

**TAXONOMY OF SUBTRIBE DENDROBIINAE
LINDLEY (ORCHIDACEAE) OF NEPAL
HIMALAYA**



**A THESIS SUBMITTED TO THE
CENTRAL DEPARTMENT OF BOTANY
INSTITUTE OF SCIENCE AND TECHNOLOGY
TRIBHUVAN UNIVERSITY
NEPAL**

**FOR THE AWARD OF
DOCTOR OF PHILOSOPHY
IN BOTANY**

**BY
BABA MAIYA PRADHAN**

February, 2021

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RECOMMENDATION

This is to recommend that **Ms. Baba Maiya Pradhan** has carried out research entitled **“Taxonomy of Subtribe Dendrobiinae Lindley (Orchidaceae) of Nepal Himalaya”** for the award of Doctor of Philosophy (Ph.D.) in **Botany** under my supervision. To my knowledge, this work has not been submitted for any other degree.

She has fulfilled all the requirements laid down by the Institute of Science and Technology (IOST), Tribhuvan University, Kirtipur for the submission of the thesis for the award of Ph.D. degree.

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February, 2021

LETTER OF APPROVAL

Date: February, 2021

On the recommendation of Prof. Dr. Devendra Mananda Bajracharya, this Ph. D. thesis submitted by Ms. Baba Maiya Pradhan, entitled “**Taxonomy of Subtribe Dendrobiinae Lindley (Orchidaceae) of Nepal Himalaya**” is forwarded by Central Department Research Committee (CDRC) to the Dean, IOST, T.U..

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DECLARATION

Thesis entitled “**Taxonomy of Subtribe Dendrobiinae Lindley (Orchidaceae) of Nepal Himalaya**” which is being submitted to the Central Department of Botany, Institute of Science and Technology (IOST), Tribhuvan University, Nepal for the award of the degree of Doctor of Philosophy (Ph.D.), is a research work carried out by me under the supervision of Prof. Dr. Devendra Mananda Bajracharya.

This research is original and has not been submitted earlier in part or full in this or any other form to any university or institute, here or elsewhere, for the award of any degree.

Baba Maiya Pradhan

February, 2021

ACKNOWLEDGEMENTS

First and foremost, I would like to express my deep and sincere gratitude to my research supervisor Prof. Dr. Devendra Mananda Bajracharya (Amrit Science Campus, retired) for giving me the opportunity to conduct research and providing invaluable guidance throughout my research work. His support and motivation were incredibly helpful for me to carry out my research work. It was a great privilege to work under his guidance.

I am indebted to Dr. Binil Aryal, Dean of Institute of Science and Technology for giving me the permission to undertake this research work. I am grateful to Prof. Dr. Ram Kailash Prasad Yadav, Head of Department, Central Department of Botany for his kind cooperation during my research work. I am indebted to Dr. Laxman Singh Kunwar, Campus Chief, Dr. Madhab Prasad Gautam, former Campus Chief of Patan Multiple Campus, for their kind cooperation to accomplish the research work.

I am extremely grateful to Heads and staffs of Botany Department, Patan Multiple Campus and Amrit Science Campus for their kind assistance and permitting me the laboratory facilities.

I am thankful to curators of herbaria like National Herbarium and Plant Laboratories (KATH) and Tribhuvan University Central Herbarium (TUCH) for permitting me to study the voucher specimens in their holdings.

My special thanks go to Renata Borosova, Royal Botanic Garden Kew (K), John Hunnux, Natural History Museum (BM), Mark Carine, Natural History Museum (BM) and Marie-Helence Weech, Royal Botanic Garden Kew (K) for providing the images of relevant specimens including types during my research work. I express sincere thanks to Andre Schuitman, Royal Botanic Garden Kew (K), Craig Brough, Royal Botanic Garden Kew (K) for sending me the valuable literatures. I am extremely thankful to Robin A. Everly, Librarian of Smithsonian Library, Washington DC, USA and Samantha D'Acunto, Librarian of New York Botanic Garden (NY), USA for their valuable help in providing the photocopy of important literatures.

I am also extending my thanks to Prof. Dr. Mohan Siwakoti, Prof. Dr. Pramod Kumar Jha, Prof. Dr. Krishna Kumar Shrestha, former heads, Central Department of Botany, and the members of CDB for their cooperation. I am extremely grateful to Prof. Dr. Sangeeta Rajbhandary for her helpful suggestions and cooperation.

I express my sincere thanks to Dr. Sudha Joshi, Dr. Ila Shrestha, Dr. Sheetal Vaidya and Rose Shrestha for their valuable suggestions and encouragements to accomplish this research work. I am highly thankful to Ratna Silwal for her help in laboratory work during my research work and also to Rajani Shrestha for providing permission to conduct Microtomy Process in Institute of Medicine, TU. I am also thankful to Alisa Rai for her help during field visits. I am grateful to Sujan Balami for his help to perform cluster analysis.

Sincere thanks go to Bhagirath Sharma, Maan Bahadur Rokaya, La Dorchee Sherpa and Siddhi Bahadur Desai who have helped me in collection of live specimens from field during my research work.

Last, but not the least, I am extremely grateful to my family members especially my husband and my son for their constant help, encouragements and moral support during my research work. Without them it would not be possible to complete this research work.

Baba Maiya Pradhan

February, 2021

ABSTRACT

Subtribe Dendrobiinae of tribe Malaxideae is a taxonomically significant group of family Orchidaceae. Subtribe Dendrobiinae has already been the focus of broad taxonomic and phylogenetic studies based on analysis. The present study was confined to single genus *Dendrobium* s.l. of subtribe Dendrobiinae found in Nepal. The genus *Dendrobium* with ca. 1500 species is considered to have one of the most intricate taxonomic problems in family Orchidaceae because of huge genus and wide range of morphological variations corresponding to its wide area of distribution. From Nepal, 29 species of *Dendrobium* s.l. of subtribe Dendrobiinae were reported. The main objective of this study was to identify the taxonomic significance of various characters such as gross morphological, micromorphological and anatomical characters to solve the taxonomic problems in *Dendrobium* and to clarify the interrelationships among the different species of genus *Dendrobium* using cluster analysis.

The present study was based on a literature review, detailed examination of voucher specimens deposited at different herbaria and live specimens from field observations. Gross morphological, anatomical and micromorphological variations were studied and their taxonomic significance was evaluated. The phylogenetic analysis was carried out based on gross morphological, micromorphological, anatomical characters and anatomical characters. The result of the present study showed that morphological characters such as position and no. of leaves on stem, texture of leaf, orientation of inflorescence, lip variations, nature of ornamentation on disc; the micromorphological characters like type of epidermal cells, type and shape of stomata, presence or absence of stegmata; the anatomical characters of leaf like thickness of cuticle layer, shape and size of epidermal cells, type and no. of mesophyll layers, shape and size of mid vascular bundle, fibre cap layers, stegmata; the anatomical characters of stem like shape and size of epidermal cells, size and no. of vascular bundle, fibre cap layers, stegmata were found to be taxonomically significant in delimiting the species in *Dendrobium*.

Based on the results of gross morphological, micromorphological and anatomical studies, the cluster analysis was carried out in species of *Dendrobium* to find out the interrelationships among the species of *Dendrobium*. Altogether 104 morphological,

micromorphological and anatomical characters were considered for cluster analysis in gross morphological, micromorphological and anatomical analysis. Out of 104 characters, 60 anatomical with micromorphological characters were considered in anatomical analysis.

The cluster dendrogram based on gross morphological, micromorphological and anatomical characters revealed two significant clusters: a cluster with *D. formosum*, *D. moschatum*, *D. chrysanthum*, *D. fimbriatum*, *D. gibsonii*, *D. fugax*, *D. denneanum*, *D. densiflorum* and another cluster with remaining species. The latter cluster was again divided into two distinct clusters: a cluster with *D. anceps*, *D. bicameratum*, *D. crepidatum*, *D. aphyllum*, *D. nobile*, *D. polyanthum*, *D. amoenum*, *D. transparens*, *D. longicornu*, *D. heterocarpum*, *D. moniliforme* and another cluster with remaining species. The cluster formed by *D. eriiflorum* and *D. monticola* showed significant *p*-value. As *D. eriiflorum* was found closely related to *D. monticola*, it can be suggested that these two species may be merged into one species with further researches on it.

The cluster analysis based on anatomical characters revealed two insignificant clusters: a cluster with *D. anceps*, *D. longicornu*, *D. polyanthum*, *D. porphyrochilum*, *D. denudans*, *D. transparens* and another cluster with remaining species. The latter cluster further divided into two clusters: a cluster with *D. moniliforme*, *D. eriiflorum*, *D. monticola*, *D. bicameratum*, *D. amoenum*, *D. aphyllum*, *D. heterocarpum* and another cluster with remaining species. The cluster formed by *D. rotundatum*, *D. amplum*, *D. fuscescens* and another cluster formed by *D. densiflorum*, *D. moschatum* showed significant *p*-values. As *D. rotundatum*, *D. amplum*, *D. fuscescens* were found closely related in a cluster and *D. densiflorum*, *D. moschatum* in another cluster, the further researches on them, may reveal the reshuffling of the species.

From the result of cluster dendrograms, it was revealed that gross morphological characters along with micromorphological and anatomical characters with high significant values rather than the anatomical characters could be used as additional parameters in solving taxonomic problems. With further research into the genus *Dendrobium*, a new classification as well as the phylogeny of the species of *Dendrobium* could be deduced.

The distribution of *Dendrobium* species of Nepal Himalaya was also revised in the present study.

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LIST OF SYMBOLS

°	degree of latitude and longitude
°C	centigrade (temperature)
#	number
∞	very numerous
—	range
×	multiplication sign
%	percentage
<	less than
>	greater than

LIST OF ACRONYMS AND ABBREVIATIONS

ACFPN	Annotated checklist of Flowering Plants of Nepal
AMES	Oakes Ames Orchid Herbarium, Harvard University, USA
BM	The Natural History Museum, London, UK
E	Royal Botanic Gardens, Edinburgh, UK
EFPN	Enumeration of the Floweing Plants of Nepal
GH	The Gray Herbarium of Harvard University, USA
GIS	Geographic Information System
K	Royal Botanic Gardens, Kew, UK
KATH	National Herbarium and Plant Laboratories, Lalitpur, Nepal
M	Botanische Staatssammlung Munchen, Germany
NTFP	Non-Timber Forest Products
NY	New York Botanical Garden, New York, USA
P	Musèum National d’Histoire Naturelle, Paris
S	Swedish Museum of Natural History Department of Botany
SING	Singapore Botanic Gardens, Singapore
TI	University of Tokyo, Japan
TU	Tribhuvan University, Nepal
TUCH	Tribhuvan University Central Herbarium, Nepal
Alt.	Altitude
C	Central
CE	Central and East
ca.	circa: about
cm	centimeter
<i>coll.</i>	collector or collection
<i>coll.?</i>	collector unknown
E	East
e.g.	for example
ed.	edition
<i>et al.</i>	<i>et aliorum</i> : and all
ex	validly published
FAA	Formalin-Acetic-Alcohol

Fig.	Figure
i.e.	<i>id est</i> : that is
km	kilometre
l	length
m	metre
mm	millimeter
µm	micrometer
<i>nom.</i>	<i>nomen</i> : name
<i>nom. cons.</i>	<i>nomen conservandrum</i> : name conserved
<i>nom. illeg.</i>	<i>nomen illegitimum</i> : illegitimate name
<i>nom. rej.</i>	<i>nomen rejiciendum</i> : rejected in favour of particular conserved
<i>non.</i>	not
<i>s. str.</i>	<i>sensu strict</i> : in a narrow sense
<i>s.l.</i>	<i>sensu lato</i> : in a broad sense
<i>s.n.</i>	<i>sine numero</i> : without collection number
S.N.	Serial number
sect.	section
<i>sensu</i>	in the sense of
ser.	series
sp.	species
spp.	species (plural)
T.S.	Transverse Section
var.	variety
viz.	namely
vol.	volume
w	width
WC	West and Central
WCE	West, Central and East

CHAPTER 1.

1. INTRODUCTION

1.1. Background

Orchids which belong to the family Orchidaceae are regarded as one of the largest, most diverse and distinctive family of flowering plants, distributed in the tropical and subtropical regions of the world (Dressler 1981, 1993). Orchids are found all over the world, in every habitat except in the coldest and driest regions, actually they are cosmopolitan (Seidenfaden & Wood, 1992). There are about 29,199 species of orchids present in the world (Govaerts *et al.*, 2017). Orchids, i.e. the members of Orchidaceae are dominant in the flora of Nepal. Nepal harbors about 380 species of orchids including 18 endemic species belonging to 107 genera (Rajbhandari & Rai, 2017).

Dendrobiinae Lindl. belongs to Malaxideae of family Orchidaceae (Chase *et al.* 2015). Dendrobiinae is taxonomically significant component of family Orchidaceae comprising 2 genera *Dendrobium* with approximately 1500 species and *Bulbophyllum* with about 2000 species (Schuitman 2017). According to Dressler (1993) Dendrobiinae comprises 6 genera (*Cadetia*, *Dendrobium*, *Diplocaulibium*, *Epigeneium*, *Flickingeria* and *Pseuderia*) and 1147 species. Dendrobiinae consists of 900 species of *Dendrobium*, 12 species of *Epigeneium* and 70 species of *Flickingeria* (Dressler, 1993). Among them, 26 species of *Dendrobium* and 2 species of *Epigeneium* have been reported from Nepal (Rajbhandari & Rai, 2017). But according to update classification, genera *Epigeneium* and *Flickingeria* were merged into *Dendrobium* s.l. (Schuiteman & Adams, 2014).

Orchids are adapted to a wide variety of habitat from high altitude in the Himalayan Mountains to lowland tropical forests and even to dry climate of the Australian desert. In Nepal they are distributed from tropical to alpine regions. Rajbhandari *et al.* (1999) reported that largest number of epiphytic orchids are found in the lower temperate regions of Central and Eastern Nepal, in sub-alpine region the epiphytic orchids are found in less number and are almost absent in the alpine region.

1.1.1. Family Orchidaceae Juss. nom. cons.

Asia seems to be the first centre of orchid distribution where four subfamilies and five tribes representing the family Orchidaceae. Asia is followed by South America where three subfamilies and four tribes representing the family, and finally Africa representing the family including two subfamilies and three tribes (Chen 1982). Among these areas, orchid diversity is focused in the Eastern Asiatic Region containing twelve genera belonging to five tribes, the Indo-Chinese Region containing nine genera belonging to four tribes and the Malaysian, Caribbean, Venezuela and Surinam, and the Amazon Region containing six genera belonging to two-three tribes (Takhtajan 1969). In the remaining regions the number of genera present is very low. From above data, the Eastern Asiatic Region is considered to be the centre of origin of orchidaceae because of presence of many primitive genera in this region.

According to Dahlgren and Rasmussen (1983), the Orchidaceae is derived from *Liliales s. str.* As Orchidaceae and Burmanniaceae families are included in the same order *Microspermae*, they are closely related to each other (Bentham & Hooker 1883). Orchidaceae is very much similar to Hypoxidaceae regarding the genera *Hypoxis* and *Curculigo* (Rolfe 1910, Hallier 1912, Gobi 1916, Hutchinson 1934, Garay 1960, Rao 1969, Takhtajan 1987). The morphological analysis, phylogenetic analysis, cladistic analysis and the molecular evidence from *rbcL* (ribulose-bisphosphate carboxylase gene sequences supports the proposed relationship between Orchidaceae and Hypoxidaceae (Dressler 1981, 1993, Dahlgren *et al.* 1985, Burns-Balogh & Funk 1986, Judd *et al.* 1993, Dressler & Chase 1995, Cameron *et al.* 1999, Freudenstein & Rasmussen 1999).

Orchids are distributed from Northern Sweden and Alaska to Tirera del Fuego and Macquarie Island in the south. Orchids are most abundant and diverse in the rain forests of these regions (Dressler 1981). On the account of species diversity, South America is the richest with 8266 species followed by Tropical Asia with 6800 species and Tropical Africa with 3131 species (Dressler 1981), within Asia, 1529 species in China, (Chen *et al.* 2009, Cheng *et al.* 2013). But the checklist includes 208 genera and 1695 taxa (Zhou *et al.* 2016). From Thailand, 1200 species (Nanakorn *et al.* 1995), from India, 1150 species (Sonowal & Baruah 2010) and from Malaysia 1000 species (Seidenfaden & Wood 1992) have been reported. In the Himalaya Region,

239 species from western Himalaya (Jalal & Jayanthi, 2015), where as 380 species from Nepal (Rajbhandari & Rai, 2017), 523 species from Sikkim (Lukosom 2007), 369 species from Bhutan (Pearce & Cribb, 2002) and 558 species from Arunachal Pradesh (Rao 2010) are reported. From Myanmar, 836 species are reported (Schuiteman 2013).

The orchids are prized for high ornamental and medicinal values. They are popular among the horticulturist for their floriculture excellence which helps to increase the economic growth of the countries. Many species are grown as ornamental plants. Orchidaceae comprises species hybrids and cultivars of *Cattleya*, *Cymbidium*, *Dendrobium*, *Epidendrum* and *Vanda*. Some of genera such as *Coelogyne*, *Cymbidium*, *Dendrobium* and *Pleione* have most beautiful flowers.

1.1.2. Characters of Orchidaceae

Terrestrial or epiphytic sometimes saprophytic perennial herbs, mostly symbiotic with fungi. Fibrous roots in terrestrial species and hanging cord-like roots in epiphytic species covered by a layer of water absorbing tissue- velamen. Stem of epiphytic species swollen at the base to form pseudobulb with hanging roots. Sympodial or monopodial growth. Leaves simple, entire, alternate rarely opposite or whorled sometimes reduced to scales, often fleshy, distichous and sheathing at the base. Inflorescence basal, lateral or terminal, erect or pendant, racemose or paniculate, one-many flowered. Flower bisexual rarely unisexual, trimerous, irregular in spike, raceme or panicle sometimes solitary. Sepals 3, free or united, green or petaloid. Petals 3, free or united, 2 petals placed on each side of dorsal sepal with median one highly modified called labellum or lip with spur or sac collecting nectar. Sometimes lateral sepals connate to form a saclike structure known as mentum. Stamens 1-2, unite together and extend upto gynoecium forming a column. Pollens usually in waxy masses called pollinia. Carpels 3, syncarpous, ovary inferior, unilocular or trilocular, parietal or axile placentation, style 1, stigma lobes usually 3 of which 2 being fertile and third one modified into small, sterile proliferated outgrowth called rostellum lying between anther and functional stigma lobes. Fruit capsule, containing many thousands of seeds. Seeds very light, small, numerous and nonendospermic.

