied

No.	Characters	*D. antennatum*	*D. discolor*	*D. stratiotes*	*D. lineale*	*D. gouldii*	*D. sylvanum*
1	Plant height (cm)	51.33	57.33	108.5	90.00	156.00	34.6
2	Pseudobulb diameter (cm)	38.3	43.00	45.00	25.2	21.67	22.5
3	Internode length (cm)	8.1	12.80	11.6	4.13	5.13	4.4
4	Leaf length (cm)	12.2	13.6	13.26	10.93	13.67	12.00
5	Leaf width (cm)	2.5	4.13	2.96	3.83	2.83	3.5
6	Leaf area (cm^2)	25.13	47.3	34.2	36.00	35.96	33.6
7	Peduncle-ovary length (cm)	2.66	2.2	3.4	2.06	2.4	1.6
8	Length of inflorescence (cm)	12.00	32.00	20.00	58.00	50.00	20.00
9	Length of flower arrangement (cm)	5.00	26.00	14.5	48.00	41.00	14.00
10	Leaf thickness (mm)	2.3	1.03	1.7	1.43	1.9	1.2
11	Flower length (cm)	4.75	4.5	9.33	5.15	3.43	2.36
12	Flower width (cm)	2.15	4.00	2.7	6.16	5.26	5.00
13	Dorsal sepal length (cm)	2.00	2.5	1.98	2.1	1.6	1.56
14	Dorsal sepal width (cm)	0.4	0.7	1.00	1.3	0.83	0.6
15	Lateral sepal length (cm)	1.85	2.5	2.6	2.9	1.9	2.36
16	Lateral sepal width (cm)	0.65	0.6	0.93	1.16	0.56	0.63
17	Petal length (cm)	3.8	4.3	6.23	4.4	3.00	2.93
18	Petal width (cm)	0.15	0.7	0.35	0.8	1.06	0.8
19	Labellum length (cm)	1.65	2.5	3.7	2.7	2.23	2.26
20	Labellum width (cm)	1.05	1.00	0.96	1.5	0.7	0.63
21	Number of flowers per spike	6.00	13.00	8.3	25.00	19.67	12.00

Dendrobium species. The lengths of *D. discolor* and *D. stratiotes* measure 12.80 cm and 11.60 cm, respectively. *D. antennatum* exhibits a length of 8.10 cm, while the shortest internodes are observed in *D. lineale*, *D. gouldii*, and *D. sylvanum* at 4.13 cm, 5.13 cm, and 4.40 cm, respectively. This suggests that plant height does not necessarily corellate to longer pseudobulb internodes in *Dendrobium* species. Besides that, the diameter of the pseudobulb varies among different *Dendrobium* species. In *D. antennatum*, *D. discolor*, and *D. stratiotes*, the pseudobulb diameter reaches 38.30 cm, 43.00 cm, and 45.00 cm, respectively. Meanwhile, for *D. lineale*, *D. gouldii*, and *D. sylvanum*, it is around 25.20 cm, 21.67 cm, and 22.50 cm.

Genetic parameters

The analysis of variance revealed a significant effect of *Dendrobium* species on all observed traits. A low coefficient of variation indicates that the variation in the data from the average is relatively small compared to the average value (Table 3). This early finding suggested the presence of genetic diversity within the *Dendrobium* species. The variance attributed to genotypes was highly significant for all the studied characteristics, indicating that the selected genotypes were genetically different (Table 4).

Genetic parameter estimation was conducted to verify the presence of genetic variability within the *Dendrobium* section *Spatulata* were observed. The high values of broad-sense heritability (Hbs) and genotypic coefficient of variation (GCV) suggest a substantial genetic influence on phenotypic variability. The genetic variability coefficient (Table 5) showed that the flowering characters, namely flower stalk length (24.86), length of inflorescence (56.43), flower series length (74.40), flower length (47.91), flower width (36.08), dorsal sepal width (38.99), lateral sepal width (31.29), petal length (29.39), petal width (51.72), labellum length (27.12), labellum width (31.38), number of florets (50.10) are included in the high genetic variability category. Other vegetative characters are leaf width (45.43), leaf thickness (28.24), leaf area (51.77), plant height (57.66), stem diameter (42.72) also characterized by high genetic variability. Besides that, the length of dorsal sepal (17.63) and lateral sepal (17.07) was categorized as moderate genetic variability, whereas the length of leaf (8.43) was categorized as low genetic variability.

