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MORPHOLOGICAL STUDY OF FOUR SECTIONS OF GENUS DENDROBIUM SW. (ORCHIDACEAE) IN PENINSULAR MALAYSIA

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Abstract

A morphological study of the four sections (*Aporum, Crumenata, Strongyle,* and *Bolbidium*) of the genus *Dendrobium* (family Orchidaceae) was conducted by using 18 morphological characters. One of the three largest Orchid genera in Orchidaceae is genus *Dendrobium*. This genus is distributed from South- East Asia, west to the Himalayas, east to Japan, and south to the Pacific Islands, New Zealand and Australia. *Dendrobiums* are one of the most popular orchids for their medicinal and commercial values. This plant occurs in the tropical regions with high annual rainfall and without a significant dry season for growth. In this study, 17 fresh samples of *Dendrobium* species were collected and identified upto the species level. The statistical analysis indicated he occurrence of two groups. The first group had four sections (*Aporum, Crumenata, Strongyle* and *Bolbidium*) and the other group had three sections (*Dendrobium*, *Callista* and *Latouria*), which were closely related. The morphological analysis showed that the four sections formed a monophyletic group compared to three other sections *Dendrobium, Callista* and *Lautoria*. The results demonstrated that sections *Aporum, Crumenata*, and *Strongyle* were close to one another and were grouped into one clade. Although section *Bolbidium* was close to them but it formed a different clade by itself. The three other sections included in the analysis formed a separate clade from these four sections .In all, according to the cluster and cladistics analysis, these four sections (*Aporum, Crumenata, Strongyle* and *Bolbidium*) can be put in the separate clade compared to the other sections of genus *Dendrobium* an can be named *Aporum* based on ICBN rules.

Key words: Morphological study, Morphological characters, *Dendrobium*, Orchidaceae,

Introduction

Phylogenic relationships have been traditionally studied based on morphological data. Two extensive methods of analyses exist to examine phylogenetic relationships: Phenetic methods and cladistic methods. Phenetic methods or numerical taxonomy uses various measures of overall similarity for the ranking of species. Any number or type of characters can be used but the data has to be converted into a numerical value. The organisms are compared together for all the characters, the similarities are calculated and then the organisms are clustered based on the similarities. These clusters are called phonograms. They do not necessarily reflect evolutionary relatedness. In contrast, the cladistic method is based on the idea that members of a group share a common evolutionary history and are more closely related to members of the same group than the members of the other group. Numerical taxonomy studies have been carried out on a wide variety of organisms and this approach has shown to be useful in evaluating and refining the existing classification. The main objective of numerical methods in taxonomy is to simplify and portray the degrees of relationships or similarity in an objective and repeatable manner. Indeed, in numerical taxonomy various characters are integrated from different sources, such as morphology, physiology, anatomy, cytology, genetics, chemistry, ecology and paleobotany, in the construction classification system.

This classification can also provide greater discrimination along the spectrum of taxonomic differences and is more sensitive in delimiting data. It provides a better and accurate classification than the conventional method. Overall, numerical taxonomy is used to classify organisms based on their overall similarity to study lineages and evolution by creating group categorization (Sneath & Sokal, 1973; Pedersen *et al.*, 2001).

There is a list of comprehensive publications for numerical taxonomy that have been carried out on various organisms by various scientists since the first study conducted by Sneath & Sokal (1973). The technique has been proven effective in microbiology (Goodfellow, 1992), and the animal kingdom for vertebrate and invertebrates (Biondi & Bologna, 1991; Dietrich & Deitz, 1991). Other studies have been done by Revilla & Tracy, 1995; Dias *et al*., 1993; Zuloaga *et al*., 1993 and Watson *et al*., 1996. The numerical taxonomy serves as a good tool to clarify taxonomic confusion. Burke & Adams (2002) used numerical analytical methods for *Dendrobium speciosum* (Orchidaceae) complex. Indeed Adam *et al*. (2006) had studied numerical taxonomy and descriptions of two taxa of *Dendrobium speciosum* Sm., Section *Dendrocoryne*: Orchidaceae in North Queensland. The other Numerical taxonomy has been employed for 31 species of the genus *Dendrobium* by Wang *et al.* (2009).

The objective of this study was to construct a phylogenetic and tree to find the relationship of the species among four sections of genus *Dendrobium*, 18 morphological characters (Table 1) were selected. For this analysis morphological data were analyzed using software PAUP*4.0 B 10 (Swofford, 2002) to construct Neighbor Joining tree (NJ) as a distance method for cluster analysis and Maximum parsimony (MP) as a character based method to demonstrate the cladistics analysis.

Table 1. Morphological characters.