1.1.3. Classification of Orchidaceae

The family Orchidaceae is the second largest family in the flowering plants after Asteraceae (The Plantlist, 2019). Because of the huge size, the classification of Orchidaceae has been changing and evolving from the very beginning.

The taxonomy of family Orchidaceae has started with Carolus Linneaus (1753). Linneaus included 69 species in 8 genera namely *Orchis*, *Satyrion*, *Ophrys*, *Serapias*, *Limodorum*, *Arethusa*, *Cypripedium* and *Epidendrum* in “Species Plantarum”. He gave the generic name *Epidendrum* to all epiphytic orchids. Three species of these plants later appeared in *Dendrobium*: *Epidendrum moniliforme*, *Epidendrum ovatum* and *Epidendrum carinatum*. *Epidendrum moniliforme* is now *Dendrobium moniliforme* which is the type species of *Dendrobium*.

Antoine Laurent de Jussieu (1789) for the first time recognized the Orchidaceae as the separate family in “Genera Plantarum”.

Olaf Swartz (1800) a Swedish botanist was the first specialist in orchid taxonomy. In orchid taxonomy he wrote the first paper which made distinction between the Diandrae and Monandrae.

John Lindley (1826), the father of orchid taxonomy, divided the most fascinating group of plants orchids into two families’ viz. Apostasiaceae and Orchidaceae. He was the first to recognize the tribes within the families in his “Orchidearum Sceletos (1826). In this work, Lindley divided the orchids into 4 groups viz. Neottieae, Orchideae, Epidendreae and Cypripedieae, which are now recognized as the tribes. However in 1833, he recognized 3 families as Orchideae, Cypripedieae and Apostasieae. In 1836, he added still 1 more family Vanillaceae comprising *Vanilla* and *Epistephium* for species with succulent fruits and unusual seeds. Later, in “The Genera and Species of Orchidaceous Plants”, he recognized 7 tribes viz. Malaxaeae, , Epidendreae, Vandeae, Ophreae, Arethuseae, Neottieae and Cypripedieae and with “sections” or “divisions” for approximately 2000 species of orchids of the family Orchidaceae, based on the anther number and type of pollinarium. His work became the basis on which all modern system of orchid classification was founded.

George Bentham (1881) for the first time recognized 5 tribes and 27 subtribes namely Tribe 1. Epidendreae with 9 subtribes viz. 1. Pleurothalleae, 2. Microstyleae, 3.

Liparideae, 4. Dendrobieae, 5. Erieeae, 6. Bletieae, 7. Coelogynae, 8. Stenoglosseae and 9. Laelieae; Tribe 2. Vandae with 8 subtribes viz. 1. Eulophieae, 2. Cymbidieae, 3. Cyrtopodieae, 4. Stanhopieae, 5. Maxillarieae, 6. Oncidieae, 7. Sarcantheae and 8. Notylieae; Tribe 3 Neottieae with 6 subtribes viz. 1. Vanilleae, 2. Corymbieae, 3. Spirantheae, 4. Diurideae, 5. Arethuseae and 6. Limodoreae; Tribe 4. Ophrydeae with 4 subtribes 1. Serapiadeae, 2. Habenarieae, 3. Diseae and 4. Corycieae and Tribe 5. Cypripedieae without subtribe in the family while preparing a system of classification for *Genera Plantarum*. Bentham's classification was presented in a paper to the Royal Society in 1881. Later on the classification was published in final volume of "*Genera Plantarum*" by George Bentham and Joseph Dalton Hooker in 1883.

Pfitzer (1887) however, criticized the Bentham's classification and gave the revised system of classification recognizing 2 subfamilies viz. Diandrae and Monandrae with 32 tribes and tribes with a number of subtribes. His classification was based primarily on vegetative features. Pfitzer's classification was followed in Engler and Prantl's "*Die Natürlichen Pflanzenfamilien*" with some minor changes. In 1888 and 1889, Pfitzer used the vegetative and column characters to separate the orchids into groups. Pfitzer's classification of Orchidaceae was criticized by many orchidologists for keeping many closely related genera into separate alliances (Balogh and Funk, 1986).

Rudolf Schlechter (1926) modified Pfitzer's classification. In this modified system of classification, Schlechter divided the family Orchidaceae into 2 subfamilies viz. Diandrae and Monandrae, based on the number of anthers. Subfamily Diandrae comprises only one tribe Cypripedilodeae and the subfamily Monandrae however was divided into 2 divisions viz. Basitonae with 1 tribe (Ophrydoideae) and Acrotonae with 2 tribes (Polychondreae and Kerosphaeraeae). The tribes were further divided into subtribes. In Schlechter's classification, categorizations of tribes were based on the anther and pollinarium characters and subtribes were based on vegetative and floral characters.

Mansfeld (1937) reviewed and modified Schlechter's classification. However, he only treated the monoandrous orchids and excluded the diandrous orchids. His groups were basically those of Lindley with many genera reshuffled in different groups.

Dressler and Dodson (1960) presented the complete classification of orchid with keys to the tribes and subtribes and is the first that followed ICBN rules consistently. Orchids in their classification were divided into two subfamilies viz. Cypridioideae (diandrous or Pleoandrous orchids) and Orchidoideae (monandrous orchids). The subfamily Cypridioideae was divided into 2 tribes viz. Apostasioeae and Cypridioeae. However latter subfamily Orchidoideae was divided into 3 tribes viz. Neottieae (with 9 subtribes), Orchideae (4 subtribes) and Epidendreae (27 subtribes) plus 2 tribes of uncertain affinity.

Orchids are divided into 3 distinct families viz. Apostasiaceae, Cypridiaceae and Orchidaceae (Vermeulen 1966; Dahlgreen 1977, 1980; Dahlgreen & Rasmussen 1983; Rasmussen 1985).

Garay (1972) divided Orchidaceae into 5 subfamilies viz. Apostasioideae, Cypridioideae, Orchidoideae, Neottioideae and Epidendroideae comprising 8 tribes; Orchidoideae with 3 tribes viz. 1. Orchideae, 2. Diseae, 3. Disperideae; Neottioideae with 3 tribes viz. 1. Epidogoneae, 2. Neottieae, 3. Cranichideae; Epidendroideae with 2 tribes viz. 1. Epidendreae 2. Vandae and no tribes in Apostasioideae and Cypridioideae.

Burns-Balogh & Funk (1986) made the phylogenetic analysis based on the consistent floral and vegetative characters of the taxa, and the cladogram obtained was used to develop the classification and natural keys for the tribes. Their analysis revealed 7 subfamilies; 3 subfamilies for non-monandrous orchids and 4 subfamilies for Monandrous orchids and 20 tribes. The non-monandrous subfamilies are: 1. Neuwiedioideae, 2. Apostasioideae and 3. Cypridioideae. The Monandrous subfamilies are: 4. Spiranthoideae (tribes; 1. Diurideae, 2. Prasophylleae and 3. Cranichideae), 5. Neottioideae (tribes; 1. Neottieae, 2. Thelymitreae, 3. Geoblasteae and 4. Pterostylideae), 6. Orchidoideae (tribes; 1. Orchideae, 2. Satyrieae and 3. Diseae) and 7. Epidendroideae (tribes; 1. Gastrodieae, 2. Triphoreae, 3. Arethuseae, 4. Vanilleae, 5. Dendrobieae, 6. Epidendreae, 7. Malaxideae, 8. Coelogyneae, 9. Maxillarieae and 10. Vandae).

Dressler (1981) divided the family Orchidaceae into 6 subfamilies (Apostasioideae, Cypridioideae, Spiranthoideae, Orchidoideae, Epidendroideae and Vandoideae).

Dressler (1993) modified his earlier work and divided the family Orchidaceae into 5 subfamilies (Apostasioideae, Cypridioideae, Spiranthoideae, Orchidoideae and Epidendroideae), 22 tribes, 70 subtribes and about 850 genera and 20,000 species. Within the subfamily Epidendroideae, their analysis reported that the tribe Dendrobieae was reported as not monophyletic. His classification was widely accepted by orchidologists.

Szlachetko (1995) divided the family into 8 subfamilies (Thelymitroideae, Orchidoideae, Tropidoideae, Spiranthoideae, Neottioideae, Vanilloideae, Epidendroideae and Vandoideae). Orchidaceae was divided into 3 to 8 subfamilies based on the classification proposed by many taxonomists. The families Apostasiaceae and Cypridiaceae had been regarded as the separate families based on phylogenetic classification (Stern *et al.* 1993b, Judd *et al.* 1993). The family Orchidaceae was divided into 3 subfamilies (Orchidoideae, Neottioideae and Epidendroideae).

Pridgeon *et al.* had published “Genera Orchidacearum” organized in 6 volumes (1999-2014). In the classification Orchidaceae was divided into 5 subfamilies viz. Apostasioideae, Cypridioideae, Orchidoideae, Vanilloideae and Epidendroideae based on morphological characters, molecular data, phylogeny and evolution.

Chase *et al.* (2015) divided Orchidaceae into 5 subfamilies viz. Apostasioideae, Vanilloideae (tribes 1. Pogonieae, 2. Vanilleae), Cypridioideae, Orchidoideae (tribes 1. Cranichideae, 2. Diurideae, 3. Codonorchideae, 4. Orchideae) and Epidendroideae (tribes 1. Neottieae, 2. Sobralieae, 3. Tropidieae, 4. Wulfschlaegeliae, 5. Triphoreae, 6. Xerorchideae, 7. Gastrodieae, 8. Nervilieae, 9. Thaliaeae, 10. Arethuseae, 11. Malaxideae, 12. Cymbidieae, 13. Vandaeae, 14. Podochileae, 15. Collabieae, 16. Epidendreae) based on DNA data.

The most accepted classification system of the family Orchidaceae was proposed by Dressler (1993) based on the anther morphology. The main drawback of Dressler’s classification (1993) was a narrow treatment of Neottiod orchids, as they were kept within subfamily Epidendroideae. The classification of orchids based on the morphology of flowers could never be accurate as they are greatly susceptible to morphological plasticity due to pollinator selection pressure, yet floral characters were used traditionally to classify the family. With the increasing availability of DNA

data and molecular phylogenetic studies, slight different relationships among subfamilies, tribes and subtribes have been revealed. Based on relationship patterns, as revealed by different DNA regions, a new classification of Orchidaceae was proposed by Chase *et al.* (2003). This classification based on morphological and molecular data divided the family Orchidaceae into five subfamilies- Apostasioideae, Vanilloideae, Cyripedioideae, Epidendroideae and Orchidoideae. Chase *et al.* (2015) again revised the classification by including a list of 736 newly recognized genera. The major changes have occurred in subfamily Epidendroideae and Orchidoideae. APG IV system has been published according to which Orchidaceae is divided into five subfamilies which are same as in Chase *et al.* classification (APG IV, 2016). So the classification of Chase *et al.* (2015) was followed in the present study.

Outline classification of Subtribe Dendrobiinae (Chase *et al.*, 2015):

Family: Orchidaceae
 Subfamily: Epidendroideae
 Tribe: Malaxideae
 Subtribe: Dendrobiinae.

1.1.4. Systematic position of *Dendrobium* Sw.

Dendrobium is a dominant genus of Orchidaceae and was established by Olof Swartz in 1799. *Dendrobium moniliforme* (L.) Sw. is the type for *Dendrobium* (Holttum, Brieger & Cribb 1979). *Dendrobium* Sw. (1799) was conserved against *Ceraia* Lour. (1790) and *Callista* Lour. (1790), soon after the principle of conservation was accepted by the Vienna congress of 1905. *D. crumenatum* Sw. was cited as a type species for the genus *Dendrobium* Sw. for the first time in the list of types of conserved names published after the Cambridge Congress of 1930. But *D. crumenatum* is not included in genus *Dendrobium* by Swartz, in the paper in which he established that genus (Nova Acta Reg. Soc. Sci. Upsal 6: 61-88. 1799). He listed it as *Angraecum crumenatum* Rumph. and admitted to the genus in the second paper published in the same year (in Schrader, Jour. Bot. 2: 237). In addition *D. crumenatum* is also improper as type species because it was not included in a section or subgenus Eu-*Dendrobium* by Pfitzer, Kranzlin or Schlechter. Afterwards Holttum *et al.* (1979) proposed the retypification of *Dendrobium* Sw.. As a result of Committee of Spermatophyta (1982), *D. moniliforme* (L.) Sw. is conserved as lectotype of genus *Dendrobium* Sw.. The basionym of *D. moniliforme* is *Epidendrum moniliforme* which

is a Japanese species. *Dendrobium moniliforme* (L.) Sw. was originally described by Linneaus in 1753 as *Epidendrum moniliforme* L. which was later chosen as the type species for *Dendrobium*. The name has been derived from Greek words *Dendron* (“tree”) and *bios* (“life”) meaning “one who lives on trees, or essentially epiphyte”. Species of *Dendrobium* are mostly epiphytes with some are lithophytes. *Dendrobium* Sw. comes under Dendrobiinae and it consists of about 1500 species worldwide (Schuiteman 2017). *Dendrobium* is the second largest genus in Dendrobiinae. The genus with about 1500 species, ranges from Sri Lanka throughout tropical Asia and pacific region, north to Japan, east to Tahiti and south to New Zealand and absent in Africa and America (Schuiteman and Adams, 2014).

1.1.5. Morphology of *Dendrobium* Sw.

Dendrobium Sw. Nova Acta Regiae Soc. Sci. Upsal. ser. 2, 6: 82. 1799; nom. cons.

Dendrobium Sw. is the second largest genus of subtribe Dendrobiinae. The genus is characterized by epiphytic, lithophytic or rarely terrestrial habits. Stems rhizomatous or erect with many nodes, erect with one to several nodes from a many-noded rhizome, tough or fleshy, one to several internodes swollen at base or along whole length to form cane-like stems. Leaves one to many, apical from pseudobulb or arranged distichously along stem, linear, lanceolate, oblong, ovate, papery or coriaceous, apex usually bilobed or emarginate. Inflorescence racemose, lateral or terminal, one to many flowered, erect, horizontal or pendant. Flowers often showy, variable in shape and colour, resupinate or non-resupinate, ephemeral or long-lived. Sepals free, short to filiform, lateral sepals adnate to elongate column foot to form a spur-like mentum. Petals free, margin entire to fimbriate. Lip entire to 3-lobed, base joined to column foot forming a closed spur, disc one to several keeled, verrucose-papillose, with a transverse basal ridge, calli rarely present. Column short, foot long, apical stelidia indistinct to distinct. Pollinia 4 in appressed pairs, naked.

1.1.6. Classification of *Dendrobium* Sw.

Dendrobium belongs to Dendrobiinae (Malaxideae: Epidendroideae: Orchidaceae) (Chase *et al.* 2015). *Dendrobium* is the second largest genus in the family Orchidaceae with about 1500 species ((Schuitman 2017). After the establishment of *Dendrobium* by Swartz (1799), various classifications have been proposed time to time.

Lindley (1829) established Dendrobiinae, firstly recognizing four sections in *Dendrobium* (Lindley 1830), and later expanding the number of sections to 10 (Lindley & Paxton, 1851). Schlechter (1912) proposed an infrageneric system of *Dendrobium* with four subgenera and 41 sections, which was followed by most authors with a few modifications recognizing a broad *Dendrobium* with a reasonably natural infrageneric system at section level (not at subgenus level). Kraenzlin (1910) in his monograph of *Dendrobium* divided the genus into ten subgenera which was also accepted by Schlechter in 1912. *Dendrobium* belongs to the subfamily Epidendroideae, tribe Epidendreae, sub tribe Dendrobiinae (Seidenfaden & Wood, 1992). In classification based on DNA proposed by Chase *et al.* in 2003, *Dendrobium* is placed in the sub family Epidendroideae, tribe Epidendreae, sub tribe Dendrobiinae. In update classification of Chase *et al.* in 2015, *Dendrobium* belongs to sub family Epidendroideae, tribe Malaxideae, sub tribe Dendrobiinae.

1.1.7. Tribe, Sub-tribe and Sectional delimitations of *Dendrobium*

1.1.7.1. Malaxideae Lindl. Coll. Bot., App. 1826.

Malaxideae is a tribe of subfamily Epidendroideae consisting of 1000 species (Cameron 2005). They are distributed in both temperate and tropical areas throughout the world. High no. of obligate, terrestrial and epiphytic species is present in Malaxideae (Atwood 1986).

Malaxideae is characterized by terrestrial or rarely epiphytic sympodial herbs. Stem fleshy, cylindric to pseudobulbous, creeping and rooting in basal part. Leaves plicate, thin textured to fleshy, sheathing at base. Inflorescences unbranched, erect racemose. Floral bracts lanceolate, persistent. Flower resupinate or not resupinate, yellow, pink, green, purple or brown. Dorsal sepal free, spreading and lateral sepals free or fused, spreading. Petals free, spreading, narrower than sepals, lip simple to lobed, flat, auriculate at base, apical margin entire or toothed, spur lacking, cushionlike or obscurely transversely ridged. Column without foot. Anther attached by a slender filament. Naked pollinia, usually four, without appendages. Stigma semicircular or ovate.

Lindley (1830) was the first to divide the family Orchidaceae into distinct 7 tribes. Among 7 tribes, one of the tribe was Malaxideae. There was no subfamily. But unfortunately Lindley's classification of many species was considered unintuitive and

incorrect. After Lindley (1830), Bentham (1881), Pfitzer (1887), Schlechter (1926), Dressler and Dodson (1960), Dressler (1960, 1981, 1993), Garay (1972), Pridgeon *et al.* (2014) and Chase *et al.* (2015) reviewed the taxonomy. In Dressler classification (1993) Dendrobiinae was placed in Dendrobieae whereas in Chase *et al.* (2015) classification Dendrobiinae was placed in Malaxideae. Chase *et al.* (2015) combined tribes Dendrobieae and Malaxideae into a single tribe Malaxideae with 2 subtribes Dendrobiinae and Malaxidinae.