Table 4 - Analysis of variance (mean square) for quantitative characters in *Dendrobium* species studied

Characters	Mean square			CV (%)
	Replication	Genotype	Error	
Peduncle-ovary length (cm)	0.035555556	1.116888889	0.058222222	10.10063
Length of inflorescence (cm)	1.791666667	989.3	0.691666667	2.585478
Length of flower arrangement (cm)	0.1666666667	885.125	0.166666667	1.768585
Leaf length (cm)	0.157222222	3.527555556	0.136555556	2.930227
Leaf width (cm)	0.093888889	16.32588889	0.041888889	3.991354
Leaf thickness (mm)	0.002222222	0.659222222	0.050888889	14.14823
Leaf area (cm2)	21.86166667	2476.621333	11.763	6.194563
Plant height (cm)	141.5555556	6649.747222	57.32222222	9.313237
Pseudobulb diameter (mm)	15.73388889	130.8982222	2.509888889	10.34715
Internode length (cm)	0.035	0.569	0.055	5.350284
Flower length (cm)	0.223888889	17.07922222	0.392222222	12.72345
Flower width (cm)	0.292638889	7.282138889	0.345305556	13.94501
Dorsal sepal length (cm)	0.000688889	0.358688889	0.000555556	1.203245
Dorsal sepal width (cm)	0.010555556	0.300555556	0.004555556	8.378672
Lateral sepal length (cm)	0.005138889	0.504138889	0.020138889	6.03166
Lateral sepal width (cm)	0.00125	0.171916667	0.002916667	7.121693
Petal length (cm)	0.010555556	4.404888889	0.025222222	3.863069
Petal width (cm)	0.001116667	0.335383333	0.00145	5.9037
Labellum length (cm)	0.000416667	1.396583333	0.00775	3.509664
Labellum width (cm)	0.000416667	0.28458333	0.00375	6.280743
Number of flowers per spike	8.166666667	152.5333333	4.9	15.81139

All traits observed in this study had high heritability (Table 6). If genetic factors rather than environmental influences primarily determine a trait, it is more likely to have high heritability. Traits controlled by a few genes with large effects, known as major genes, are often highly heritable.

Table 5 - Coefficient of genetic variability (CGV), and coefficient of phenotypic variability in the *Dendrobium* species studied

Characters	Range	Mean	CGV	Category	CPV	Category
Peduncle-ovary length (cm)	1.60 - 3.40	2.38	24.86	High	26.84	High
Length of inflorescence (cm)	12.50 - 59.00	32.17	56.43	High	56.49	High
Length of flower arrangement (cm)	5.00 - 48.00	23.08	74.4	High	74.42	High
Leaf length (cm)	10.80 - 14.00	12.61	8.43	Low	8.92	Low
Leaf width (cm)	2.40 - 9.00	5.12	45.43	High	45.6	High
Leaf thickness (cm)	0.80 - 2.40	1.58	28.24	High	31.58	High
Leaf area (cm^2)	23.70 - 112.40	55.37	51.77	High	52.14	High
Plant height (cm)	24.60 - 156.00	81.29	57.66	High	58.41	High
Pseudobulb diameter (cm)	7.30 - 28.60	15.31	42.72	High	43.96	High
Internode length (cm)	3.50 - 5.40	4.38	9.44	Low	10.85	Moderate
Flower length (cm)	2.30 - 10.00	4.92	47.91	High	49.57	High
Flower width (cm)	2.00 - 7.50	4.21	36.08	High	38.68	High
Dorsal sepal length (cm)	1.60 - 2.50	1.95	17.63	Moderate	17.67	Moderate
Dorsal sepal width (cm)	0.30 - 1.30	0.8	38.99	High	39.88	High
Lateral sepal length (cm)	1.60 - 3.00	2.35	17.07	Moderate	18.1	Moderate
Lateral sepal width (cm)	0.50 - 1.20	0.75	31.29	High	32.09	High
Petal length (cm)	2.80 - 6.30	4.11	29.39	High	29.64	High
Petal width (cm)	0.10 - 1.10	0.64	51.72	High	52.06	High
Labellum length (cm)	1.50 - 3.80	2.5	27.12	High	27.35	High
Labellum width (cm)	0.60 - 1.60	0.97	31.38	High	32	High
Number of flowers per spike	6.00 - 25.00	14.00	50.1	High	52.54	High