	Characters	Scores		
1.	Plant size	0= Small (≤ 10 cm)	/ 1= Medium (11cm-59cm)	2= Large ≥60 cm
2.	Pseudobulb	0= Present	1= Absent	-
3.	Pseudo bulb shape	0= Rounded or Club shaped	1= Ovoid or Oblong	-
4.	Stem or Pseudo bulb Habit	0= Erect	1= Pendulous	-
5.	Leaf shape	0= Flattened bilaterally	1= Flattened dorso-ventrally	2= terete or needle- shaped
6.	Stem characters	0= With fleshy swollen internodes	1= without fleshy swollen internodes	-
7.	Leaves sheaths	0= With distinct sheaths (covering internodes, pseudo bulb, rhizome)	1= Without distinct sheaths	-
8.	Number of Leaves on the shoot	0= 1 or 2 leaves per shoot	1= 3 or 6 leaves per shoot	2= more than 6 leaves per shoot
9.	I nflorescence position	0= Basal	1= From many internodes of the stem or pseudobulb	2= Only from one or a few of the upper internodes of the stem or pseudobulb
10.	Number of flower	0= Single flowered	1= Multiple flowered	-
11.	Flower size	0= Small (≤ 2cm)	1= Medium to Large (> 2cm)	-
12.	Flowering longevity	0= Short (one or few days)	1= Long (more than a week)	-
13.	Lip	0= With slide lobes (Blobbed or 3lobbed)	1= Without slide lobes	-
14.	Lip surface	0= Hairy	1= without hair	-
15.	Leaf thickness	0= Papery	1= Succulent/Fleshy	-
16.	Lip apex	0= curved	1= Straight (erect)	-
17.	Flower color	0= Yellowish or greenish yellow with another color such as purple	1= White (maybe or usually with another color e.g. Pink, purple, yellow)	2= Other colors
18.	Lip ornaments	0= With varying ornaments on blade	1= Without ornaments except for callus at base	

Materials and Methods

Sampling: One of the greatest challenges that faced through this study was sampling, as finding the species of these four sections was difficult in Peninsular Malaysia. Some of the collected samples were without flowers, so their identity could not be ascertained. *Dendrobium* species belonging to sections *Aporum, Crumenata, Strongyle* and *Bolbidium* were collected from different areas in Peninsular Malaysia during orchids' flowering season, mainly at the end of the year (November-December) and middle of the year (May-June). All observations concerning the nature of the habitat and findings were recorded for the fresh samples. All the samples were identified based on morphological characters. Table 2 lists the fresh samples used in this study.

Species identification and enumeration: Morphological characters of vegetative structures, such as size of plant, leaves and pseudobulb and flower structure including color, shape of the lip and inflorescences, were observed and studied for morphological analysis. All the features were noted and identified by Henderson, (1954); Holttum, (1964); Seidenfaden & Wood, (1992); Wood *et al.* (1993); Wood & Cribb, (1994) and Comber, (2001). The identifications were also done by comparing the collected samples with herbarium specimens at the Herbarium of Biology Department, Faculty Science, Universiti Putra Malaysia (UPM), also online – specimens from the National Herbarium of The Netherlands- Liden University branch (NHN-L) and the Internet Orchid species photo encyclopedia (http://www.orchidspecies.com/indexed.htm). Especially for samples of three sections *Dendrobium*, *Callista* and *Latouria* where we did not have any fresh specimen, the investigation of morphological characters has been done through an intensive search and comparison using information from books: Seidenfaden & Wood, (1992); Lavarack *et al*. (2000) and the Internet sources (http://www.orchidspecies.com/indexed.htm and http:// www.nationaal herbarium.nl/pubs/orchid web/genera/*Dendrobium*).

Morphological data: In this study, 17 fresh samples of the genus *Dendrobium* from four sections *Aporum, Crumenata, Strongyle* and *Bolbidium* were investigated. Indeed morphological characters of 8 species from another section of the genus *Dendrobium* were also included for comparison and two species of the genus *Bulbophyllum* were used as out group. These selected species were described by Seidenfaden & Wood (1992), and Lavarack *et al*. (2000). A total of 18 different binary morphological characters were defined. The choice of characters is often subject to much argument and involves a number of difficult problems. One of the most important steps before making a classification is to decide which characters are the most suitable traits for morphological analysis (Amurrio *et al.,* 1995). The selected characters for this study are shown in Table 1. After selecting characters, the next step is to score the characters, which resulted in a data matrix. The resemblance matrix for qualitative traits is converted into a dissimilarity resemblance matrix multiplying by (- , 2, 1, 0). The data matrix is shown in Table 3. Software PAUP*4. 0 B 10 was used to construct trees (Swofford, 2002).