1.1.7.2. Dendrobiinae Lindl. ex Endl. Hort. Brit. (Sweet), ed. 3. 638 (1839).

Dendrobiinae are characterized by the presence of stem with pseudobulb, distichous or duplicate leaves, spiral flowers with basally jointed lips with prominent spurs formed by the column foot and four naked pollinia in two pairs. The members of Dendrobiinae thrive in diverse habitats with respect to substrates, moisture regimes, elevations, latitudes and exposures.

Dendrobiinae Lindl. comprises a diverse group of epiphytic, lithophytic and terrestrial herbs classified in six genera (Dressler 1993). Species of this sub tribe occurred mainly throughout paleotropical regions with extensions to temperate Asia (Seidenfaden & Woods 1992), the Philippines, the Malay Archipelago, New Guinea, Australia, New Caledonia, south-west pacific islands, and New Zealand (Clements, 2003).

Dendrobiinae was created as a section within Malaxideae Lindl., with the description and illustration of *Dendrobium secundum* (Blume) Lindl. in the Botanical Magazine (Lindley 1829). Then after Lindley enumerated his concept of Dendrobiinae embracing 20 genera and grouping them together on the possession of two, four or eight pollinia (Lindley 1830).

Bentham and Hooker (1883) recognized only 5 tribes (Epidendreae, Vandaeae, Neottieae, Ophrydeae and Cypripedieae) and 27 subtribes. They recognized subtribes for the first time. They placed subtribe Dendrobieae under the tribe Epidendreae.

Then after subsequent authors Pfitzer (1889), Schlechter (1926), Dressler and Dodson (1960) and Dressler (1981), have progressively narrowed the interpretation of the Dendrobiinae.

Brieger (1981) proposed major changes dividing subtribe Dendrobiinae into 44 genera grouped into 6 series. Many of his genera are traditional sectional groups. He made

many artificial associations, the most egregious being mixing of *Eria* and *Dendrobium*. He also made many mistakes regarding names and taxonomic details. His classification was artificial and rejected.

Dressler (1993) in his most recent of the morphology-based classifications of Orchidaceae recognised only six genera with approximately 1147 species within Dendrobieae viz *Cadetia* Gaudich. (67 spp.), *Dendrobium* Sw. (ca. 900 spp.), *Diplocaulobium* Kraenzl. (94 spp.), *Epigeneium* Gagnep. (12 spp.), *Flickingeria* A. Hawkes (70 spp.) and *Pseuderia* Schltr. (4 spp.).

Pridgeon *et al.* (2014) placed Dendrobieae in Dendrobieae. Dendrobieae comprises 2 genera *Dendrobium* Sw. s. l. (1500 spp.) and *Bulbophyllum* Thouars (2000 spp.)

Chase *et al.* (2015) in the update classification placed Dendrobieae in Malaxideae because Dendrobieae has clear relationship with Malaxideae based on low-copy nuclear gene *Xdh* (Gorniak *et al.* 2010), and plastid DNA (Xiang *et al.* 2012).

Dendrobieae is taxonomically significant component of family Orchidaceae comprising 2 genera (*Dendrobium* Sw. s.l. and *Bulbophyllum* Thouars). This subtribe consists of 1500 species of *Dendrobium* Sw. s.l. and 2000 species of *Bulbophyllum* Thouars (Schuitman 2017). Out of two genera, only genus *Dendrobium* Sw. is considered in the present study. According to Dressler classification (1993) subtribe Dendrobieae comprises 3 genera *Dendrobium*, *Epigeneium* and *Flickingeria* from Nepal Himalaya. But according to update classification, genera *Epigeneium* and *Flickingeria* were merged into genus *Dendrobium* s.l. (Schuiteman & Adams, 2014).

1.1.7.3. Sectional delimitations in *Dendrobium* Sw.

Dendrobium (Epidendroideae; Malaxideae; Dendrobieae) is the second largest genus in the Orchidaceae. Various generic delimitations and infrageneric systems have been proposed by Kranzlin 1910, Schlechter 1912, Brieger 1981, Seidenfaden 1985, Clements 2006, Wood 2006, Schuitman and Adams 2014 based on the morphological and molecular characters after the establishment of *Dendrobium* by Swartz in 1799.

Blume (1825) divided *Dendrobium* into 7 sections: *Pedilonum*, *Onychium*, *Desmotrichum*, *Grastidium*, *Aporum*, *Macrostromum* and *Oxystophyllum* based on the

floral characters but later in the same year he gave it generic rank. Blume's genera have been reduced to sections of *Dendrobium* by most successive authors.

Lindley (1844a) divided *Dendrobium* into 4 sections viz. *Eudendrobium*, *Stachyobium*, *Ceratobium* and *Pedilonum* (Table 1).

Lindley & Paxton (1850) revised the 4 sections of *Dendrobium* and raised it upto 10 sections. Sect. I. *Aporum*, Sect. II. *Strongyle*, Sect. III. *Desmotrichum*, Sect. IV. *Eudendrobium*: This section is divided into 2 divisions based on the form of the lip.

Lip undivided and Lip three-lobed. Sect. V. *Pedilonum*, Sect. VI. *Stachyobium*: This section is divided into 2 divisions based on the form of the lip. Lip undivided and Lip three-lobed, Sect. VII. *Ceratobium*, Sect. VIII. *Dendrocoryne*, Sect. IX. *Bolbodium*, Sect. X. *Rhizobium* (Table 1).

Lindley (1858) expanded his sectional arrangement based on the study of more than 200 species and noted that all had four pollinia-masses nearly equal in size and of uniform breadth at either end. His review work was focused on Asian orchids. He divided *Dendrobium* into 10 sections. Two new sections, *Holochrysa* and *Aclinia* were recognized. Section *Dendrocoryne* included earlier sections *Desmotrichum* and *Bolbodium*. Sections are as included Sect. I. *Aporum* Blume, Sect. II. *Strongyle* Lindl., Sect. III. *Rhizobium* Lindl., Sect. IV. *Dendrocoryne* Lindl., Sect. V. *Holochrysa* Lindl., Sect. VI. *Aclinia* Griffith, Sect. VII. *Eudendrobium* Lindl.: Section *Eudendrobium* is divided into 2 divisions based on the characters of stem. Stem short and fleshy and Stem elongate: This division is divided into 3 groups based on the characters of labellum, Sect. VIII. *Pedilonum* Blume, Sect. IX. *Stachyobium* Lindl.: This section is divided into 2 divisions based on the characters of labellum, Sect. X. *Ceratobium* Lindl (Table 1).

Miquel (1859) divided *Dendrobium* into 12 sections. He included 3 sections in addition to Lindley's sections with the exclusion of Section *Rhizobium*. His broad sectional concept included some species which have been placed elsewhere by succeeding authors. The sections are: Sect. I. *Aporum* Blume, Sect. II. *Strongyle* Lindl., Sect. III. *Dendrocoryne* Lindl., Sect. IV. *Holochrysa* Lindl., Sect. V. *Aclinia* Griffith, Sect. VI. *Eudendrobium* Lindl., Sect. VII. *Pedilonum* Blume, Sect. VIII.

Stachyobium Lindl., Sect. IX. *Ceratobium* Lindl., Sect. X. *Sarcostoma* Blume, Sect. XI. *Oxytophyllum* Blume and Sect. XII. *Latouria* Blume (Table 1).

Bentham & Hooker (1883) reduced Lindley's ten sections of *Dendrobium* to seven sections, dividing section *Stachyobium* into 6 series and section *Eudendrobium* into 5 series. The sections are: Sect. I. *Aporum*; Sect. II. *Rhizobium*; Sect. III. *Cadetia*; Sect. IV. *Sarcopodium*; Sect. V. *Stachyobium* with 6 series viz. a. Humiles, b. Germinatae, c. Eriaeflorae, d. Elatiores, e. Speciosae, and f. Ramosissimae; Sect. VI. *Strongyle* and Sect. VII. *Eudendrobium* with 5 series viz. a. Pycnostachya, b. Formosae, c. Calostachyae, d. Fasciculata and e. Foliosae.

Pfitzer (1889) divided *Dendrobium* into 11 sections. Sections are as follows:

Sect. I. *Eudendrobium* Lindl.: This section is divided into 10 subsections. Subsect. 1. *Calceolaria*, Subsect. 2. *Chrysostachya*, Subsect. 3. *Rhodostachya*, Subsect. 4. *Chrysantha*, Subsect. 5. *Nobilia*, Subsect. 6. *Nigrohirsuta*, Subsect. 7. *Pedilonum*, Subsect. 8. *Perulacea*; Subsect. 9. *Trilobata* and Subsect. 10. *Antennata*; Sect. II. *Crumentata* Pfitzer; Sect. III. *Ampullaria* Pfitzer; Sect. IV. *Dendrocoryne* Lindl.; Sect. V. *Desmotrichum* Lindl.; Sect. VI. *Crinifera* Pfitzer; Sect. VII. *Bolbodium* Lindl.; Sect. VIII. *Sarcopodium* Lindl.; Sect. IX. *Diplocaulobium* Rchb.f.; Sect. X. *Rhizobium* Lindl.; Sect. XI. *Strongyle* Lindl (Table 1).

Hooker (1890) working on Indian orchids devised a different system for *Dendrobium*. He divided *Dendrobium* into 12 sections belonging to 2 series based on lateral or terminal inflorescences. Series 1. Inflorescence terminal (from base of a terminal arrested internode) or both terminal and lateral. Sections under Series 1. are as follows: Sect. I. *Sarcopodium*; Sect. II. *Bolbodium*; Sect. III. *Cadetia*; Sect. IV. *Stachyobium*: Side lobes of lip strongly inciso-serrate and Side lobes of lip entire, serrulate or crenulate; Sect. V. *Formosae*. Series 2. Inflorescence lateral on the stem or pseudobulb. Sections under Series 2 are: Sect. VI. *Aporum*; Sect. VII. *Strongyle*; Sect. VIII. *Virgatae*; Sect. IX. *Breviflores*; Sect. X. *Pedilonium*; Sect. XI. *Distichophyllae*; Sect. XII. *Eudendrobium* (Table 1).

Kranzlin (1910) included 10 subgenera and 27 sections *Dendrobium*. Subgenera and sections are: Subg. I. *Eudendrobium*: It is divided into 9 sections. Sect. 1. *Nobilia*; Sect. 2. *Aurea*; Sect. 3. *Aquea*; Sect. 4. *Stuposa*; Sect. 5. *Macrostachya*; Sect. 6.

Chrysotoxa; Sect. 7. *Anisopetala*; Sect. 8. *Herbacea*; Sect. 9. *Stachyobia*; Subg. II. *Nigro-hirsuta*; Subg. III. *Pedilonum*: It is divided into 5 sections: Sections 1. *Secunda*, 2. *Glomerata*, 3. *Capitata*, 4. *Ceratobium*, 5. *Brevisaccata*. Subg. IV. *Grastidium*: It is divided into 4 sections. Sections 1. *Conostalix*, 2. *Angustifolia* s. *Bambusacea*, 3. *Revoluta*, 4. *Eugrastidium*. Subg. V. *Aporum*: It is divided into 2 sections: Sect. 1. *Hemiphylla*; Sect. 2. *Homophylla*. Subg. VI. *Strongyle*, Subg. VII. *Crumenata*, Subg. VIII. *Dendrocoryne*: It includes 7 sections. Sections 1. *Tokai*; 2. *Trachytheca*; 3. *Leiotheca*; 4. *Superbientia*; 5. *Euphlebia*; 6. *Platycaula*; 7. *Speciosa*. Subg. IX. *Bolbodium*, Subg. X. *Rhizobium*. Kranzlin's work has been much criticized and has not been widely adopted (Table 1).

Smith (1905b) described 68 species *Dendrobium* from Java under 10 sections. Sect. I. *Bolbodium* Lindl.; Sect. II. *Desmotrichum* Bl.; Sect. III. *Crumenata* Pfitz.; Sect. IV. *Strongyle* Lindl.; Sect. V. *Aporum* Bl.; Sect. VI. *Oxystophyllum* Bl.; Sect. VII. *Fugacia* J. J. S.; Sect. VIII. *Sarcopodium* Lindl.; Sect. IX. *Dendrocoryne* Lindl.; Sect. X. *Grastidium* Bl.

Schlechter (1912) divided *Dendrobium* into 41 sections arranged in 4 subgenera. Schlechter's system of *Dendrobium* classification has been used for nearly 90 years. Subgenera are as follows: Subg. I. *Authceebium*: Leaves without leaf sheaths. This subgenus is divided into 12 sections. Sect. 1. *Desmotrichum*, Sect. 2. *Microphytanthe*, Sect. 3. *Goniobulbon*, Sect. 4. *Diplocaulobium*, Sect. 5. *Bolbidium*, Sect. 6. *Euphlebiun*, Sect. 7. *Rhizobium*, Sect. 8. *Sarcopodium*, Sect. 9. *Dendrocoryne*, Sect. 10. *Latourea*, Sect. 11. *Inobulbon*, Sect. 12. *Callista*. Subg. II. *Eu-Dendrobium*: Thick stems bearing leaf sheaths. This subgenus is divided into 2 groups based on the characters of lip. Group I. Lip entire. Under this group there are 6 sections. Sect. 1. *Eugenanthe*; Sect. 2. *Platycaulon*; Sect. 3. *Pedilonum*; Sect. 4. *Calyptrochilus*; Sect. 5. *Cuthbertsonia*; Sect. 6. *Oxyglossum*. Group II. Lip three-lobed. Under this group there are 11 sections. Sect. 1. *Brachyanthe*: This includes *D. bicameratum*; Sect. 2. *Stachyobium*; Sect. 3. *Fytchianthe*; Sect. 4. *Phalaenanthe*; Sect. 5. *Eleutheroglossum*; Sect. 6. *Ceratobium*; Sect. 7. *Trachyrhizum*; Sect. 8. *Distichophyllum*; Sect. 9. *Oxygenianthe*; Sect. 10. *Amblyanthus*; Sect. 11. *Kinetochilus*. Subg. III. *Rhopalobium*: Basal thickening of the stem. This subgenus consists of one section. Sect. *Rhopalanthe*; Subg. IV. *Xerobium*: Thin wiry stems. This subgenus is divided into 11

sections. Sect. 1. *Aporum*, Sect. 2. *Oxystophyllum*, Sect. 3. *Grastidium*, Sect. 4. *Dichopus*, Sect. 5. *Eriopexis*, Sect. 6. *Pleianthe*, Sect. 7. *Macrocladium*, Sect. 8. *Dolichocentrum*, Sect. 9. *Conostalix*, Sect. 10. *Monanthos*, Sect. 11. *Herpethophytum* (Table 1).

Brieger (1981) divided subtribe Dendrobiinae into 28 genera grouped into six series. He raised many recognized sections to genera and also made many artificial associations, the worse being mixing together fragments of *Eria* and *Dendrobium*. *Dendrobium* was included in Series Dendrobia. *Dendrobium* is divided into 2 subgenera *Dendrobium* with 5 sections and *Stachyobium* with 5 sections. Brieger's classification was rejected as it was considered as artificial. Subgenera and sections of *Dendrobium* are: Subg. I. *Dendrobium*: Relatively small inflorescences at right angles to the axis of the spur. It includes 5 sections. Sect. 1. *Dendrobium*, Sect. 2. *Nigrohirsuta* Lindl., Sect. 3. *Stuposa* Krzl.; Sect. 4. *Distichophylla* Hook.f.; Sect. 5. *Breviflores* Hook.f.; Subg. II. *Stachyobium* Lindl.: Ascending inflorescence sometimes quite long inflorescence. It includes 5 sections. Sect. I. *Stachyobium*; Sect. II. *Anisopetala*; Sect. III. *Phalaenanthe*; Sect. IV. *Ceratobium*; Sect. V. *Eleutheroglossum* (Table 1).

Seidenfaden (1985) has followed Schlechter scheme for the Dendrobiinae. He has not changed the established sectional names. His work mainly based on Orchids of Thailand and includes most of the Asian taxa and as well as Malesian species.

Wood (2006) recognized 44 sections in *Dendrobium* (9 sections in northern Asian group, 12 sections in southern Malesian group, 11 sections in northern Malesian group and 12 sections in southern Australian group), 3 sections in *Epigeneium* and 3 sections in *Flickingeria*. *Dendrobium*: Sections of *Dendrobium* in northern Asian group were considered here because *Dendrobium* species of Nepal Himalaya were included in this Asian group. Sect. 1. *Dendrobium*: It is divided into 4 subgroups based on bloom style and physical features; Sect. 2. *Holochrysa* Lindl.; Sect. 3. *Densiflora* Finet; Sect. 4. *Breviflores* Hk. f.; Sect. 5. *Stuposa* Kraenzl; Sect. 6. *Formosae* (Benth. and Hk.f.) Hk. f.; Sect. 7. *Stachyobium* Lindl.; Sect. 8. *Fytchianthe* Schltr.; Sect. 9. *Herbacea* Kraenzl.. *Epigeneium*: *Epigeneium* is divided into 3 sections: Sect. 1. *Epigeneium*; Sect. 2. *Katherinea*; Sect. 3. *Racemosum*.

Flickingeria: *Flickingeria* is divided into 3 sections. Sect. 1. *Flickingeria*; Sect. 2. *Plicatiles*; Sect. 3. *Bilobulatae* (Table 1).

Schuitman and Adams (2014) rearranged the sections and divided *Dendrobium* into 30 sections. They included 2 genera *Epigeneium* F. Gagnepain and *Flickingeria* A. D. Hawkes into *Dendrobium*. *Dendrobium* is divided into 30 sections. Sect. 1. *Ablyanthus*; Sect. 2. *Aporum*; Sect. 3. *Biloba*, Sect. 4. *Brevisacat*; Sect. 5. *Cadetia*; Sect. 6. *Calyptrochilus*; Sect. 7. *Conostalix*; Sect. 8. *Crinifera*; Sect. 9. *Dendrobium*; Sect. 10. *Dendrocoryne*; Sect. 11. *Diplocaulobium*; Sect. 12. *Distichophyllae*; Sect. 13. *Eleutheroglossum*; Sect. 14. *Formosae*; Sect. 15. *Fugacia*; Sect. 16. *Fytchianthe*; Sect. 17. *Grastidium*; Sect. 18. *Herpethophytum*; Sect. 19. *Latouria*; Sect. 20. *Lichenastrum*; Sect. 21. *Macrocladium*; Sect. 22. *Microphytanthe*; Sect. 23. *Monophyllaea*; Sect. 24. *Pedilonum*; Sect. 25. *Phalaenanthe*; Sect. 26. *Pleianthe*; Sect. 27. *Rhizobium*; Sect. 28. *Sarcopodium*; Sect. 29. *Spatulata*; Sect. 30. *Stachyobium* on the basis of nature of stem or pseudobulb, leaves, inflorescence, flower, lip and column characters (Table 1).