Table 6 - Heritability of in the *Dendrobium* species studied

Characters	σ2e	σ2*g*	σ2f	H2bs	Category
Peduncle-ovary length (cm)	0.0582	0.3528	0.4111	85.83	High
Length of inflorescence (cm)	0.6916	329.53	330.22	99.79	High
Length of flower arrangement (cm)	0.1667	294.98	295.15	99.94	High
Leaf length (cm)	0.1365	11.303	12.668	89.22	High
Leaf width (cm)	0.0418	5.428	54.698	99.23	High
Leaf thickness (cm)	0.05	0.202	0.253	79.93	High
Leaf area (cm2)	11.763	821.61	833.38	98.58	High
Plant height (cm)	57.32	2197.475	2254.797	97.45	High
Pseudobulb diameter (cm)	2.509	42.796	45.306	94.46	High
Internode length (cm)	0.055	0.1713	0.2263	75.69	High
Flower length (cm)	0.392	5.562	5.954	93.41	High
Flower width (cm)	0.3453	23.122	26.575	87	High
Dorsal sepal length (cm)	0.0005	0.1193	0.1199	99.53	High
Dorsal sepal width (cm)	0.0045	0.0986	0.1032	95.58	High
Lateral sepal length (cm)	0.02	0.161	0.181	88.9	High
Lateral sepal width (cm)	0.0029	0.056	0.059	95.07	High
Petal length (cm)	0.0252	14.598	14.851	98.3	High
Petal width (cm)	0.00145	0.11311	0.11276	98.71	High
Labellum length (cm)	0.00775	0.4629	0.4706	98.35	High
Labellum width (cm)	0.00375	0.0936	0.0973	96.14	High
Number of flowers per spike	4.9	49.21	54.11	90.94	High

4. Discussion and Conclusions

Morphological characteristics

In the context of orchids, flowers typically consist of three outer floral parts known as sepals and three inner floral parts called petals. The petals are often more colorful and visually striking than the sepals. They play a crucial role in attracting pollinators, such as insects, and contribute to the overall aesthetic appeal of the orchid flower. The arrangement and characteristics of petals are important features used in the identification and classification of orchid species (Dirks-Mulder *et al.*, 2017)

In addition to attracting pollinators, orchid petals, along with other floral parts, may also have specialized structures or markings that aid in the orchid's reproductive process, such as facilitating the transfer of pollen. Orchids are known for their intricate and diverse floral structures, and the characteristics of their petals contribute significantly to their overall beauty and ecological function (Li *et al.,* 2021). The labellum is a specialized petal in orchids that stands out from the other floral parts due to its distinct shape, size, and often elaborate structure. It is the modified third petal of the orchid flower, differentiating from the two lateral petals and three sepals (Dalayap *et al.*, 2011). The diversity in the part of *Dendrobium* flower studied, can be a source of diversity in plant breedingaimed at increasing the aesthetic value of hybrid *Dendrobium* orchids.

Studying leaf shape contributes to understanding the phenotypic variation within a species. This information is essential for describing the diversity and range of characteristics exhibited by plants. Considerable genetic diversity exists in both the size and shape of leaves among different species and populations within the same species. This diversity was influenced by robust heredity, carrying both genetic and environmental information that contributes to variations (Ren *et al*., 2020).