Table 2. List of samples in this study

	Species	Section	Voucher	Location	Habitat
1.	*Dendrobiumaloifolium*	*Aporum*	WY 193	UPM Green house, No.5	epiphytic, lowland and hill forests
2.	*Dendrobiumgrande*	*Aporum*	RG 2746	Labuk Tapah, Selai, PM	epiphytic, low stature hill forests
3.	*Dendrobiumleonis*	*Aporum*	RG 2491	UPM Green house, No.5	epiphytic, lowland forests
4.	*Dendrobiumquadrilobatum*	*Aporum*	RG 2970	Kuala Krai, Kelantan, PM	epiphytic, lowland forests
5.	*Dendrobiumrosellum*	*Aporum*	D001	UPM Green house, No.5	epiphytic, hill and lower Montane forests
6.	*Dendrobiumterminale*	*Aporum*	RG 2783	Sungai Bertedung, Endau Rompin, PM	epiphytic, lowland forests
7.	*Dendrobiumclavator*	*Crumenata*	RG 2778	Sungai Bertedung, Endau Rompin, PM	epiphytic, lowland forests
8.	*Dendrobiumcrumenatum*	*Crumenata*	D008/M.M.1	Genting Highlands, PM	epiphytic, lowland forests
9.	*Dendrobiumsetifolium*	*Crumenata*	RG 2779	Sungai Bertedung, Endau Rompin, PM	epiphytic,lower Montane forests
10.	*Dendrobiumtruncatum*	*Crumenata*	RG 2625	Cameron Highlands, PM	epiphytic, lowland and lower Montane forests
11.	*Dendrobiumacerosum*	*Strongyle*	WY 302	Biology Department Herbarium, UPM	epiphytic, lowland and Swamp Forests
12.	*Dendrobiumkentrophyllum*	*Strongyle*	FAN.FH.162	Fraser's Hill, PM	epiphytic, peat swamps, hill, ridge-top and lower Montane forests
13.	*Dendrobiumsingaporense*	*Strongyle*	RG 2635	Cameron Highlands, PM	Epiphytic, lowland and hill forests
14.	*Dendrobiumsubulatum*	*Strongyle*	LST 023	Gunung Nuang, PM	epiphytic, lowland forests
15.	*Dendrobiumpachyphyllum*	*Bolbidium*	FAN.FH.392	Fraser's Hill, PM	epiphytic,hill, and lower Montane forests
16.	*Dendrobiumhymenanthum*	*Bolbidium*	RG 2154	Cameron Highlands, PM	epiphytic, Montane forests
17.	*Dendrobiumstriatellum*	*Bolbidium*	RG 2969	Kuala Krai, Kelantan, PM	epiphytic,hill and lower Montane Forests
24.	*Bulbophyllummacranthum*	*Sestochillus*	B001/FAN.FH-426	Cameron Highlands, PM	epiphytic, Mountain Forest
25.	*Bulbophylluminunctum*	*Sestochillus*	B002/SH.K-109	Gunung Jerai, PM	epiphytic, Hill Forest to Mountain Forest

Table 3. Morphological Characters.

OTUs	Characters																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Dendrobium leonis (A)	1	1	-	0	0	1	0	2	2	0	0	0	0	1	1	1	0	0
Dendrobiu m aloifolium (A)	1	1	-	0	0	1	0	2	1	0	0	1	0	1	1	0	1	0
Dendrobium rosellum (A)	1	1	-	0	0	1	0	2	1	0	0	0	0	1	1	0	1	0
Dendrobium quadrilobatum (A)	1	1	-	0	0	1	0	2	2	0	0	0	0	1	1	1	0	0
Dendrobium grande (A)	1	1	-	1	0	1	0	2	2	0	0	0	0	1	1	1	0	0
Dendrobium terminale (A)	1	1	-	0	0	1	0	2	2	0	0	0	0	1	1	1	1	0
Dendrobium crumenata (C)	1	0	0	1	1	0	0	2	2	0	0	0	1	1	1	0	1	0
Dendrobium truncatum (C)	1	0	0	0	1	0	0	2	2	0	0	0	1	1	0	0	1	0
Dendrobium clavator (C)	1	0	0	0	2	0	0	2	2	0	0	0	1	1	0	1	0	0
Dendrobium setifolium (C)	1	0	0	0	2	0	0	2	2	0	0	0	1	1	0	0	0	0
Dendrobium kentrophyllum (S)	1	1	-	0	0	1	0	2	2	0	0	0	1	1	1	1	2	0
Dendrobium singaporense (S)	1	1	-	0	2	1	0	2	2	0	0	0	1	1	1	1	1	0
Dendrobium subulatum (S)	1	1	-	0	0	1	0	2	2	1	0	1	1	1	1	0	1	0
Dendrobium acerosum (S)	1	1	-	0	0	1	0	2	2	1	0	1	1	1	1	0	1	0
Dendrobium pachyphyllum (B)	0	0	0	0	1	0	1	0	2	0	0	0	0	1	1	0	1	0
Dendrobium hymenanthum (B)	0	0	0	0	1	0	1	0	2	0	0	0	0	1	1	0	1	0
Dendrobium striatellum (B)	0	0	0	0	1	0	1	0	2	0	0	0	0	1	1	0	1	0
Dendrobium heterocarpum (D)	1	0	0	0	1	0	0	2	1	1	1	1	1	0	0	1	1	1
Dendrobium nobile (D)	2	0	0	0	1	0	0	2	1	1	1	1	1	1	0	1	2	1
Dendrobium crepidatum (D)	1	0	0	1	1	0	0	2	1	1	1	1	1	0	0	1	2	1
Dendrobium fimbriatum (D)	2	0	0	0	1	0	0	2	1	1	1	0	1	0	0	1	0	1
Dendrobium gibsonii (D)	2	0	0	0	1	0	0	2	1	1	1	1	1	0	0	1	2	1
Dendrobium thyrsiflorum (Cal)	2	0	0	1	1	0	1	1	2	1	1	0	1	0	0	1	1	1
Dendrobium farmeri (Cal)	1	0	0	1	1	0	1	1	2	1	1	0	1	0	0	1	1	1
Dendrobium macrophyllum (L)	2	0	0	0	1	0	1	1	2	1	1	1	0	1	1	0	2	1
Bulbophyllum inunctum (OG)	1	0	1	0	1	0	0	1	0	1	1	1	0	1	1	0	2	0
Bulbophyllum macranthum (OG)	1	0	1	0	1	0	0	1	0	1	1	1	0	1	1	0	2	0