In the present study, out of 30 sections (Schuitman and Adams, 2014) only 6 sections have been accepted as the species of *Dendrobium* of Nepal come under these sections. Sect. 2. *Aporum* Blume: *D. anceps* Sw.; Sect. 8. *Crinifera* Pfitzer: *D. fugax* Rchb.f. and *D. plicatile* Lindl.; Sect. 9. *Dendrobium*: *D. amoenum* Wall. ex Lindl., *D. aphyllum* (Roxb.) C.E.C. Fisch, *D. bicameratum* Lindl., *D. chrysanthum* Wall. ex Lindl., *D. chryseum* Rolfe, *D. crepidatum* Lindl. & Paxton, *D. denneanum* Kerr, *D. densiflorum* Wall., *D. fimbriatum* Hook., *D. gibsonii* Paxton, *D. heterocarpum* Wall. ex Lindl., *D. moniliforme* (L.) Sw., *D. moschatum* (Buch.-Ham.) Sw., *D. nobile* Lindl., *D. polyanthum* Wall. ex Lindl. and *D. transparens* Wall. ex Lindl.; Sect. 14. *Formosae* (Benth. & Hook.f.) Hook.f.: *D. formosum* Roxb. ex Lindl. and *D. longicornu* Lindl.; Sect. 28. *Sarcopodium* Benth. & Hook.f.: *D. amplum* Lindl., *D. fuscescens* Griff. and *D. rotundatum* (Lindl.) Hook.f.; Sect. 30. *Stachyobium* Lindl.: *D. darjeelingense* Pradhan, *D. denudans* D. Don, *D. eriiflorum* Griff., *D. monticola* P.F.Hunt & Summerh and *D. porphyrochilum* Lindl..

Table 1: Sectional delimitations in *Dendrobium* Sw. (Orchidaceae)

Taxa	Lindley (1844a)	Lindley & Paxton (1850)	Lindley (1858)	Miquel (1859)	Pfitzer (1889)	Hooker (1890)	Kranzlin (1910)	Schlechter (1912)	Brieger (1981)	Wood (2006)	Schuitman & Adams (2014)	Present work (2021)
<i>D. amoenum</i>	<i>Eudend</i>	<i>Eudend</i>	<i>Eudend</i>			<i>Eudend</i>	<i>Macro</i>			<i>Dendro</i>	<i>Dendro</i>	<i>Dendro</i>
<i>D. amplum</i>		<i>Rhizo</i>			<i>Sarco</i>	<i>Sarco</i>					<i>Sarco</i>	<i>Sarco</i>
<i>D. anceps</i>			<i>Aporu</i>			<i>Aporu</i>	<i>Aporu</i>				<i>Aporu</i>	<i>Aporu</i>
<i>D. aphyllum</i>										<i>Dendro</i>	<i>Dendro</i>	<i>Dendro</i>
<i>D. bicameratum</i>	<i>Stachy</i>	<i>Stachy</i>				<i>Brevif</i>	<i>Stachy</i>	<i>Brachy</i>	<i>Brevif</i>	<i>Brevif</i>	<i>Dendro</i>	<i>Dendro</i>
<i>D. chrysanthum</i>	<i>Eudend</i>	<i>Eudend</i>			<i>Eudend</i>	<i>Eudend</i>	<i>Aure</i>		<i>Dendro</i>	<i>Dendro</i>	<i>Dendro</i>	<i>Dendro</i>
<i>D. chryseum</i>						<i>Eudend</i>				<i>Holoch</i>	<i>Dendro</i>	<i>Dendro</i>
<i>D. crepidatum</i>		<i>Eudend</i>				<i>Eudend</i>	<i>Nobili</i>			<i>Dendro</i>	<i>Dendro</i>	<i>Dendro</i>
<i>D. darjeelingense</i>										<i>Stachy</i>	<i>Stachy</i>	<i>Stachy</i>
<i>D. denneanum</i>											<i>Dendro</i>	<i>Dendro</i>
<i>D. densiflorum</i>		<i>Dend</i>			<i>Desmo</i>	<i>Eudend</i>	<i>Chryso</i>			<i>Densi</i>	<i>Dendro</i>	<i>Dendro</i>
<i>D. denudans</i>	<i>Stachy</i>	<i>Stachy</i>	<i>Stachy</i>			<i>Stachy</i>	<i>Stachy</i>		<i>Stachy</i>	<i>Stachy</i>	<i>Stachy</i>	<i>Stachy</i>
<i>D. eriiflorum</i>			<i>Stachy</i>			<i>Stachy</i>	<i>Stachy</i>	<i>Stachy</i>		<i>Stachy</i>	<i>Stachy</i>	<i>Stachy</i>
<i>D. fimbriatum</i>	<i>Stachy</i>	<i>Stachy</i>		<i>Dend</i>	<i>Eudend</i>	<i>Eudend</i>	<i>Aure</i>		<i>Dendro</i>	<i>Holoch</i>	<i>Dendro</i>	<i>Dendro</i>
<i>D. formosum</i>	<i>Stachy</i>	<i>Stachy</i>	<i>Eudend</i>		<i>Eudend</i>	<i>Formos</i>	<i>Nigro</i>	<i>Oxygen</i>	<i>Nigro</i>	<i>Formos</i>	<i>Formos</i>	<i>Formos</i>
<i>D. fugax</i>											<i>Crini</i>	<i>Crini</i>
<i>D. fuscescens</i>						<i>Sarco</i>					<i>Sarco</i>	<i>Sarco</i>
<i>D. gibsonii</i>						<i>Eudend</i>	<i>Aure</i>			<i>Holoch</i>	<i>Dendro</i>	<i>Dendro</i>
<i>D. heterocarpum</i>	<i>Eudend</i>					<i>Eudend</i>	<i>Aure</i>		<i>Dendro</i>	<i>Dendro</i>	<i>Dendro</i>	<i>Dendro</i>
<i>D. longicornu</i>	<i>Eudend</i>	<i>Eudend</i>	<i>Eudend</i>			<i>Formos</i>	<i>Nigro</i>		<i>Nigro</i>	<i>Formos</i>	<i>Formos</i>	<i>Formos</i>
<i>D. moniliforme</i>	<i>Eudend</i>	<i>Eudend</i>				<i>Eudend</i>	<i>Macro</i>			<i>Dendro</i>	<i>Dendro</i>	<i>Dendro</i>

<i>D. monticola</i>										<i>Stachy</i>	<i>Stachy</i>	<i>Stachy</i>
<i>D. moschatum</i>	<i>Stachy</i>	<i>Stachy</i>			<i>Eudend</i>		<i>Aure</i>		<i>Dendro</i>	<i>Holoch</i>	<i>Dendro</i>	<i>Dendro</i>
<i>D. nobile</i>	<i>Eudend</i>	<i>Eudend</i>	<i>Eudend</i>		<i>Eudend</i>	<i>Eudend</i>	<i>Nobili</i>		<i>Dendro</i>	<i>Dendro</i>	<i>Dendro</i>	<i>Dendro</i>
<i>D. plicatile</i>											<i>Crini</i>	<i>Crini</i>
<i>D. polyanthum</i>	<i>Stachy</i>	<i>Stachy</i>				<i>Eudend</i>	<i>Nobili</i>		<i>Dendro</i>	<i>Dendro</i>	<i>Dendro</i>	<i>Dendro</i>
<i>D. porphyrochilum</i>			<i>Stachy</i>			<i>Stachy</i>	<i>Stachy</i>			<i>Stachy</i>	<i>Stachy</i>	<i>Stachy</i>
<i>D. rotundatum</i>						<i>Sarco</i>					<i>Sarco</i>	<i>Sarco</i>
<i>D. transparens</i>	<i>Eudend</i>	<i>Eudend</i>	<i>Eudend</i>			<i>Eudend</i>	<i>Macro</i>			<i>Dendro</i>	<i>Dendro</i>	<i>Dendro</i>

Abbreviations used: *Eudend*= *Eudendrobium*, *Stachy*= *Stachyobium*, *Rhizo*= *Rhizobium*, *Dend*=*Dendrocoryne*, *Aporu*= *Aporum*, *Sarco*= *Sarcopodium*, *Desmo*= *Desmotrichum*, *Brevif*= *Breviflores*, *Formos*= *Formosae*, *Macro*= *Macrostachya*, *Aure*= *Aurea*, *Nobili*= *Nobilia*, *Chryso*= *Chrysotoxa*, *Nigro*= *Nigrohirsuta*, *Brachy*= *Brachyanthe*, *Oxygen*= *Oxygenianthe*, *Holoch*= *Holochrysa*, *Densi*= *Densiflora*, *Crini*= *Crinifera*.

1.2. Rationale of the Study

Subtribe Dendrobiinae is a significant group in subfamily Epidendroideae which has been regarded as largest, most diverse and difficult subfamily to classify and interpret phylogenetically (Dressler 1981, Cameron *et al.* 1999). Subtribe Dendrobiinae has already been the focus of a broad taxonomic and phylogenetic studies based on analysis (Brieger, 1981). Dressler (1993) pointed out that anatomical work on the Orchidaceae is needed as it has been rather spotty and may well be one of the best hopes for additional derived features. The cladistic analysis based on morphology, micromorphology, anatomy and DNA will required for better understanding of the phylogeny of subtribe Dendrobiinae (Morris, Stern & Judd, 1996). In subtribe Dendrobiinae, only certain species have been studied anatomically as part of a broad investigation. The study has showed the usefulness of vegetative anatomical characters in the phylogenetic analysis of the group. Although morphological and floristic studies of Orchidaceae have been carried out extensively, anatomical investigations are yet inadequate on Orchids from Nepal. Only a few anatomical characters have been explored by some of the workers as a supplementary portion on the revision of respective genera *Eria* (Bajracharya, 2003), *Oberonia* (Shakya, 1999), *Coelogyne* (Dangol, 2006) and *Dendrobium* (Shrestha *et al.* 2010) in Nepal. The phylogenetic interpretations on the basis of morphological and anatomical characters have not yet been recorded in this subtribe Dendrobiinae. Hence this study has been done on gross morphological, micromorphological and anatomical characters in solving the taxonomic problems existing within the species of subtribe Dendrobiinae of Nepal Himalaya.

1.3. Research Questions

1. What are different species of *Dendrobium* present in Nepal?
2. What are the gross morphological, micromorphological and anatomical variations within different species of *Dendrobium* of Nepal?
3. What are the interrelationships among different species of *Dendrobium* based on grossmorphological, micromorphological and anatomical characters?

1.4. Objectives of the Study

General objective of the present study is:

To carry out the macro and micromorphological study of different species of *Dendrobium* of Nepal Himalaya.

The specific objectives are stated as below:

1. To record the geographical distribution of different species of *Dendrobium* of Nepal Himalaya.
2. To study gross-morphological, micromorphological and anatomical variations within different species of *Dendrobium* and to find out their significance in taxonomy.
3. To establish the interrelationships within the different species of *Dendrobium* using cluster analysis based on morphological, micromorphological and anatomical characters.

CHAPTER 2.

2. LITERATURE REVIEW

Dendrobium Sw. is one of the largest and most problematic genus of subtribe Dendrobiinae. The exploration of the orchid flora of Nepal begins in 1802 with the collections by Buchanan-Hamilton. D. Don published “Prodromus Florae Nepalensis” in 1825 based on the plant collections of Buchanan-Hamilton and Wallich. Wallich published “Tentamen Florae Nepalensis” in 1824-1826.

Buchanan-Hamilton (1802-1803) described *Epidendron moschatum* (= *Dendrobium moschatum*) in his unpublished manuscript from Nepal where as **Hooker (1823)** described *Dendrobium fimbriatum* from Nepal. Later on **Don (1825)** described *Dendrobium moschatum*, *Dendrobium denudans* from Wallich’s collection of Nepal in Prodromus Florae Nepalensis. **Wallich (1830)** described *Dendrobium aphyllum*, *D. formosum*, *D. densiflorum*, *D. heterocarpum* and *D. moschatum* in Plantae asiaticae rariores. **Lindley (1830)** described *Dendrobium longicornu* from Nepal and *Dendrobium formosum* from Nepal in 1839. Besides that **Lindley (1859)** described 72 species of *Dendrobium* is described from India included *D. anceps*, *D. eriiflorum*, *D. longicornu*, *D. nobile*, *D. amoenum*, *D. transparens*, *D. primulinum*, *D. pierardi*, *D. pulchellum*, *D. ochreatum*, *D. chrysanthum*, *D. hookerianum*, *D. densiflorum*. **Tuyama (1966)** described *Dendrobium* viz. *D. amplum*, *D. anceps*, *D. candidum*, *D. densiflorum*, *D. eriiflorum*, *D. longicornu* and *D. pierardi* from Nepal. **Tuyama (1971)** mentioned *Dendrobium* viz. *D. amoenum*, *D. chrysanthum*, *D. densiflorum*, *D. eriaeflorum*, *D. heterocarpum*, *D. longicornu*, *D. nobile*, *D. pierardi* and *D. porphyrochilum* from Nepal in “Flora of Eastern Himalaya”. Later on **Tuyama (1975)** described *Dendrobium eriaeflorum*, *Dendrobium pierardi* and *Dendrobium porphyrochilum* from Nepal in “Flora of Eastern Himalaya”.

Suwal (1969) enlisted *Dendrobium bicameratum* and *Dendrobium longicornu* from Phulchowki and Godawari area of Nepal. **Malla, Shrestha, Rajbhandari, Shrestha, Adhikari and Adhikari (1976)** reported *Dendrobium aphyllum* and *Dendrobium eriiflorum* from Langtang Valley of Nepal. **Hara, Stearn and Williams (1978)** enumerated 26 species of *Dendrobium* viz. *D. amoenum*, *D. anceps*, *D. aphyllum*, *D. bicameratum*, *D. candidum*, *D. chrysanthum*, *D. crepidatum*, *D. denneanum*, *D. densiflorum*, *D. denudans*, *D. eriiflorum*, *D. fimbriatum*, *D. floribundum*, *D.*

formosum, *D. gibsonii*, *D. heterocarpum*, *D. longicornu*, *D. monticola*, *D. moschatum*, *D. nobile*, *D. parviflorum*, *D. peguanum*, *D. porphyrochilum*, *D. primulinum*, *D. pulchellum* and *D. transparens*, 3 species of *Epigeneium* viz. *E. amplum*, *E. fuscescens* and *E. rotundatum* from Nepal. **Mierow and Shrestha (1978)** described *Dendrobium densiflorum* and *Dendrobium nobile* from Pokhara and Arun valley of Nepal. **Banerji and Thapa (1978)** reported 20 species of *Dendrobium* viz. *D. aplestre*, *D. amoenum*, *D. anceps*, *D. candidum*, *D. chrysanthum*, *D. clavatum*, *D. crepidatum*, *D. densiflorum*, *D. denudans*, *D. eriaeflorum*, *D. formosum*, *D. gibsonii*, *D. heterocarpum*, *D. longicornu*, *D. moschatum*, *D. nobile*, *D. pierardi*, *D. primulinum*, *D. pulchellum*, *D. pygmaeum* and 2 species of *Epigeneium* viz. *E. amplum* and *E. rotundatum* from Nepal.

Paudyal and Shakya (1981) reported 12 species of *Dendrobium* from Southern Regions of Kathmandu Valley, Nepal. **Banerji (1982)** enlisted 21 species of *Dendrobium* from different locations of Nepal. **Amatya (1982)** reported 11 species of *Dendrobium* from Northern Hill Forests of Kathmandu valley of Nepal. **Paudyal (1982)** reported 11 species of *Dendrobium* from Southern Range of Kathmandu valley of Nepal. **Banerji and Pradhan (1984)** enlisted 21 species of *Dendrobium* from Nepal Himalaya. **Gupta, V. N. P. (1984)** enlisted 26 species of *Dendrobium* and 3 species of *Epigeneium* from Kathmandu Valley of Nepal. **Malla, Rajbhandari, Shrestha, Adhikari, Adhikari and Shakya (1986)** enlisted 10 species of *Dendrobium* from Kathmandu Valley of Nepal. **Shakya, Bajracharya and Chettri (1994)** reported 14 species of *Dendrobium* and 2 species of *Epigeneium* from Kathmandu Valley of Nepal. **Kumar and Manilal (1994)** enlisted 29 species of *Dendrobium* from Nepal Himalaya. **Sparrow (1995)** reported 4 species of *Dendrobium* viz. and *Flickingeria fugax* from Middle altitudes and *D. longicornu* from Cloud forests of Nepal Himalaya. **Bajracharya and Shakya (1997)** enlisted 5 species of *Dendrobium* from lower Gorkha district of Manaslu Region of Nepal. **Bania and Shakya (1999)** enlisted *Dendrobium longicornu* from Chandragiri of Nepal. **Paudyal and Subedi (1999)** enlisted 8 species of *Dendrobium* from Pokhara Valley of Nepal.