Pseudo bulb is a modified form of stem in several types of orchid plants. A pseudobulb in orchids is a specialized, swollen, or bulbous structure that serves as a storage organ for water and nutrients. This structure is a key adaptation to various environmental conditions, particularly in epiphytic and lithophytic orchids (Zhang *et al*., 2018). The pseudobulbs on *Dendrobium* orchids belong to the homoblastic type, characterized by two or more internodes of the same or varying lengths (Ng and Hew, 2000). Furthermore, the nature of stem (pseudobulbs) can vary significantly among different *Dendrobium* species. *D. antennatum*, *D. discolor*, *D. lineale*, *D. gouldii*, and *D. sylvanum* typically exhibit cylindrical canes. In contrast, D. stratiotes stands out with its cane-shaped stem, representing a distinctive morphological trait within the genus.

The size of the pseudobulb indicates the large carbohydrate reserves in the organ. According to Ng and Hew (2000), carbohydrate reserves in orchid pseudobulbs are an important part in the initiation of new seedling growth. The large size of the pseudobulb also functions to support the growth of new shoot and flower development.

Genetic parameters

Genetic diversity plays an important role in the development of *Dendrobium* breedings with high economic value. It serves as the main germplasm in plant breeding. Greater genetic diversity increases the potential for enhancing plants in accordance with the desired traits. This variability offers ample opportunities for plant breeders to choose superior genotypes for improving crops (Swarup *et al*., 2021).

High genetic diversity in plants reflects substantial genetic variation, signifying numerous genetic differences between individual plants. This diversity holds promising potential for more effective plant breeding endeavors. Moniruzzaman *et al.* (2012) supports this, emphasizing the critical role of high genetic diversity in breeding programs, particularly in the development of new crop varieties featuring improved traits like exotic flower diversity. Genetic variation offers breeders a wide genetic reservoir, enabling the selection and crossbreeding of individuals to produce desirable hybrids.

In this study, high CGV values indicate that genetic factors have a significant influence on the observed traits. On the other hand, it is also known that there is a difference in value between CPV and CGV for each lower trait. These findings suggest that the environment has comparatively minor influence on the observed traits. This is in accordance with research of Malek *et al*. (2014) stated that narrow distinction between CPV and CGV in the majority of traits suggests a minimum impact of environmental factors on the manifestation of these traits, increasing the probability of achieving significant selection gains.

The observation results showed that all the observed characters showed high broad sense

heritability (Table 6). This suggests that the variability in these traits is primarily influenced by genetic factors rather than environmental factors (Swarup *et al.*, 2021). In the research of Singh *et al*. (2018) on *Dendrobium* orchid, heritability estimates were identified for characteristics such as plant height, leaf count per shoot, quantity of aerial roots, length and thickness of aerial roots, shoot thickness, internodal length, leaf length, and leaf area. Heritability values represent the degree of genetic impact on a trait (Hadi *et al.*, 2019). Heritability of quantitative traits are influenced by multiple genes as well as environmental factors. If a trait is primarily determined by genetic factors rather than environmental influences, it is more likely to have high heritability. Traits controlled by a few genes with large effects, known as major genes, are often highly heritable. The potential for improvement through direct selection was indicated by high heritability with high genetic variability flower stalk length, length of inflorescence, flower arrangement length, flower length, flower width, dorsal sepal width, lateral sepal width, petal length, petal width, labellum length, labellum width, number of florets. When heritability is high in plants, it indicates that a significant genetic variation is a primary factor in the observed traits. High heritability typically indicates that the majority of phenotypic variation in a trait can be attributed to genetic factors, and this is frequently associated with the influence of additive genes (Amien *et al.*, 2021). Additive genes contribute cumulatively to the phenotypic expression of a trait, and when these genes are predominant, heritability tends to be high (Beavis *et al.*, 2021). Therefore, high heritability is commonly regarded as an indication that genetic factors, especially additive genes, exert a substantial influence on the plant's traits (Karavolias *et al*., 2020). High GCV and Hbs values increase the chances of obtaining *Dendrobium* orchids have superior characters that can be inherited in their phylogeny. Genetic variability plays a crucial role in selecting parents for hybridization and breeding initiatives effectively (Mazid *et al*., 2013; Mai *et al*., 2021).

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