A: Section *Aporum*, C: Section *Crumenata*, S: Section *Strongyle*, B: Section *Bolbidium*, D: Section *Dendrobium*, Cal: Section *Callista*, L: Section *Latouria* and OG: Out group

Morphological characteristics of the selected species and species enumeration: One of the important parameters that are widely used for evaluating aspects of plant biodiversity and enumeration of the species is the richness of the species. Enumeration of species is associated with a particular sample, area and habitat and can be distinguished as a significant tool to find the species richness and biodiversity situation. Morphological information on the selected species in this study was described by observation of fresh samples as well as information from previous works (Seidenfaden & Wood, 1992; Lavarack *et al*., 2000; Go & Hamzah, 2008 and Go *et al*., 2010).

Results

Cluster analysis: Cluster analysis was carried out to investigate the relationships among four sections of Genus *Dendrobium* based on overall similarity (Phenetic system). A total of 18 morphological binary characters was defined and used for morphological analysis. In order to determine the relationships among four sections, cluster analysis using distance method, Neighbor-Joining (NJ) was performed. The phenogram of morphological characters is shown in Fig. 1. The phenogram consists of two major clusters. One of the clusters consisted of all the 7 sections of genus *Dendrobium* and the other cluster included two species of genus *Bulbophyllum* used as out group. *Dendrobium* cluster contained two sub clusters, one of the sub-clusters were made up of section later and another sub-cluster included the other six sections of genus Dendrobium. This clade involved one major sub-clade that consisted of the sections *Aporum, Crumenata, Strongyle* and *Bolbidium*, and the other sub-clade included sections *Dendrobium* and *Callista*.

The morphological analysis showed that the four sections (*Aporum, Crumenata, Strongyle* and *Bolbidium)* formed a monophyletic group compared to other sections (*Dendrobium, Callista* and *Lautoria).* However, these four sections were not all monophyletic. The results demonstrated that two sections *Crumenata* and *Bolbidium* were monophyletic whereas other two sections *Aporum* and *Strongyle* were polyphyletic. In addition, based on the results sections *Aporum, Crumenata*, and *Strongyle* were close and were grouped into one clade. In contrast, section *Bolbidium* was close to them, but it formed a different clade by itself. The other sections (*Dendrobium, Callista* and *Lautoria*) formed a separate clade from the four sections.