Press, Shrestha and Sutton (2000) enumerated 26 species of *Dendrobium* viz. *D. amoenum*, *D. anceps*, *D. aphyllum*, *D. bicameratum*, *D. candidum*, *D. chrysanthum*,

D. crepidatum, *D. denneanum*, *D. densiflorum*, *D. denudans*, *D. eriiflorum*, *D. fimbriatum*, *D. floribundum*, *D. formosum*, *D. gibsonii*, *D. heterocarpum*, *D. longicornu*, *D. monticola*, *D. moschatum*, *D. nobile*, *D. parviflorum*, *D. peguanum*, *D. porphyrochilum*, *D. primulinum*, *D. pulchellum*, *D. transparens* and 3 species of *Epigeneium* viz. *E. amplum*, *E. fuscescens*, *E. rotundatum* from Nepal. **White and Sharma (2000)** described 22 species of *Dendrobium* 1 species of *Epigeneium* viz. *E. amplum* and 1 species of *Flickingeria* viz. *F. fugax*. from Tribhuvan Rajpath and Hetauda of Nepal. **Rajbhandari and Bhattarai (2001)** described and illustrated 17 species of *Dendrobium* and *Epigeneium amplum* in Beautiful Orchids of Nepal. **Rajbhandari, Adhikari and Bista (2001)** enlisted 28 species of *Dendrobium* and 3 species of *Epigeneium* from Nepal. **Bajracharya, Shakya and Subedi (2001)** recorded 9 species of *Dendrobium* from Raja Rani Area of Morang district of Nepal. **Bajracharya and Shakya (2002)** recorded 29 species of *Dendrobium* among them, *D. chryseum*, *D. cumulatum*, *D. darjeelingensis*, *D. farmeri*, *D. hookerianum*, 3 species of *Epigeneium* and 2 species of *Flickingeria* viz. *F. fimbriata* and *F. fugax* from Nepal Himalaya. **Ghimire (2002)** enlisted *Dendrobium aphyllum*, *D. densiflorum*, *D. denudans*, *D. eriiflorum*, *D. fimbriatum* and *D. heterocarpum* from Bajrabarahi of Nepal. **Sharma and Adhikari (2003)** enlisted *Dendrobium amoenum*, *D. bicameratum*, *D. candidum*, *D. chrysanthum*, *D. heterocarpum* and *D. longicornu* from Royal Botanical Garden, Godawari of Nepal. **Amatya (2003)** enlisted 9 species of *Dendrobium* viz. and *Flickingeria fugax* from Doti district of Nepal. **Amatya (2003)** described 8 species of *Dendrobium* viz. from Dhading district of Central Nepal. **Subedi (2003)** enlisted 10 species of *Dendrobium* and *Epigeneium amplum* and *Flickingeria fugax* from Seti and Marsyangdi River Valleys of Central Nepal. **Rajbhandari and Dahal (2004)** enlisted 26 species of *Dendrobium* and 3 species of *Epigeneium* and *Flickingeria fugax* from Nepal. **Milleville and Shrestha (2004)** described 23 species of *Dendrobium* and 2 species of *Epigeneium* viz. from Nepal. **Raskoti (2009)** enlisted 26 species of *Dendrobium* 2 species of *Epigeneium* and 1 species of *Flickingeria* from Nepal Himalaya. **Rajbhandari and Baral (2010)** recorded 21 species of *Dendrobium* 2 species of *Epigeneium* and 1 species of *Flickingeria* from the study of Herbarium specimens preserved in KATH. **Bajracharya (2010)** described key to *Dendrobium* species of Nepal.

Rokaya, Raskoti, Timsina and Munzbergova (2013) enlisted 31 species of *Dendrobium* viz. *D. chryseum*, *D. cumulatum*, *D. darjeelingense*, *D. farmeri*, *D. formosum*, *D. hookerianum*, *D. moniliforme*, *D. monticola*, *D. ochreatum*, *D. polyanthum*, *D. pulchellum*, 3 species of *Epigeneium* and 2 species of *Flickingeria* from Nepal Himalaya. **Pant and Raskoti (2013)** described medicinal values of 13 species of *Dendrobium* viz. *D. amoenum*, *D. candidum*, *D. crepidatum*, *D. densiflorum*, *D. eriiflorum*, *D. fimbriatum*, *D. fugax*, *D. heterocarpum*, *D. longicornu*, *D. moniliforme*, *D. monticola*, *D. moschatum*, *D. nobile*. **Rajbhandari (2014)** enlisted 30 species of *Dendrobium* viz. *D. chryseum*, *D. cumulatum*, *D. darjeelingense*, *D. farmeri*, *D. hookerianum*, *D. moniliforme*, *D. ochreatum*, *D. plicatile*, *D. polyanthum*, *D. pulchellum*, 3 species of *Epigeneium* and 2 species of *Flickingeria* from Nepal Himalaya.

Rajbhandari and Rai (2017) enlisted 26 species of *Dendrobium* viz. *D. amoenum*, *D. anceps*, *D. aphyllum*, *D. bicameratum*, *D. chrysanthum*, *D. chryseum*, *D. crepidatum*, *D. darjeelingense*, *D. denneanum*, *D. densiflorum*, *D. denudans*, *D. eriiflorum*, *D. fimbriatum*, *D. formosum*, *D. fugax*, *D. gibsonii*, *D. heterocarpum*, *D. longicornu*, *D. moniliforme*, *D. monticola*, *D. moschatum*, *D. nobile*, *D. plicatile*, *D. polyanthum*, *D. porphyrochilum*, *D. transparens* and 2 species of *Epigeneium* viz. *E. amplum*, *E. fuscescens* from Nepal Himalaya based on herbarium specimens deposited at KATH. **Shrestha, Bhattarai and Bhandari (2018)** enumerated 30 species of *Dendrobium*, 3 species of *Epigeneium* and 2 species of *Flickingeria*.

CHAPTER 3.

3. MATERIALS AND METHODS

3.1. Study Area

Nepal Himalaya is more or less rectangular in shape occupying a total area of 147,181 sq. km. It is located between the latitudes 26°22' and 30°27' N and the longitudes 80°40' and 88°12' E (Chaudhary, 1998). It extends 885 km in length from east to west and extends between 145-241 km in width. Nepal lies in Central Himalaya. Nepal Himalaya has been further divided into three phytogeographical regions (i) Western region (W) - Kumaun frontier to 83° E longitude, (ii) Central region (C) - 83° E to 86°30' E and (iii) Eastern region (E) - 86°30' E to Sikkim frontier (Stearn, 1960). On the basis of altitude and different types of climate, five types of vegetation zones have been attributed to Nepal Himalaya, and they are Tropical zone: up to 1000 m.; Subtropical zone: 1100 to 2000m. Temperate zone: 2100 to 3000 m. Subalpine zone: 3100 to 4000 m. Alpine zone: 4100 to 5500 m. (Chaudhary, 1998). The present study covered the study of *Dendrobium* Sw. from tropical to temperate zones and different phytogeographical regions Western, Central to Eastern Nepal Himalaya. It covered 29 species of *Dendrobium* viz. *D. amoenum* Wall. ex Lindl., *D. amplum* Lindl., *D. anceps* Sw., *D. aphyllum* (Roxb.) C.E.C.Fisch, *D. bicameratum* Lindl., *D. chrysanthum* Wall. ex Lindl., *D. chryseum* Rolfe, , *D. crepidatum* Lindl. & Paxton, *D. darjeelingense* Pradhan, *D. denneanum* Kerr, *D. densiflorum* Wall., *D. denudans* D. Don, *D. eriiflorum* Griff., *D. fimbriatum* Hook., *D. formosum* Roxb. ex Lindl., *D. fugax* Rchb. f., *D. fuscescens* Griff., *D. gibsonii* Paxton, *D. heterocarpum* Wall. ex Lindl., *D. longicornu* Lindl., *D. moniliforme* (L.) Sw., *D. monticola* P.F. Hunt & Summerh., *D. moschatum* (Buch.-Ham.) Sw., *D. nobile* Lindl., *D. plicatile* Lindl., *D. polyanthum* Wall. ex Lindl., *D. porphyrochilum* Lindl., *D. rotundatum* (Lindl.) Hook. f. and *D. transparens* Wall. ex Lindl..

3.2. Methodology

The study was based on the collected live specimens and voucher specimens deposited at different herbaria like KATH, TUCH, BM, TI, E, and K (Holmgren *et al.*, 1990). The specimens were collected from different localities of Nepal Himalaya from the year 2011–2017.

3.2.1. Collection of the specimens

The specimens were collected during several field visits from different localities of west to east of Nepal Himalaya from the year 2011 -2017. The specimens of different species of *Dendrobium* were collected from different altitudes and habitats. At field visit sites, the localities were noted and the specimens were photographed and collected. For field collections of specimens, traditional herbarium methods were followed (Bridson & Forman, 1998). The herbarium specimens were prepared from the collected specimens. The voucher specimens of all collections will be deposited at National Herbarium and Plant Laboratories (KATH) and Tribhuvan University Central Herbarium (TUCH). List of specimens collected during field visits were given in Appendix I.

3.2.2. Herbarium Study

The voucher specimens deposited over National Herbarium and Plant Laboratories (KATH) and Tribhuvan University Central Herbarium (TUCH) were studied by visiting over there regularly. The images of voucher specimens collected from Nepal Himalaya deposited in herbaria like K, BM, TI and E and type specimens were acquired by personal contact. New York Botanical Garden and Smithsonian National Museum of Natural History were visited during year 2019. The images of the type specimens were acquired from online website. Some images of the type specimens deposited at K, BM, E and TI were acquired by personal contact.

3.2.3. Study of voucher specimens and live specimens

The collected live specimens as well as voucher specimens were studied for morphological variations existing within them. The gross morphological characters like habit and height of plant; surface and shape of stem or pseudobulb; position, texture, phyllotaxy, number and size of leaf; type and orientation of inflorescence; length of rachis; shape, apex, no. of veins and length of floral bract; colour and size of flower; length of pedicel with ovary; shape, size, apex and no. of veins of dorsal sepal, shape, size, apex and no. of veins of lateral sepals; shape, size, apex and no. of veins of petals; size, margin and apex of lip; nature of ornamentation on disc; shape and size of pollinia were observed and data were stored in data matrix for the further analysis.

Besides gross morphological study, micromorphological and anatomical studies were carried out in collected live specimens. The cluster analysis based on gross morphological, micromorphological and anatomical characters was carried out to establish the interrelationships within different species.

The distribution of different species in phytogeographical regions were also analysed by literature review, herbarium data and field observations. The distribution maps of species were generated by GIS.

3.2.4. Identification and Authentication of the specimens

Identification of specimens is of utmost importance in the taxonomic study. The protologue texts and type specimens are needed for the authentic identification of the specimens. The specimens for present study have to be identified by tallying with protologues, valid taxonomic literatures and type specimens deposited at different herbaria of the world. The literature used for authentic identification of each specimen from different sources included Species Plantarum (Linnaeus, 1753); Edward's Botanical Register (Lindley, 1799-1865); Prodrum Florae Nepalensis (Don, 1825); The Genera and Species of Orchidaceous Plants (Lindley, 1830-1840), Genera Plantarum Vol. 3 (Bentham & Hooker, 1883); The Flora of British India Vol. 5 (Hooker, 1890); Das Pflanzenreich Vol. 45 (Kranzlin, 1910); The Flora of Eastern Himalaya (Tuyama, 1966-1975); The Orchids of Bhutan (Pearce & Cribb, 2002); Orchids of Nepal (Banerji & Thapa, 1978); The Orchids Of Nepal Himalaya (Banerji & Pradhan, 1984); Phylogeny and Classification of the Orchid Family (Dressler, 1993); The Dendrobiums (Wood, 2006) and Flora of China (Chen *et al.*, 2009). Protologues were acquired through online website Biodiversity Heritage Library (www.biodiversity.org) and botanical literatures through website Botanicus (www.botanicus). The type specimens (Holotype, Isotype, Lectotype and Paratype) were determined on the basis of protologue texts. The type specimens were acquired from different online websites Jstor Plant Database (www.jstor.org), Kew Herbarium Catalogue (www.kew.org), Natural History Museum (www.nhm.ac.uk), Royal Botanic Garden Edinburgh (www.rbge.org.uk) and personal contact. Online websites such as Catalogue of life (www.catalogueoflife.org) was used to get the current accepted names of the specimens.

CHAPTER 4.

4. RESULT AND DISCUSSION

4.1. Gross Morphology of Genus *Dendrobium* Sw.

4.1.1. Result

In plant taxonomy, the gross morphological characters are very important for identifying different species. The wide range of morphological variations helps in delimitation and identification of plants upto lowest level of taxonomic hierarchy. From Nepal Himalaya, 29 species of *Dendrobium* *D. amoenum* Wall. ex Lindl., *D. amplum* Lindl., *D. anceps* Sw., *D. aphyllum* (Roxb.) C.E.C. Fisch, *D. bicameratum* Lindl., *D. chrysanthum* Wall. ex Lindl., *D. chryseum* Rolfe, , *D. crepidatum* Lindl. & Paxton, *D. darjeelingense* Pradhan, *D. denneanum* Kerr, *D. densiflorum* Wall., *D. denudans* D. Don, *D. eriiflorum* Griff., *D. fimbriatum* Hook., *D. formosum* Roxb. ex Lindl., *D. fugax* Rchb. f., *D. fuscescens* Griff., *D. gibsonii* Paxton, *D. heterocarpum* Wall. ex Lindl., *D. longicornu* Lindl., *D. moniliforme* (L.) Sw., *D. monticola* P.F. Hunt & Summerh., *D. moschatum* (Buch.-Ham.) Sw., *D. nobile* Lindl., *D. plicatile* Lindl., *D. polyanthum* Wall. ex Lindl., *D. porphyrochilum* Lindl., *D. rotundatum* (Lindl.) Hook. f. and *D. transparens* Wall. ex Lindl are recorded on the basis of gross morphological characters.

4.1.1.1. Range of vegetative structures

a. Habit and Habitat

Section I. Aporum

Section Aporum is represented by a single species *D. anceps*. The habit of *D. anceps* (Fig. 1.1, Plate 1.A) is sympodial with elongated cane-like stem. The species is a perennial and epiphytic herb. The height of plant varies from 15-56 cm (Table 2). The species is distributed to tropical to subtropical regions ranging from 200-1400 m (Table 2).

Section II. Crinifera

Section Crinifera is represented by two species: *D. fugax* and *D. plicatile*. The habits of both species *D. fugax* (Fig. 1.2, Plate 1.B) and *D. plicatile* (Fig. 1.3) are sympodial with pseudobulbs. Both species are perennial and epiphytic herbs but *D. plicatile* is

lithophyte also. The height of both plants is more or less similar ranging from 20-29 cm (Table 2). *D. fugax* is distributed to tropical to subtropical regions Nepal ranging from 500-1600 m whereas *D. plicatile* is distributed to tropical to temperate regions ranging from 500-2400 m (Table 2).

Section III. Dendrobium

Section Dendrobium is represented by sixteen species: *D. amoenum* (Fig. 1.4, Plate 1.C), *D. aphyllum* (Fig. 1.5, Plate 1.D), *D. bicameratum* (Fig. 1.6, Plate 1.E), *D. chrysanthum* (Fig. 1.7, Plate 1.F), *D. chryseum* (Fig. 1.8), *D. crepidatum* (Fig. 1.9, Plate 1.G), *D. denneanum* (Fig. 1.10), *D. densiflorum* (Fig. 1.11, Plate 1.H), *D. fimbriatum* (Fig. 1.12, Plate 1.I), *D. gibsonii* (Fig. 1.13), *D. heterocarpum* (Fig. 1.14, Plate 1.J), *D. moniliforme* (Fig. 1.15, Plate 1.K), *D. moschatum* (Fig. 1.16, Plate 1.L), *D. nobile* (Fig. 1.17, Plate 1.M), *D. polyanthum* (Fig. 1.18) and *D. transparens* (Fig. 1.19). The habits of all species are sympodial with elongated cane-like stems. All species are perennial, epiphytic and some with lithophytic like *D. amoenum*, *D. denneanum* and *D. fimbriatum*. The height ranges from 20-150 cm, the smallest *D. crepidatum* and the largest *D. moschatum* (Table 1). All species are adapted to a wide variety of habitats from high altitudes to lowland humid forests. *D. fimbriatum* is the only species distributed in tropical region while other species are distributed from tropical, subtropical to temperate regions ranging from 200-2500 m. *D. amoenum* and *D. aphyllum* are found at 200 m whereas *D. denneanum* and *D. moniliforme* are found at 2500 m (Table 2).

Section IV. Formosae

Section Formosae is represented by two species *D. formosum* (Fig. 1.20, Plate 1.N) and *D. longicornu* (Fig. 1.21, Plate 1.O). The habit of both species is sympodial with elongated cane-like stems. Both species are perennial and epiphytic herbs. The height of both species ranges from 13-39 cm, the smallest being *D. formosum* and the largest *D. longicornu* (Table 1). *D. formosum* is distributed in tropical region only and *D. longicornu* in subtropical to temperate regions ranging from 500-2900 m (Table 2).

Section V. Sarcopodium

Section Sarcopodium is represented by three species: *D. amplum* (Fig. 1.22, Plate 1.P) *D. fuscescens* (Fig. 1.23) and *D. rotundatum* (Fig. 1.24, Plate 1.Q). The habit is sympodial with pseudobulbs in all species. The species are perennial, epiphytic in *D.*

amplum and *D. rotundatum* and with lithophytic in *D. fuscescens*. The height of species ranges from 40-64 cm, the largest being *D. amplum* and smallest are *D. rotundatum* and *D. fuscescens* (Table 1). *D. fuscescens* is distributed from tropical to subtropical regions whereas *D. amplum* and *D. rotundatum* from subtropical to temperate regions ranging from 600-2500 m (Table 2). Among these species *D. rotundatum* is found upto 2500 m.

Section VI. Stachyobium

Section Stachyobium is represented by five species: *D. darjeelingense*, *D. denudans*, *D. eriiflorum*, *D. monticola* and *D. porphyrochilum*. The habit is sympodial with cane-like stems in *D. darjeelingense* (Fig. 1.25), *D. denudans* (Fig. 1.26), *D. eriiflorum* (Fig. 1.27, Plate 1.R) and pseudobulbs in *D. monticola* (Fig. 1.28, Plate 1.S) and *D. porphyrochilum* (Fig. 1.29, Plate 1.T). The species are perennial, epiphytic and some with lithophytic in *D. eriiflorum* and *D. monticola*. The height ranges from 1-21 cm, the smallest being *D. porphyrochilum* and the largest is *D. darjeelingense*. The species are distributed from tropical, subtropical to temperate regions ranging from 1000-2500 m. The species are distributed from subtropical to temperate regions except *D. denudans* from tropical to subtropical regions ranging from 1000-2500 m. *D. porphyrochilum* is found upto 2500 m (Table 2).

b. Root and Rhizome

Roots of *Dendrobium* are developed from base of stem or pseudobulb and from rhizome. The roots are developed from nodes allowing the development of adventitious growth. The roots are fasciculate, thick and covered by spongy, shiny, silver-grey layer called velamen. The roots are slender, wiry and strong. Rhizome is found in some section like Section II. Crinifera (*D. fugax* and *D. plicatile*) and Section V. Sarcopodium (*D. amplum*, *D. fuscescens* and *D. rotundatum*) and absent in other sections. Rhizomes are creeping, branched and covered with sheaths. Roots are developed from nodes of rhizome.

c. Stem/Pseudobulb

Section I. Aporum

In *D. anceps* the stems are elongated cane-like, compressed, flattened without any fleshy internodes and leaves are present all along the stem.