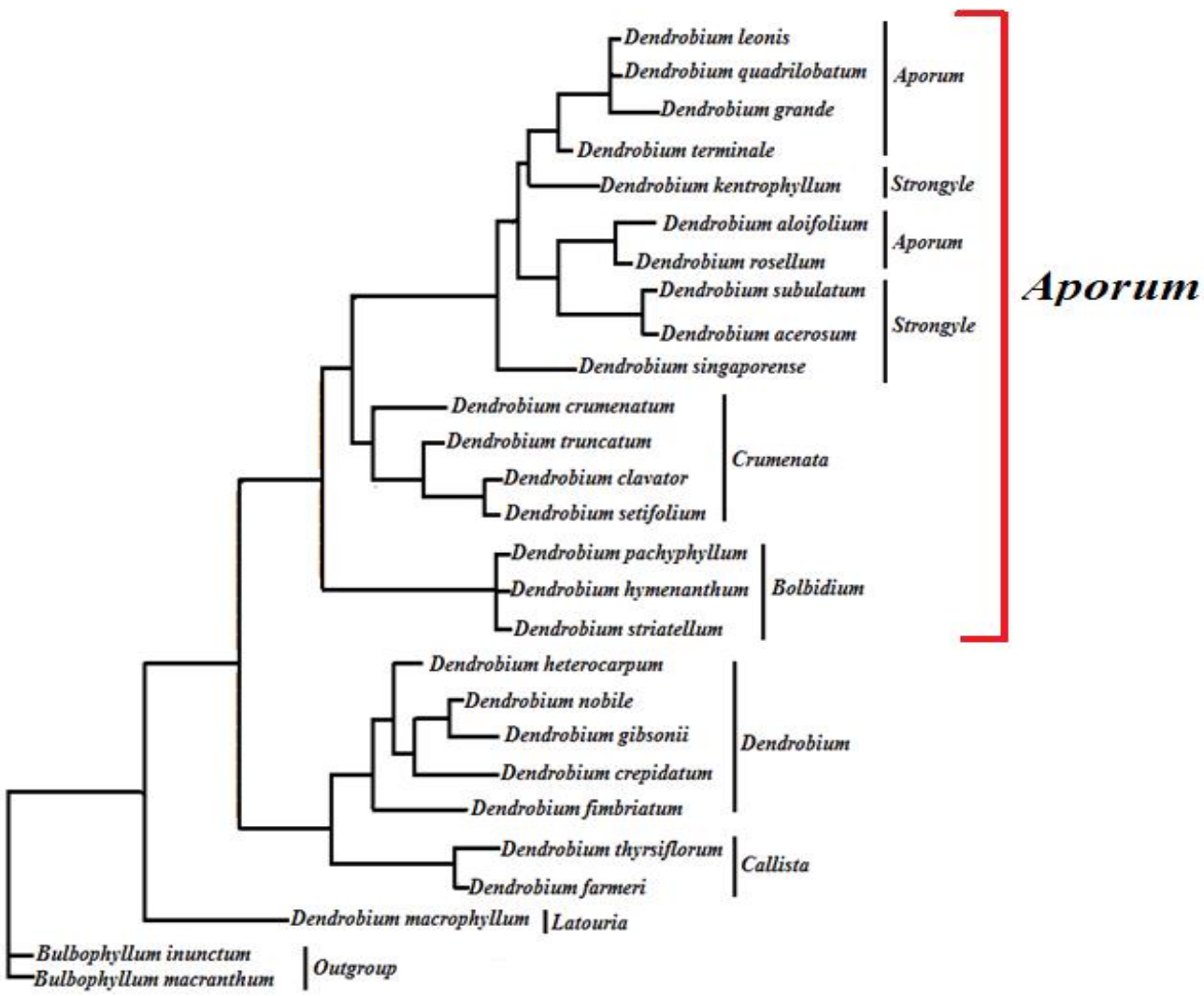

Fig. 1. Dendrogram constructed according to Neighbor-*Joining* cluster analysis based on the morphological characters. The four sections *Aporum*, *Crumenata*, *Strongyle* and *Bolbidium* formed a monophyletic group and can be considered as one section named *Aporum*.

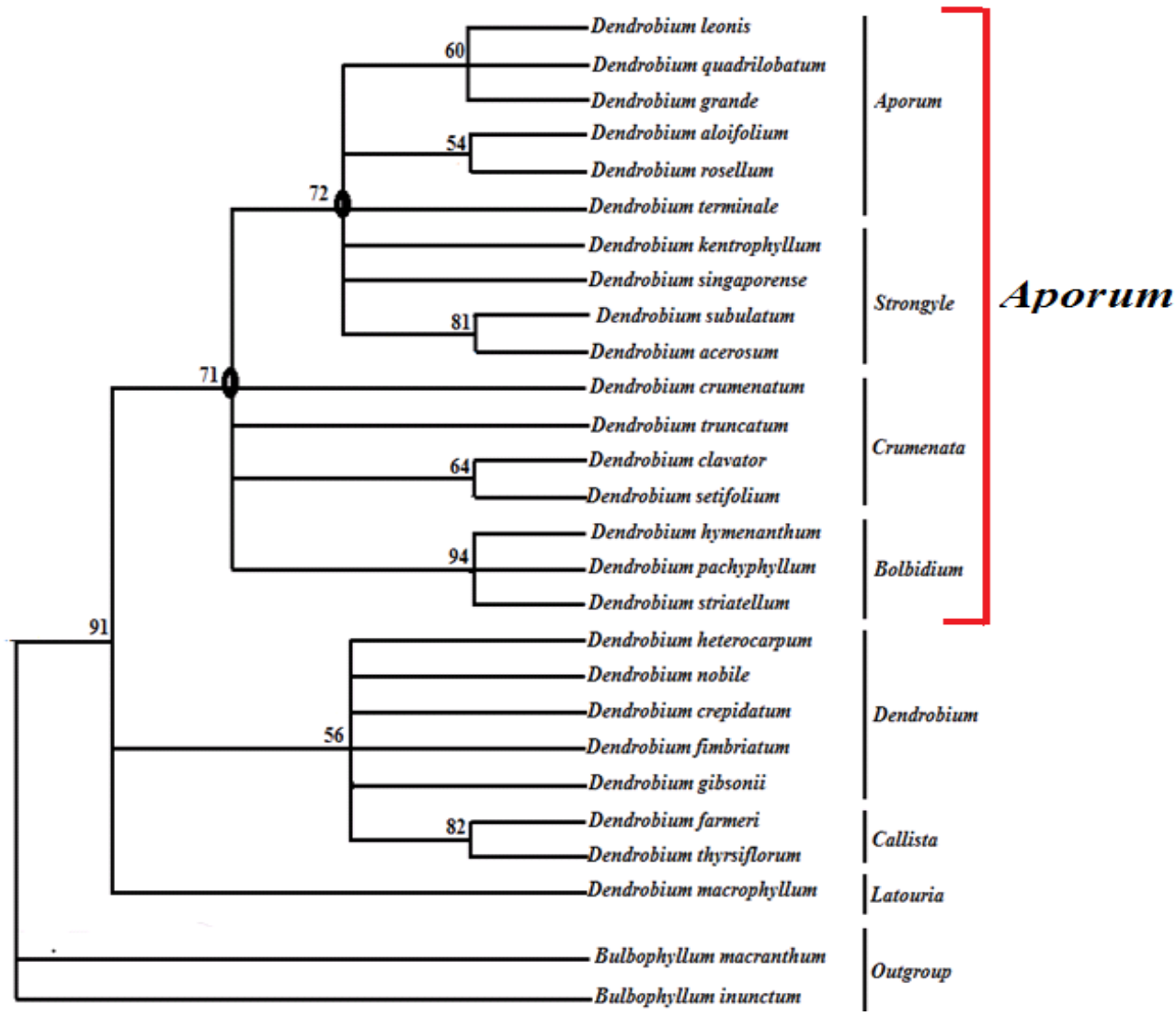

Fig. 2. The bootstrap 50% majority rule consensus tree inferred from 504 most parsimonious trees is shown for morphological characters. Bootstrap percentage ≥ 50 are indicated above the nodes. The four sections *Aporum, Crumenata, Strongyle* and *Bolbidium* formed a monophyletic group and can be considered as one section named *Aporum*.

Cladistic analysis of morphological characters: The consensus tree was inferred from 504 most parsimonious trees (Fig. 2). The tree has a length of 53, consistency index of 0.45 and the retention index of 0.81. All of the characters are parsimony informative. One major clade involved three sub-clades, which included sections of the genus *Dendrobium* with a bootstrap value of more than 90% and another clade consisted of genus *Bulbophyllum* as out group. The major clade contained three sub-clades as follows:

1. First clade is made of four sections *Aporum, Strongyle, Crumenata* and *Bolbidium*.
2. Second clade consisted of two sections *Dendrobium* and *Callista*.
3. Third clade included Section *Latouria*.

The 50% majority rule consensus tree inferred from the most parsimonious trees was approximately the same as the cluster analysis. Four sections *Aporum, Crumenata, Strongyle* and *Bolbidium* formed a monophyletic group (BP71). Based on the results two sections *Aporum* and *Strongyle* are nested together (BP 72). Furthermore, the results showed that each these four sections were not all monophyletic excluding section *Bolbidium*. On the other hand, the results from one of the most parsimonious trees were considerably similar to the cluster analysis (Fig. 3). This tree showed that these four sections (*Aporum, Crumenata, Strongyle and Bolbidium)* formed one main clade compared to the other sections *Dendrobium, Callista, Lautoria* and also two species of *Bulbophyllum* as out group confirming that each section *Aporum, Crumenata, Strongyle and Bolbidium* were not all monophyletic. Two sections *Crumenata* and *Bolbidium* were monophyletic, whereas other two sections *Aporum* and *Strongyle* were polyphyletic. In addition, the results showed that two sections *Aporum* and *Strongyle* were nested together. Section *Crumenata* was also included with them in one clade, whereas section *Bolbidium* formed a separate clade by itself. Overall, according to cluster and cladistics analysis sections *Aporum, Crumenata, Strongyle* and *Bolbidium* formed a monophyletic group compared to the other sections *Dendrobium, Callista* and *Lautoria* of the genus *Dendrobium*.