Table 2: Distribution range and comparative morphological characters in *Dendrobium*

S.N .	Taxa	Altitude (m)	Length of Stem/Pseudobulb (cm)	Length of Internode (cm)	Leaf texture	Leaf size l x w (cm)	Inflorescence position	Length of peduncle (cm)	Length of rachis (cm)	No. of flowers /inflorescence	Length of Pedicel with ovary (cm)	Flower size (cm)	Colour of Flower	Pollinia	
														Shape	Size (mm)
1	<i>D. amoenum</i>	200 – 2000	24.0-75.0	2.5-3.0	Membranous	4.4-10.9 x 0.6-1.8	Axillary	0.6	Absent	Two-three	2.8-3.0	2.0-3.0	White with tinged of purple	Elliptic	1.45 x 1.25
2	<i>D. amplum</i>	1300- 2100	60.0-64.0	3.0-5.5	Coriaceous	9.0-18.0 x 2.2-5.0	Terminal	2	Absent	one	5	7.5	Yellowish brown, lip deep purple with bronze edges	Oblong	2.4 x 2.0
3	<i>D. anceps</i>	200-1400	15.0-56.0	2.0-2.5	Fleshy	2.5-3.5 x 0.8-1.2	Axillary	0.2	Absent	one	0.6	1.2	Yellowish green with pink lines	Oblong lanceolate	1.0 x 0.8
4	<i>D. aphyllum</i>	200-1500	20.0-50.0	2.5-3.0	Fleshy	4.0-6.0 x 1.5-3.0	Axillary	0.2	Absent	one-three	3.0	4	White with pale purplish red	Elliptic	2.3 x 2.3
5	<i>D. bicameratum</i>	1400- 2400	10.0-26.0	1.7-3.0	Membranous	5.0-8.0 x 1.2-2.5	Lateral or subterminal	0.5	0.3-0.8	four-six	0.8	1	Yellow with dull red in circular heads	Oblong	1.2 x 0.7

6	<i>D. chrysanthum</i>	1300-2000	25.0-70.0	3.0-3.2	Membranous	8.5-20.0 x 2.5-4.5	Lateral	0.1	Absent	two-four	7	5	Golden yellow with purplish red blotch	Oblong	1.6 x 1.2
7	<i>D. chryseum</i>	1200-2100	25.0-50.0	2.0-5.0	Coriaceous	10.0-14.0 x 2.0-4.0	Lateral	4.0-6.0	3.0-10.0	two-four	3.5-5.0	4.0-6.0	Yellow orange with purple blotch	N.O.	N.O.
8	<i>D. crepidatum</i>	600-1400	14.0-20.0	2.0-2.5	Subleathery	5.5-9.5 x 1.0-1.6	Lateral	0.3	Absent	two-three	3.5	2.5	White with pale purplish pink	Oblong	2.0 x 1.6
9	<i>D. darjeelingense</i>	1500-2000	20.0-21.0	1.5-2.0	Membranous	6.0 x 1.2	Terminal or axillary	1-1.5	4	sixteen-twenty	0.4	1	Creamy with light greenish tinge	Oblong	0.5 x 0.2
10	<i>D. denneanum</i>	600-2500	40.0-65.0	2.0-3.0	Coriaceous	8.5- 12.0 x 1.5-2.5	Subterminal	1.5-2.0	7.0-12.0	five	2.0-4.0	4.0-5.5	Dark yellow	Ovate oblong	2.0 x 1.8
11	<i>D. densiflorum</i>	900-1500	20.0-40.0	2.5-3.8	Coriaceous	10.0-16.0 x 2.0-3.5	Axillary	4	10 to 12	more than ten	2.5-3.0	2.5-4.0	Light Yellow	Ovate oblong	1.6 x1.1
12	<i>D. denudans</i>	1000-2200	4.0-15.0	1.0-2.0	Membranous	6.0-10.0 x 1.0-1.5	Axillary	2.5-3.0	5.0-7.0	eight-many	0.6-0.9	1.0-2.0	Creamy to pale green with red-purple lines	Oblong	1.1 x 1.0
13	<i>D. eriiflorum</i>	1500-2100	7.0-12.0	1.6-2.0	Membranous	4.0-6.8 x 0.3-0.6	Terminal or axillary	2.5-3.0	3.0-10.0	more than ten	0.7	1.5	Light greenish white	Oblong lanceolate	1.1 x 1.0
14	<i>D. fimbriatum</i>	500-1000	55.0-70.0	2.5-5.0	Coriaceous	12.5-14.0 x 1.4-3.5	Axillary	2	5.0-8.0	six-eight	2.5-3.0	4.5-5.5	Orange-	Oblong	2.0 x1.5

													yellow		
15	<i>D. formosum</i>	500-1000	18.0-21.0	1.8-2.0	Coriaceous	5.5-8.0 x 2.0-2.8	Terminal or lateral	4.0-4.5	Absent	one-five	5.5	8.0-10.0	White with attractive yellow inner lip	Oblong	2.5 x 1.0
16	<i>D. fugax</i>	500-1600	21.0-29.0	2.0-3.0	Coriaceous	14.0-16.0 x 2.0-2.5	Terminal	1	Absent	one-two	0.6	2	White sprinkled with pink-purple spots	Oblong	1.1 x 1.0
17	<i>D. fuscescens</i>	600-1800	42.0-46.0	3.0-4.0	Coriaceous	7.5-9.0 x 1.7-2.0	Terminal	0.3-0.4	Absent	one	2.5-3.0	4.5-5.0	Purplish-brown	N.O.	N.O.
18	<i>D. gibsonii</i>	900-2000	25.0-48.0	2.0-3.0	Coriaceous	9.0-18.5 x 2.0-4.0	Lateral	1.0-2.0	9.0-13.0	six-twelve	4.7	3	Orange yellow with a rounded deep purple blotch on each sides	Oblong	2.0 x 1.5
19	<i>D. heterocarpum</i>	900-2130	15.0-25.0	2.0-3.0	Coriaceous	7.0-12.0 x 1.0-2.0	Axillary	0.4	Absent	one-three	2.5	4.5	Pale yellow	Oblong	2.0 x 1.6
20	<i>D. longicornu</i>	1300-2900	13.0-36.0	2.5-3.0	Coriaceous	4.0-6.0 x 0.7-1.6	Axillary	0.5	Absent	one-three	2.5	3.5	White with orange yellow lip	Oblong elliptic	2.0 x 1.4
21	<i>D. moniliforme</i>	1700-2500	15.0-25.0	1.5-3.0	Membranous	3.5-8.0 x 0.5-1.3	Axillary	0.3	0.9	one-three	1.2	2.0-2.5	White with yellowish green spot	Oblong	1.1 x 1.2

22	<i>D. monticola</i>	1700–2200	4.0-6.0	1.0-1.5	Membranous	2.5-3.0 x 0.4-0.6	Terminal	1.5	2.5	three-eight	0.6	1.5	White with purplish red stripes	N.O.	N.O.
23	<i>D. moschatum</i>	200-1200	78.0-150.0	3.0-4.5	Coriaceous	7.5-14.5 x 1.5-5.5	Lateral	3.5-5.0	16.0-26.0	eight-twelve	5	6.5-7.0	Pale yellow with purplish brown blotches on lip	Oblong	2.0 x 1.6
24	<i>D. nobile</i>	400-1500	25.0-40.0	2.0-2.5	Coriaceous	8.0-13 x 1.5-2.5	Lateral	0.5-1.5	Absent	one-four	3.5-4.0	6.0-7.0	White at base, mauve above	Oblong	2.0 x 1.5
25	<i>D. plicatile</i>	500-2400	20.0-28.0	0.7-0.8	Coriaceous	10.0 -20.0 x 3.0-5.0	Terminal	0.7	Absent	one-three	0.6	2	Milky yellow tinged with purplish red spots	N.O.	N.O.
26	<i>D. polyanthum</i>	400-1400	10.0-25.0	1.5-2.0	Membranous	7.0-10.0 x 2.0-3.0	Lateral	0.2	Absent	two-three	2.0-2.5	6	Pink-purple	Ellipsoid	2.2 x 2.5
27	<i>D. porphyrochilum</i>	1800-2500	1.0-2.0	0.5	Membranous	2.5–5.0 x 0.5–0.8	Terminal	3	4.0-5.0	seven-twelve	0.7	0.8-1.0	Creamy or yellowish green	N.O.	N.O.
28	<i>D. rotundatum</i>	1300-2500	40.0-48.0	2.5-5.0	Coriaceous	4.0-13.5 x 1.2-2.8	Terminal	0.5	Absent	one	2.5	3.4	Pale yellowish brown	Oblong	1.8 x 1.7
29	<i>D. transparens</i>	700-2100	24.0-40.0	2.0-2.5	Membranous	5.0-10.5 x 1.5-2.0	Axillary	0.1	Absent	eight-twelve	3.5	3.4	White with pink flooded	Oblong	1.0 x 0.8

Note: N.O. = Not Observed

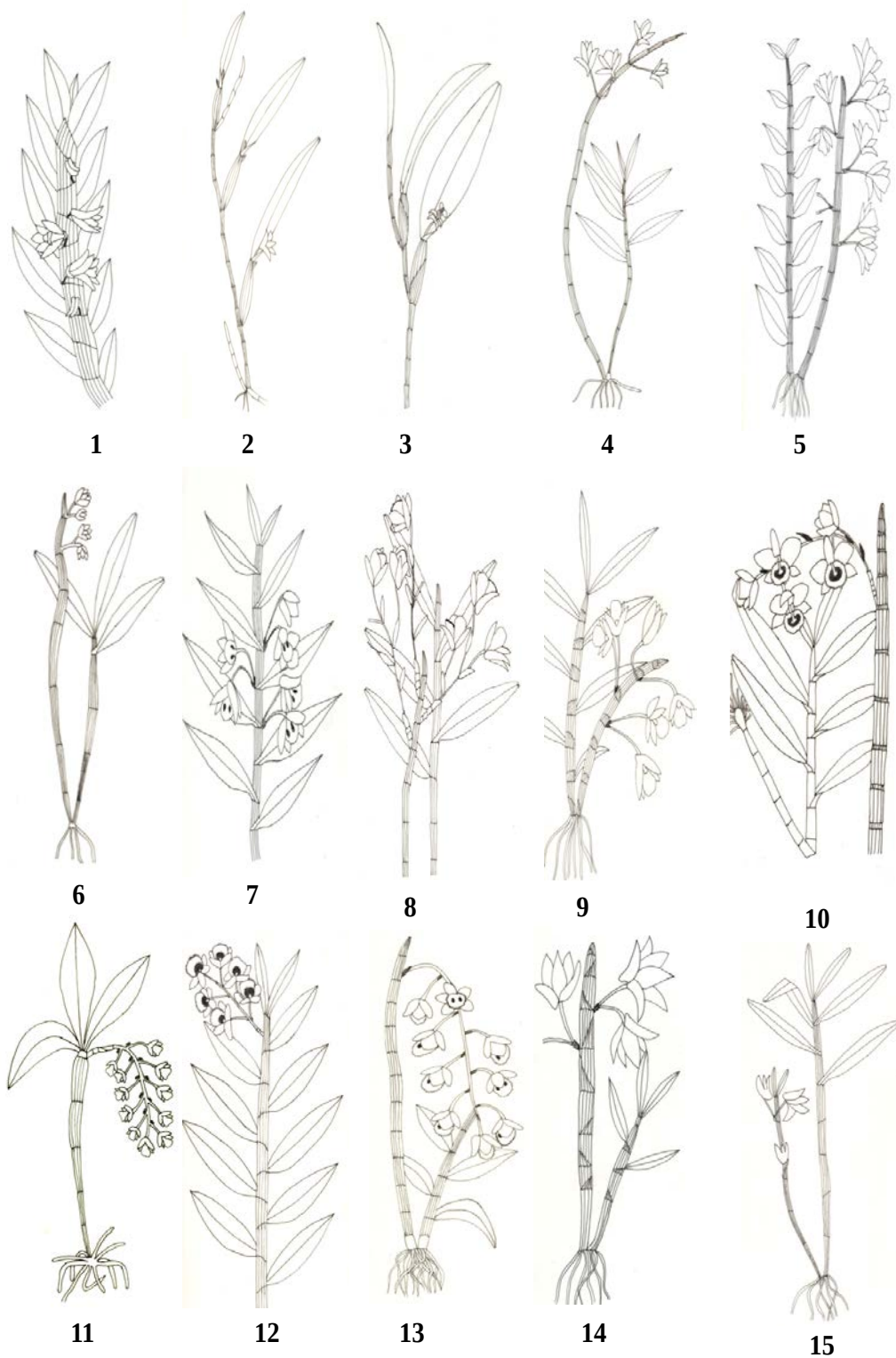


Fig. 1. Habit of *Dendrobium* species.

1. *D. anceps* 2. *D. fugax* 3. *D. plicatile* 4. *D. amoenum* 5. *D. aphyllum* 6. *D. bicameratum* 7. *D. chrysanthum* 8. *D. chryseum* 9. *D. crepidatum* 10. *D. denneanum* 11. *D. densiflorum* 12. *D. fimbriatum* 13. *D. gibsonii* 14. *D. heterocarpum* 15. *D. moniliforme*.

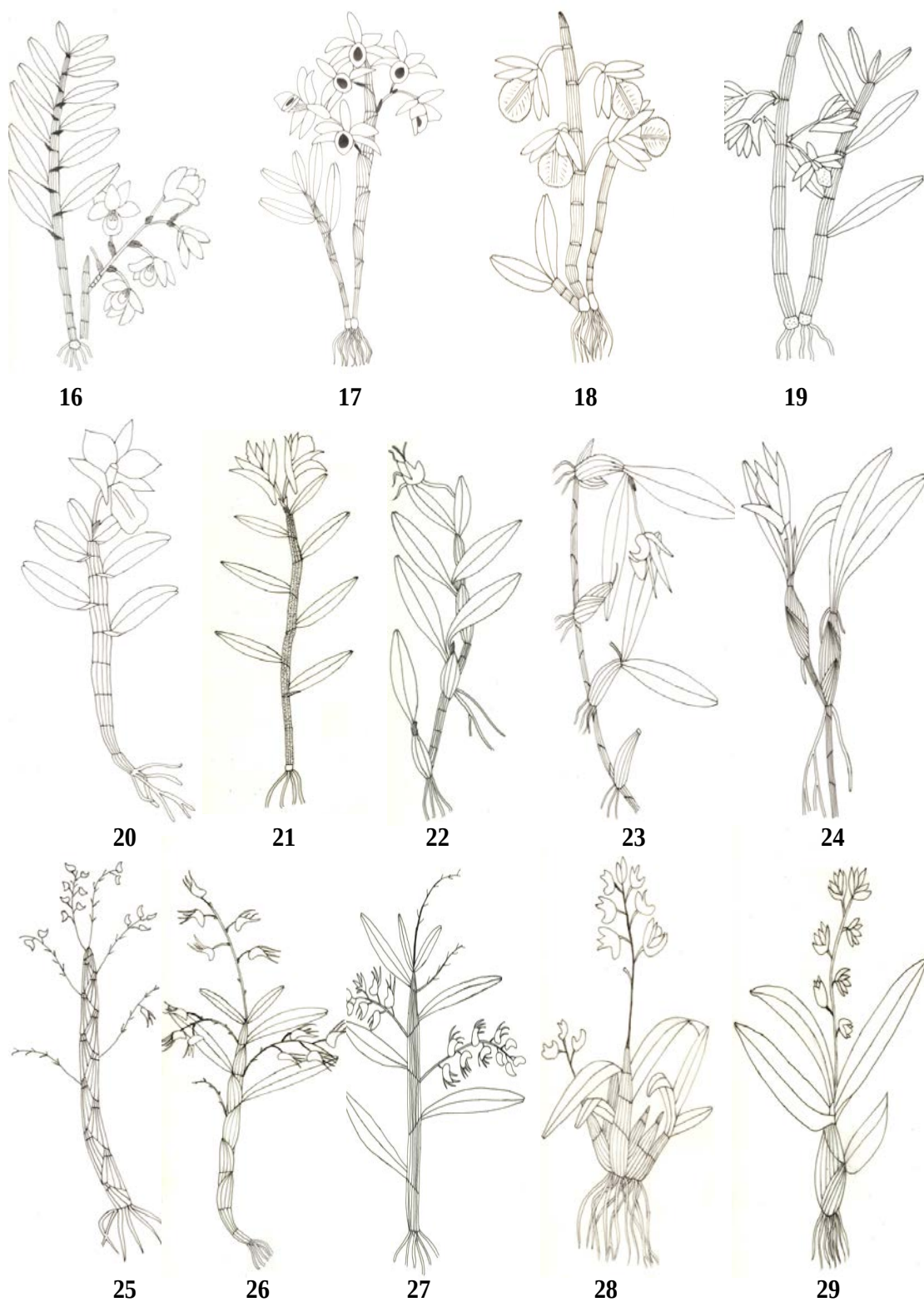


Fig. 1 contd.

16. *D. moschatum* 17. *D. nobile* 18. *D. polyanthum* 19. *D. transparens* 20. *D. formosae* 21. *D. longicornu* 22. *D. amplum* 23. *D. fuscescens* 24. *D. rotundatum* 25. *D. darjeelingense* 26. *D. denudans* 27. *D. eriiflorum* 28. *D. monticola* 29. *D. porphyrochilum*.