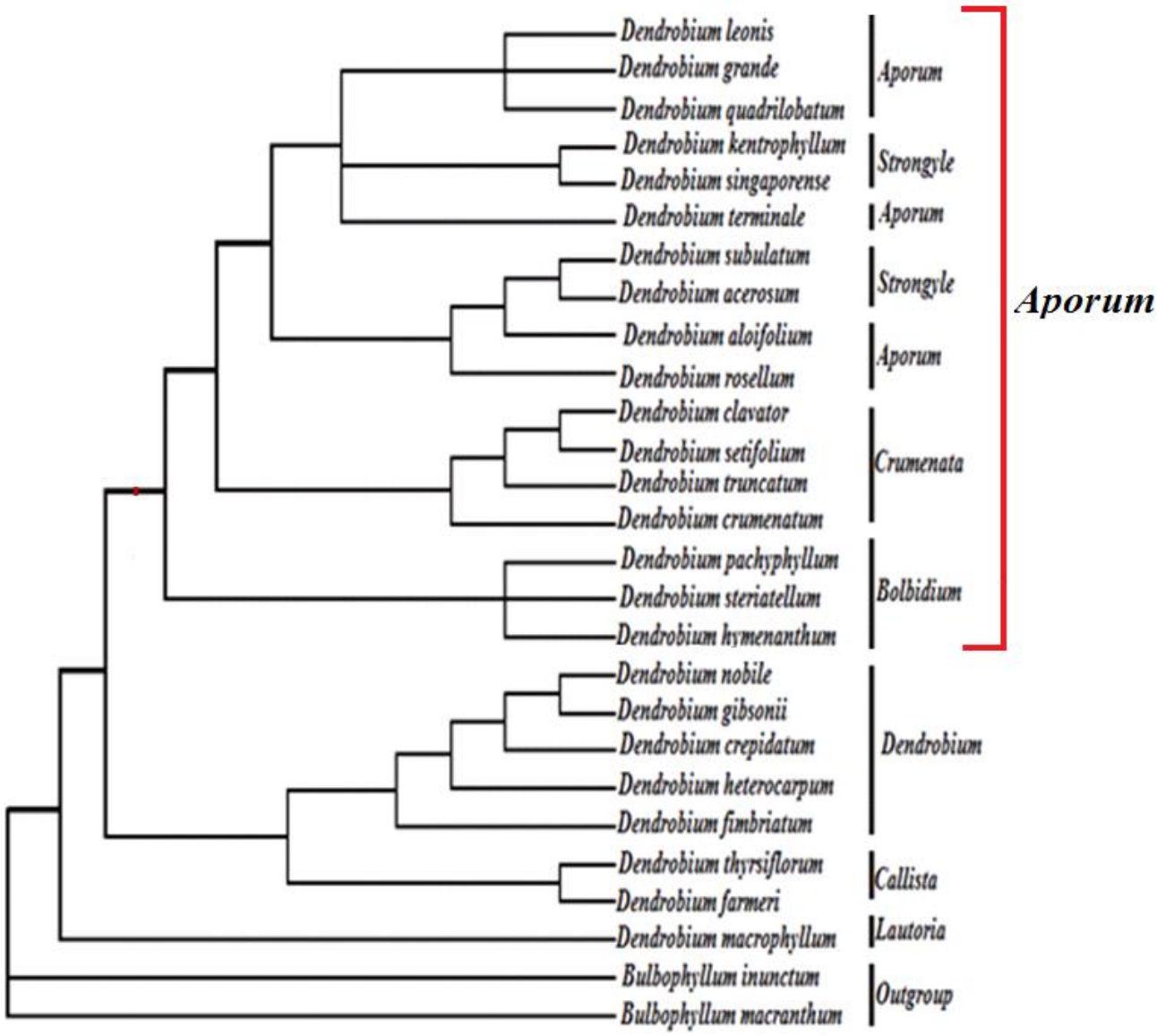

Fig. 3. One of the most parsimonious trees of 504 most parsimonious trees is shown for morphological characters. The four sections *Aporum, Crumenata, Strongyle* and *Bolbidium* formed a monophyletic group and can be considered as one section named *Aporum*.

Discussion

The results of this study support that sections *Aporum* and *Strongyle* are nested together in both cluster and caladistic analyses. The similarities among species in section *Aporum* and *Strongyle* were also noted by Schlechter (1912) who treated the latter as a part of *Aporum*, as cited in Clements (2003). Indeed, Seidenfaden & Wood (1992); Lavarack *et al.* (2000), and Clements (2003) have confirmed the relationships between *Aporum* and *Strongyle*. Despite some diversity in the origin of the inflorescence and floral morphology, the two sections are held together with its vegetative characters, particularly: possession of overlapping leaves; lack of any form of thickening of the unsheathed wiry stems; production of persistent, compact, lateral and terminal inflorescences with persistent indeterminate meristematic regions from generated single, occasionally multiple flowers are produced. These common characters suggests they should be treated as representative of a single taxon, the earliest and most commonly applied generic or sectional name being *Aporum* (Clements, 2003) be followed.

Actually, these two sections with wiry stems without fleshy, swollen internodes, equitant leaves and leafless par in the stem are very close to each other (Seidenfaden & Wood, 1992; Lavarack *et al.*, 2000). Although in section *Aporum* the leaves are laterally compressed and flattened, in section *Stongyle* often the leaves are terete. If the leaves are laterally flattened, they will usually be longer and not overlapping at the base. Based on the morphological observation and analysis section *Strongyle* has been preferred to be merged with section *Aporum*. The results of cluster analysis showed that section *Crumenata* was grouped with sections *Aporum* and *Stongyle* in one clade. However, in cladistics analysis, this section formed a separate clade from sections *Aporum* and *Strongyle* and formed a paraphyletic clade with section *Bolbidium*. Schlechter (1912) formed a single section *Rhophalanthe* (*Crumenata*) in his subgenus *Rhopalobium* within *Dendrobium*, for those species with pseudobulbs or stems thickened on 1–3 internodes only. Thus, he

recognized its closeness to *Aporum*. Therefore, Schlechter (1912) proposed the subsection name *Aporopsis* having the species with equitant leaves (Clements, 2003). Indeed, the inflorescences in section *Aporum* are the same as section *Crumenata*; the flowers are from small chaffy bracts, which never increase in length from any node or only from the stem apex (Seidenfaden & Wood, 1992). In addition, the synchronous flowering habit, the broad, membranous, concave column foot, very short column, and the thin, spreading labella with a broadly lobed apex are the other characters that are the same between the two sections *Aporum* and *Crumenata*. However, *Aporum* lacks the swollen based nodes of *Crumenata*. Section *Strongyle* is close to section *Crumenata*, this section lacks the usual basal swelling of *Crumenata*, but it usually has a leafless terminal part and flowers are borne from a small group of chaffy bracts, similar to section *Crumenata*. The section *Strongyle* can be considered as a link between sections *Aporum* and *Crumenata*.

Based on the results of both cluster and cladistics analyses, section *Bolbidium* was grouped with sections *Aporum, Crumenata,* and *Strongyle* in one clade compared to the other sections of genus *Dendrobium* and *Bulbophyllum* species as outgroup. However, section *Bolbidium* formed a separate clade itself. In Schlechter's system of classification of the Dendrobiinae, section *Bolbidium* was placed in the first subgenus *Anthecebium*, well separated from the third subgenus *Rhopalobium* that contained *D. crumenata*. Section *Bolbidium* is a representative species possessing one to several swollen, near basal leafless internodes; the vegetative form varies from the crassulate duplicate two leaved in the species having stems with fleshy swollen internodes. These characters contribute to the closeness of this section to section *Crumenata*. Section *Bolbidium* was monophyletic. Although Lavarack *et al.* (2000) noted that section *Bolbidium* was close to section *Dendobium* based on morphological characters. The four sections (*Aporum, Crumenata, Strongyle* and *Bolbidium*) are close together and may be considered as one clade because of having virtually identical, ephemeral flowers occuring in each of the four sections (Schuiteman, 2011).

Other sections (*Dendrobium, Callista* and *Lautoria*) were grouped into a separate clade. Sections *Dendrobium* and *Callista* that were nested together, have similar vegetative characters such as dorsi-ventrally leaves, flower structure, flowering longevity, inflorescences with many flowers, plant size. However, there are some differences among them. *Callista* has species that the swollen parts of their stems have several internodes, and their leaves without distinct sheaths. In contrast, in section *Dendrobium*, species have stems with at least some fleshy swollen internodes, and the leaves have distinct sheaths covering internodes (Seidenfaden & Wood, 1992). Lavarack *et al.* (2000) noted that section *Callista* is close to section *Dendrobium* and perhaps section *Latouria.* Section *Lautoria* is similar to the two sections of *Dendrobium* and *Callista* in some morphological characters, such as having inflorescences with many flowers and large flower or the leaf shape. Nevertheless, Lavarack *et al.* (2000) cited that section *Latouria* was close to section *Dendrocoryne*, but could be distinguished by the fleshy flowers and the firm attachment of the lip. Therefore, in the result, it is obvious that sections *Dendrobium* and *Callista* were nested together and *Latouria* formed a separate clade by itself.

Conclusion

In this study, the relationships among four sections (*Aporum, Crumenata, Strongyle* and *Bolbidium*) of the genus *Dendrobium* were shown based on morphological characters using cluster and cladistic analyses. Four sections *Aporum, Crumenata, Strongyle* and *Bolbidium* form a monophyletic group together, and can be put in one clade compared to the other sections (*Dendrobium, Callista* and *Lautoria*). In addition, two sections *Aporum* and *Strongyle are* morphologically closely related together, whereas section *Crumenata* occur in the same clade with two sections *Aporum* and *Strongyle* in cluster analysis, but form a separate clade in cladistics analysis. Both methods of analysis suggest that *Bolbidium* is morphologically close to the other three sections (*Aporum, Crumenata* and *Strongyle*) but occur separately. As a whole, the results demonstrate that the four sections form a monophyletic group and that it is best to recognize only one section instead of four. Therefore, based on ICBN rules, the name *Aporum* has priority for use in this new classification.

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