Plate 1. Habitat of *Dendrobium* species

A. *Dendrobium anceps* Swartz (Churiyamai, Makawanpur);

B. *Dendrobium fugax* (Rchb. F.) Seidenf. (Churiyamai, Makawanpur);

C. *Dendrobium amoenum* Wall. ex Lindl. (Sulung, Ilam);

D. *Dendrobium aphyllum* (Roxb.) G.E.C. Fisher (Sindhuligadi, Sindhuli).

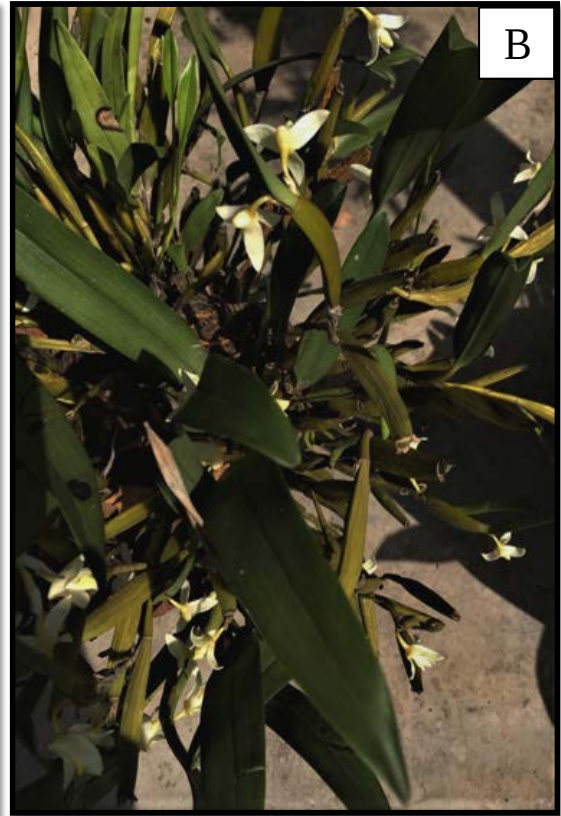


Plate 1. (Contd.)

- E. *Dendrobium bicameratum* Lindl. (Tistung, Makawanpur);
- F. *Dendrobium chrysanthum* Wall. ex Lindl. (Hanspokhari, Ilam);
- G. *Dendrobium crepidatum* Lindl. & Paxton (Daman, Makawanpur);
- H. *Dendrobium densiflorum* Lindl. (Bajrabarahi, Lalitpur).



Plate 1. (Contd.)

- I. *Dendrobium fimbriatum* var. *oculatum* Hook. f. (Hetauda, Makawanpur);
- J. *Dendrobium heterocarpum* Wall. ex Lindl. (Suryabinayak, Bhaktapur);
- K. *Dendrobium moniliforme* (Linn.) Swartz (Daman, Makawanpur);
- L. *Dendrobium moschatum* (Buch.-Ham.) Swartz.



Plate 1. (Contd.)

M. *Dendrobium nobile* Lindl. (Deurali, Ilam);

N. *Dendrobium formosum* Roxb. ex Lindl. (Hetauda, Makawanpur);

O. *Dendrobium longicornu* Lindl. (Godavari, Lalitpur);

P. *Dendrobium amplum* Lindl. (Maipokhari, Ilam).

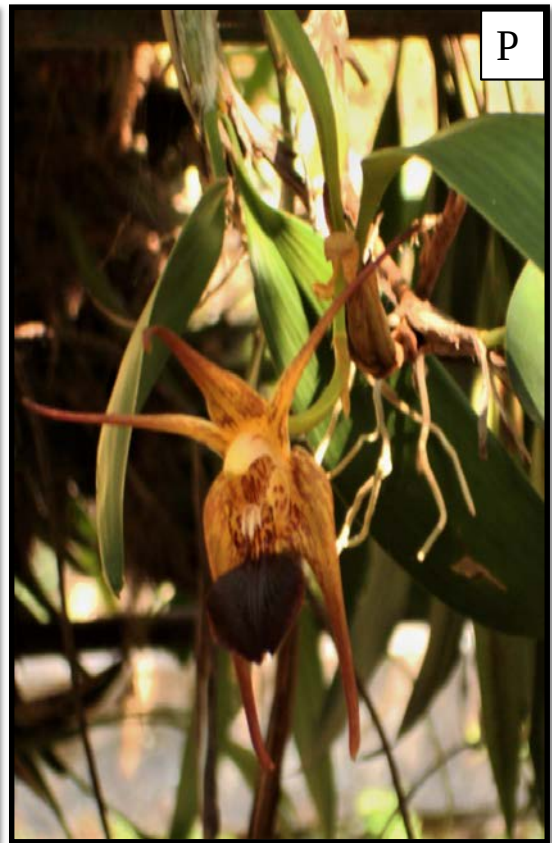


Plate 2. (Contd.)

Q. *Dendrobium rotundatum* (Lindl.) Hook.f. (Maipokhari, Ilam);

R. *Dendrobium eriiflorum* Griff. (Panchase, Kaski);

S. *Dendrobium monticola* P.F. Hunt & Summerh. (Shivapuri, Kathmandu);

T. *Dendrobium porphyrochilum* Lindl. (Panchase, Kaski).



Section II. *Crinifera*

In *D. fugax* and *D. plicatile* the stems are pseudobulbous, pendant with few to many nodes and branched with leaf sheaths. Pseudobulb is fusiform shaped in both species.

Section III. *Dendrobium*

The stems are elongated cane-like, erect or pendant and branched or unbranched with leaf sheaths. Species like *D. amoenum*, *D. aphyllum*, *D. chrysanthum*, *D. chryseum*, *D. crepidatum*, *D. gibsonii* and *D. polyanthum*, have pendant stems and remaining species with erect stems. Unbranched stems are found in species like *D. aphyllum*, *D. bicameratum*, *D. chrysanthum*, *D. chryseum*, *D. crepidatum*, *D. fimbriatum*, *D. gibsonii*, *D. moniliforme*, *D. moschatum*, *D. nobile*, *D. polyanthum* and branched stems in remaining species. In *D. densiflorum* the stems are stout, clavate, compressed and quadrangular with leaves at apex. In *D. bicameratum* the stems are slender and swollen towards the apex.

Section IV. *Formosae*

The stems are elongated cane-like, erect and branched (*D. formosum*) and unbranched (*D. longicornu*) with leaf sheaths. The stems are tapering towards tip in *D. formosum* and fractiflex in *D. longicornu*. The stems are clothed in fine black hairs in *D. formosum* and short coarse black hairs on stem and slightly on leaves in *D. longicornu*.

Section V. *Sarcopodium*

The stems are pseudobulbous, pendant and branched with leaf sheaths. Pseudobulb varies in different species. Pseudobulbs are large, ellipsoid in *D. amplum*, cylindric-ovoid in *D. fuscescens* and ovoid in *D. rotundatum*.

Section VI. *Stachyobium*

The stems are elongated cane-like (*D. darjeelingense*, *D. denudans*, *D. eriiflorum*) or pseudobulbous (*D. monticola*, *D. porphyrochilum*), erect, branched or unbranched with leaf sheaths. In *D. darjeelingense*, *D. denudans*, *D. eriiflorum* the stems are long, slender and fusiform tapering towards the apex. In *D. darjeelingense* the stems are unbranched. In *D. monticola* and *D. porphyrochilum* the pseudobulbs are small, elongate and cylindrical.

a. Leaves and Leaf sheaths

Section I. *Aporum*

In *D. anceps* the leaves are distichous, fleshy, overlapping, lanceolate, acute with equitant sheathing bases (Fig. 1.1). The size of leaf varies from 2.5-3.5 cm in length and 0.8-1.2 cm in width (Table 2).

Section II. *Crinifera*

In *D. fugax* (Fig. 1.2) and *D. plicate* (Fig. 1.3), the leaves are solitary, terminal on pseudobulb, coriaceous, ovate-lanceolate (*D. fugax*) and oblong-elliptic (*D. plicatilis*), bifid, sessile with leaf bases. Leaf size varies in both species, 14.0-16.0 cm in length and 2.0-2.5 cm in width in *D. fugax* and 10.0-20.0 cm in length and 3.0-5.0 cm in width in *D. plicatilis* (Table 2).

Section III. *Dendrobium*

In Section *Dendrobium*, the leaves are arranged distichously along the stem with leaf sheaths. Regarding the shape, it ranges from lanceolate in *D. denneanum* (Fig. 1.10), *D. moniliforme* (Fig. 1.15); linear lanceolate in *D. aphyllum* (Fig. 1.5), *D. crepidatum* (Fig. 1.9), *D. transparens* (Fig. 1.19); oblong lanceolate in *D. amoenum* (Fig. 1.4), *D. chryseum* (Fig. 1.8), *D. fimbriatum* (Fig. 1.12), *D. heterocarpum* (Fig. 1.14); ovate lanceolate in *D. chrysanthum* (Fig. 1.7), *D. densiflorum* (Fig. 1.11), *D. gibsonii* (Fig. 1.13), *D. moschatum* (Fig. 1.16) to oblong *D. bicameratum* (Fig. 1.6), *D. nobile* (Fig. 1.17), *D. polyanthum* (Fig. 1.18). The leaves are membranous in *D. amoenum*, *D. bicameratum*, *D. chrysanthum*, *D. moniliforme*, *D. polyanthum*, *D. transparens*; coriaceous in *D. chryseum*, *D. denneanum*, *D. densiflorum*, *D. fimbriatum*, *D. gibsonii*, *D. heterocarpum*, *D. moschatum*, *D. nobile*; fleshy in *D. aphyllum* and subleathery in *D. crepidatum* (Table 2). The apex of leaf varies in different species: acute in *D. amoenum* (slightly oblique), *D. bicameratum* (bifid), *D. densiflorum*, *D. fimbriatum* (bilobed), *D. gibsonii*, *D. transparens* (oblique) and subacute in *D. heterocarpum*; obtuse in *D. chryseum* (obliquely hooked), *D. denneanum*, *D. moniliforme* (obliquely bifid), *D. nobile*, *D. polyanthum* (unequally bifid) and acuminate in *D. aphyllum*, *D. chrysanthum*, *D. crepidatum*, *D. moschatum*. The size of leaf varies greatly: 4.0-6.0 cm (l) and 1.5-3.0 (w) in *D. aphyllum* and 8.5-20.0 cm (l) and 2.5-4.5 cm (w) in *D. chrysanthum* (Table 2).

Section IV. *Formosae*

In Section *Formosae*, the leaves are distichous, coriaceous, oblong-elliptical (*D. formosum*) (Fig.1.20), linear-lanceolate (*D. longicornu*) (Fig. 1.21), obtuse with unequally notched in *D. formosum*, acute with obliquely bifid in *D. longicornu*. The leaf sheaths are tubular in both species. The hairs are present slightly on both surfaces of leaves in *D. longicornu* whereas absent in *D. formosum*. The size of leaf varies 5.5-8.0 cm (l) and 2.0-2.8 (w) in *D. formosum* and 4.0-6.0 cm (l) and 0.7-1.6 cm (w) in *D. longicornu* (Table 2).

Section V. *Sarcopodium*

In Section *Sarcopodium*, two leaves are arranged at apex of pseudobulb in *D. amplum* (Fig. 1.22), *D. fuscescens* (Fig. 1.23) and *D. rotundatum* (Fig.1.24). The leaves are coriaceous, elliptic-oblong in *D. amplum*, *D. rotundatum* and elliptic-lanceolate in *D. fuscescens*, petiolate in *D. amplum*. The apex of leaf is acute with notch in *D. amplum*, obtuse with notch in *D. fuscescens* and retuse in *D. rotundatum*. Scarious sheaths are present in all species but larger sheaths are present in *D. amplum*. The size of leaf varies 4.0-13.5 cm (l) and 1.2-2.8 cm (w) in *D. rotundatum*, 7.5-9.0 cm (l) and 1.7-2.0 cm (w) in *D. fuscescens*, 9.0-18.0 cm (l) and 2.2-5.0 cm (w) in *D. amplum* (Table 2).

Section VI. *Stachyobium*

In Section *Stachyobium*, the leaves are distichous in *D. darjeelingense* (Fig.1.25), *D. denudans* (Fig.1.26), *D. eriiflorum* (Fig.1.27), and at apex of pseudobulb 3-4 leaves in *D. monticola* (Fig. 1.28), 1-3 in *D. porphyrochilum* (Fig. 1.29). The leaf sheaths are present in all species. The leaves are membranous but thinly leathery in *D. monticola*. Leaves are linear-ovoid in *D. darjeelingense*, linear-oblong in *D. denudans*, *D. porphyrochilum* and linear lanceolate in *D. eriiflorum*, *D. monticola*. The apex of leaf is acute, unequally notched in *D. darjeelingense* and obliquely emarginated in *D. denudans* and obtuse, obliquely emarginated in *D. eriiflorum*, slightly curved and bilobed in *D. monticola* and obliquely notched in *D. porphyrochilum*. The size varies from 2.5-3.0 cm (l) and 0.4-0.6 cm in *D. monticola* to 6-10 cm and 1-1.5 cm in *D. denudans* (Table 2).

4.1.1.2. Range of reproductive structures

b. Inflorescence

Section I. *Aporum*

In *D. anceps* the inflorescence is erect, solitary axillary raceme, one-flowered, borne at nodes between the leaf axils, peduncle attenuate, sheathed, short, 0.6 mm long (Table 2, Fig. 1.1).

Section II. *Crinifera*

In Section *Crinifera*, the inflorescences are erect, terminal raceme, borne at apex of pseudobulb at base of leaf, 1-2 flowered in *D. fugax* (Fig. 1.2) and 1-3 flowered in *D. plicatile* (Fig. 1.3), peduncle short, 1 cm long covered with sheaths upto 8mm in *D. fugax* and 0.7 cm long in *D. plicatile* (Table 2). The sheaths are overlapping, membranous, lanceolate and acute.

Section III. *Dendrobium*

In Section *Dendrobium*, the inflorescences are pendulous with axillary raceme in *D. amoenum* (Fig. 1.4), *D. aphyllum* (Fig. 1.5), *D. densiflorum* (Fig. 1.11), *D. fimbriatum* (Fig. 1.12), lateral racemes in *D. chrysanthum* (Fig. 1.7), *D. crepidatum* (Fig. 1.9), *D. gibsonii* (Fig. 1.13), *D. moschatum* (Fig. 1.16), *D. polyanthum* (Fig. 1.18) and subterminal raceme in *D. denneanum* (Fig. 1.10); erect with axillary raceme in *D. heterocarpum* (Fig. 1.14), *D. moniliforme* (Fig. 1.15), *D. transparens* (Fig. 1.19), lateral raceme in *D. bicameratum* (Fig. 1.6), *D. chryseum* (Fig. 1.8), *D. nobile* (Fig. 1.17) (Table 2). The inflorescences are borne on nodes of leafless stems in most species, on leafy stems in *D. chrysanthum*, *D. denneanum*, *D. densiflorum*, *D. gibsonii*, *D. nobile* and leafy or leafless stems in *D. fimbriatum*, *D. moschatum*. The no. of flowers on inflorescences varies in different species (Table 2). The flowers are borne on nodes in most species and on rachis in species like *D. bicameratum*, *D. chryseum*, *D. denneanum*, *D. densiflorum*, *D. fimbriatum*, *D. gibsonii*, *D. moniliforme*, *D. moschatum*. The size of rachis ranges from 0.3-0.8 cm long (*D. bicameratum*) to 16.0-26.0 cm long (*D. moschatum*) (Table 1). Rachis with densely many flowers having pine apples like appearance is found in *D. densiflorum*. Peduncle with sheaths are present in all species. The size of peduncle ranges from 0.1 cm long (*D. chrysanthum* and *D. moschatum*) to 4.0-6.0 cm long (*D. chryseum*) (Table 2).

Section IV. *Formosae*

In Section *Formosae*, the inflorescences are erect, terminal or lateral raceme in *D. formosum* (Fig. 1.20), terminal or axillary in *D. longicornu* (Fig. 1.21), borne at nodes on leafy stem in both species but near the apex of leafy stem in *D. formosum*. Flower no. varies: 1-5 in *D. formosum* and 1-3 in *D. longicornu* (Table 2). Peduncle sheathed, 4-4.5 cm long in *D. formosum* and 0.5 cm long in *D. longicornu* (Table 2).

Section V. *Sarcopodium*

In Section *Sarcopodium*, the inflorescences are erect, terminal raceme with a solitary flower arises in between leaves in *D. amplum* (Fig. 1.22), *D. fuscescens* (Fig. 1.23), and *D. rotundatum* (Fig. 1.24). Peduncle 2.0 cm long in *D. amplum*, 0.3-0.4 cm long in *D. fuscescens* and 0.5 cm long in *D. rotundatum* (Table 2). Peduncles are enclosed in sheaths.

Section VI. *Stachyobium*

In Section *Stachyobium*, the inflorescences are erect with terminal or axillary raceme (*D. darjeelingense*, *D. eriiflorum*), terminal raceme (*D. monticola*); pendant with axillary raceme (*D. denudans*), terminal raceme (*D. porphyrochilum*). The inflorescences are 3-8 flowered (*D. monticola*) to many flowered (*D. eriiflorum*) (Table 1). Peduncle varies in size 1.0-1.5 cm long (*D. darjeelingense*) to 3.0 cm long (*D. porphyrochilum*) (Table 2). Peduncles are enclosed in sheaths.

c. Flowers

Orchid flowers are quite different from other flowers. The flowers are trimerous, colourful and some with scents. Outermost whorl consists of three sepals and innermost whorl consists of three petals. The anther and stigma are greatly reduced (Plate 2 A).

Lip or Labellum (Plate 2 B): Lip or labellum is the modified petal of orchid flower. The anterior part of lip is expanded. The anterior part has side lobe and mid lobe. The posterior part is called claw. Lip can be divided into hypochile (posterior part), mesochile (middle part) and epichile (anterior part).

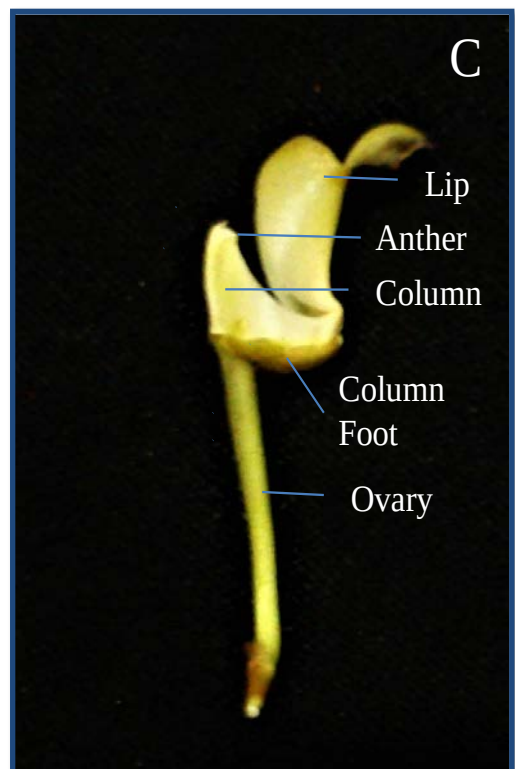
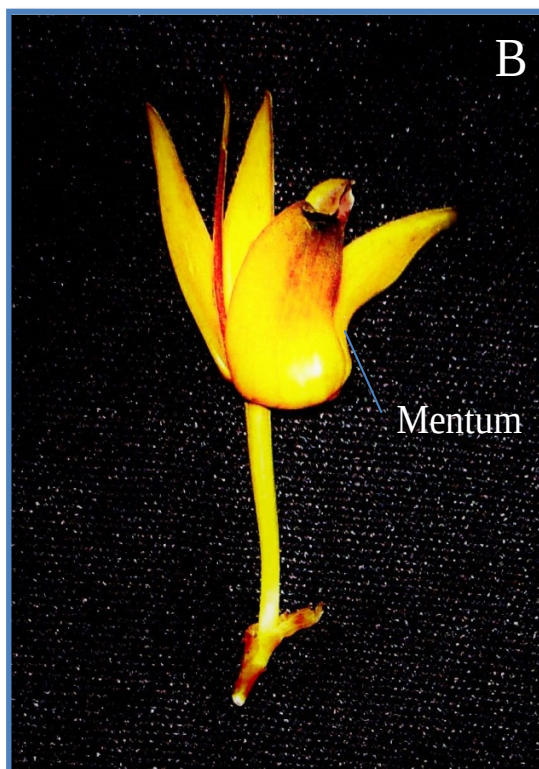
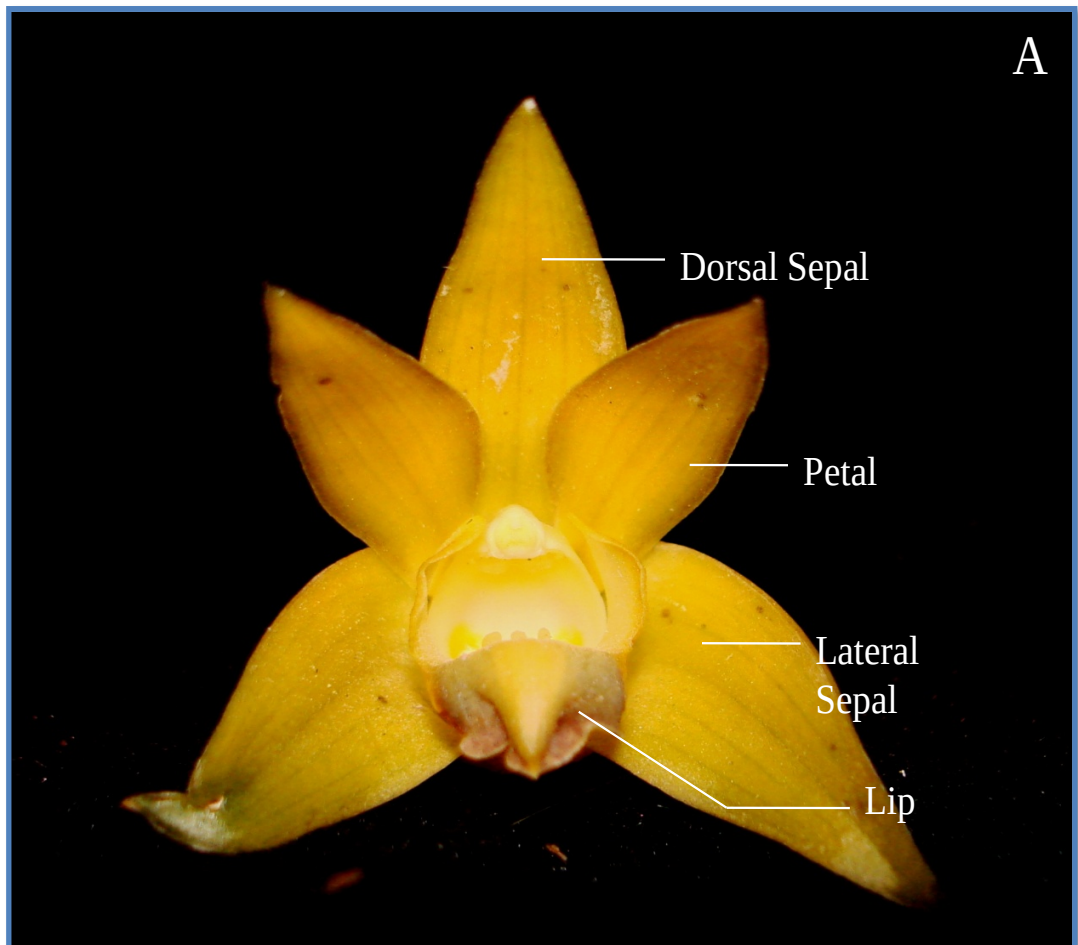
Column (Plate 2 C): In orchid flower the reproductive organs are fused into a single structure called column. The stigma is a shallow hollow on inner side of column. The stigma is three lobed and one of these lobes modified into rostellum. The rostellum separates the stigma from anther. Extension of column at its base is called column foot.

Plate 2. Flower of *Dendrobium*

A. Parts of Flower

B. Mentum

C. Column



Mentum

Lateral sepals adnate to column foot to form mentum. The shape of mentum varies in different species of *Dendrobium*.

Pollinia

The aggregation of pollen grains into small masses called pollinia. Each pollinium contains thousand of pollen grains. In *Dendrobium* pollinia are four in two pairs.

Section I. Aporum

In *D. anceps* the flower is bracteate and yellowish green with pink lines on lateral sepals (Plate 3.A). Flower size is 1.2 cm across and pedicel with ovary is 0.6 cm long (Table 2).

Section II. Crinifera

In Section *Crinifera*, the flowers are bracteate, fugacious and white sprinkled with pink purple spots in *D. fugax* (Plate 3.B) and milky yellow tinged with purplish red spots on sepals and petals in *D. plicatile*. Flower size 2.0 cm across and pedicel with ovary 0.6 cm long in both species (Table 2).

Section III. Dendrobium

In Section *Dendrobium*, the flowers are bracteate in all species. The colour and size of flower varies in different species. The colour of flower ranges from purplish white with faint purplish tinge towards sepal apex and pink purple spots at petal and lip apex (*D. amoenum*, Plate 3.C) to white with pink flooded (*D. transparens*, Plate 3.M) (Table 2). The size of flower also varies: smallest flower 1.0 cm across (*D. bicameratum*) to largest flower 6.5-7.0 cm across (*D. moschatum*, Plate 3.K) (Table 1). Pedicel with ovary varies in different species ranging from 0.8 cm long (*D. bicameratum*, Plate 3.E) to 7.0 cm long (*D. chrysanthum*, Plate 3.F)) (Table 2).

Section IV. Formosae

In Section *Formosae*, the flowers are bracteate, white with attractive yellow inner lip (*D. formosum*) and white with orange yellow inner lip (*D. longicornu*, Plate 3.N). The flowers are showy, larger in *D. formosum* (8.0-10.0 cm across) than in *D. longicornu* (3.5 cm across) (Table 2). In *D. formosum* the flower is largest among different species of *Dendrobium*. The size of pedicel with ovary is 5.5 cm long in *D. formosum* and 2.5 cm long in *D. longicornu* (Table 2).

Plate 3. Flowers of *Dendrobium* species

A. *Dendrobium anceps* Swartz

B. *Dendrobium fugax* (Rchb. F.)

C. *Dendrobium amoenum* Wall. ex Lindl.

D. *Dendrobium aphyllum* (Roxb.) G.E.C. Fisher

E. *Dendrobium bicameratum* Lindl

F. *Dendrobium chrysanthum* Wall. ex Lindl.

G. *Dendrobium crepidatum* Lindl. & Paxton

H. *Dendrobium fimbriatum* var. *oculatum* Hook. f.

I. *Dendrobium heterocarpum* Wall. ex Lindl.

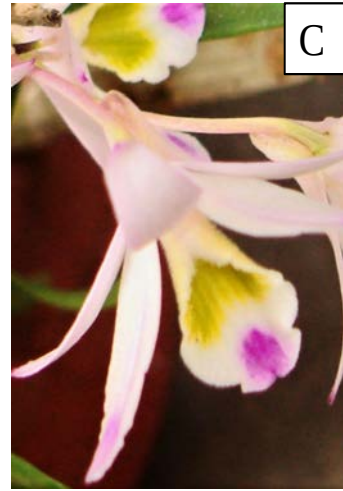
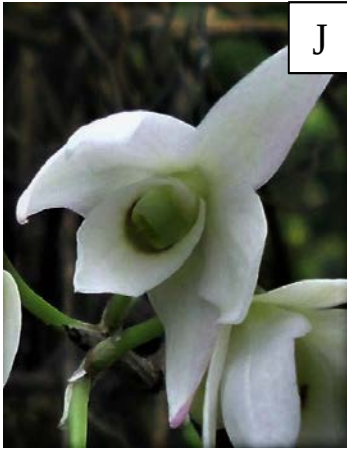
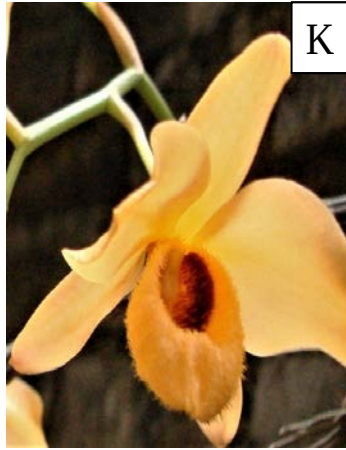


Plate 3. (Contd.)

- J. *Dendrobium moniliforme* (Linn.) Swartz
- K. *Dendrobium moschatum* (Buch.-Ham.) Swartz.
- L. *Dendrobium nobile* Lindl.
- M. *Dendrobium transparens* Lindl.
- N. *Dendrobium longicornu* Lindl.
- O. *Dendrobium amplum* Lindl
- P. *Dendrobium rotundatum* (Lindl.) Hook.f.
- Q. *Dendrobium denudans* D. Don
- R. *Dendrobium eriiflorum* Griff.



J



K



L



M



N



O



P



Q



R

Section V. *Sarcopodium*

In Section *Sarcopodium*, the flowers are bracteate and variously coloured. The flower is yellowish brown, lip deep purple with bronze edges, profusely spotted and blotched with dark brown in *D. amplum* (Plate 3.O), purplish brown in *D. fuscescens* and pale yellowish brown, lip yellow with brown spots in *D. rotundatum* (Plate 3.P). The size of flower varies ranging from 3.4 cm across (*D. rotundatum*) to 7.5 cm across (*D. amplum*) (Table 2). The size of pedicel with ovary ranges from 2.5 cm long (*D. rotundatum*) to 5.0 cm long (*D. amplum*) (Table 2).

Section VI. *Stachyobium*

In Section *Stachyobium*, the flowers are bracteate, small and variously coloured. The colour of flower varies in different species. The colour of flower ranges from creamy with light greenish tinge on sepal and petals and red lines on lip (*D. darjeelingense*) to creamy or yellowish green (*D. porphyrochilum*) (Table 2). The flower size varies from 0.8-1.0 cm across (*D. porphyrochilum*) to 1.5 cm across (*D. eriiflorum* Plate 3.R, *D. monticola*) (Table 2). The smallest flower is present in *D. porphyrochilum* among the different species of *Dendrobium*. The size of pedicel with ovary ranges from 0.4 cm long (*D. darjeelingense*) to 0.6– 0.9 cm long (*D. denudans*, Plate 3.R) (Table 2).

d. Floral Bracts

Section I. *Aporum*

In *D. anceps* the floral bract is oblong, obtuse, 5-veined, 3.5 mm in length and 2.0 mm in width in size (Table 3).

Section II. *Crinifera*

In Section *Crinifera*, the floral bracts are similar in *D. fugax* and *D. plicatile*. The floral bracts are small, triangular, membranous, acute and 1-veined. The size of floral bract is 1.0 mm in length and 1.2 mm in width in both species (Table 3).

Section III. *Dendrobium*

In Section *Dendrobium*, there is variation in shape of floral bracts ranging from ovate, oblong, lanceolate, ovate-lanceolate, ovate-oblong to ovate-triangular in all species (Table 3). The floral bracts are membranous in all species except in *D. moschatum* it is leathery. The apex of floral bract is acute in *D. amoenum*, *D. aphyllum*, *D.*

Table 3: Comparative Floral Bract Structures in *Dendrobium*

S.N.	Taxa	Length (cm)	Width (cm)	Shape	Veins	Apex	Distinguished Characters
1	<i>D. amoenum</i>	0.7	0.2	Ovate-lanceolate	3	Acute	Membranous, much shorter than ovary
2	<i>D. amplum</i>	1.7	0.5	Ovate-oblong	5	Acute	Large, scarious
3	<i>D. anceps</i>	0.35	0.2	Oblong	5	Obtuse	Much shorter than ovary
4	<i>D. aphyllum</i>	0.3	0.25	Ovate	1	Acute	Pale-white and membranous
5	<i>D. bicameratum</i>	0.6	0.4	Oblong-ovate	3	Acute	Sheathing the shortly stalked ovary
6	<i>D. chrysanthum</i>	0.4	0.25	Ovate-triangular	1	Acute	Small and scarious
7	<i>D. chryseum</i>	1.5-2.0	0.4-0.5	Ovate-lanceolate	5	Obtuse	Membranous
8	<i>D. crepidatum</i>	0.4	0.2	Ovate	1	Acute	Small, thin and membranous
9	<i>D. darjeelingense</i>	0.4	0.1	Triangular	3	Acute	Small and membranous
10	<i>D. denneanum</i>	2	0.6	Oblong	7	Acute	Large and membranous
11	<i>D. densiflorum</i>	1.9	1	Oblong	7	Obtuse	Large, membranous, twisted, margin revolute
12	<i>D. denudans</i>	0.3	0.15	Lanceolate	1	Acute	Minute and membranous
13	<i>D. eriiflorum</i>	0.4	0.15	Ovate-lanceolate	1	Acuminate	Minute and membranous
14	<i>D. fimbriatum</i>	0.4	0.3	Ovate-triangular	5	Acute	Small and membranous
15	<i>D. formosum</i>	0.5	0.2	Ovate	5	Subacute	Much shorter than ovary and

							sheathing
16	<i>D. fugax</i>	1	1.2	Triangular	1	Acute	Small, membranous
17	<i>D. fuscescens</i>	1	0.5	Ovate-lanceolate	5	Acute	Small, scarious, shorter than pedicel with ovary
18	<i>D. gibsonii</i>	0.5-0.7	0.2-0.3	Lanceolate	5	Acute	Minute, membranous and cymbiform
19	<i>D. heterocarpum</i>	0.6	0.4	Ovate	3	Obtuse	Broad and convolute
20	<i>D. longicornu</i>	1.5	0.5	Ovate-lanceolate	5	Acute	Concave and hairy abaxially
21	<i>D. moniliforme</i>	0.6	0.3	Ovate	3	Acute	Pale white with brown spots
22	<i>D. monticola</i>	0.35	0.2	Ovate	1	Acute	Small and membranous
23	<i>D. moschatum</i>	1.5	0.7	Lanceolate	5	Obtuse	Leathery
24	<i>D. nobile</i>	0.5-0.9	0.4-0.6	Oblong-ovate	5	Obtuse	Scarious
25	<i>D. plicatile</i>	0.1	0.12	Triangular	1	Acute	Small and membranous
26	<i>D. polyanthum</i>	0.8	0.5	Ovate	1	Obtuse	Minute and memebranous
27	<i>D. porphyrochilum</i>	0.2-0.4	0.1-0.12	Lanceolate	1	Acuminate	Minute, longer than pedicel with ovary
28	<i>D. rotundatum</i>	1	0.6	Ovate	5	Acute	Small, scarious
29	<i>D. transparens</i>	1.1	0.7	Lanceolate	5	Acute	Scarious, much shorter than stalked ovary

bicameratum, *D. chrysanthum*, *D. crepidatum*, *D. denneanum*, *D. fimbriatum*, *D. gibsonii*, *D. moniliforme*, *D. transparens* and obtuse in *D. chryseum*, *D. densiflorum*, *D. heterocarpum*, *D. moschatum*, *D. nobile* and *D. polyanthum* (Table 3). The number of veins of floral bract varies from one to seven veins in all species (Table 3). The number of veins in floral bract varies from one to seven in different species (Table 2). The size of floral bract ranges from 0.3 cm in length and 0.25 cm in width (*D. aphyllum*) to 2.0 cm in length and 0.6 cm in width (*D. denneanum*) (Table 3).

Section IV. *Formosae*

In Section *Formosae*, the floral bract is ovate, subacute, 5-veined in *D. formosum* and ovate-lanceolate, acute, 5-veined in *D. longicornu*. Hairs are present on abaxial side in *D. longicornu*. The floral bract size is 0.5 cm in length and 0.2 cm in width in *D. formosum* and 1.5 cm in length and 0.5 cm in width (Table 3).

Section V. *Sarcopodium*

In Section *Sarcopodium*, the floral bracts are acute, 5-veined in *D. amplum*, *D. fuscescens* and *D. rotundatum*. The floral bracts are ovate-oblong, scarious in *D. amplum* ovate-lanceolate, scarious in *D. fuscescens* and ovate, membranous in *D. rotundatum*. The size of floral bract is 1.7 cm in length and 0.5 cm in width (*D. amplum*), 1.0 cm in length and 0.5 cm in width (*D. fuscescens*) and 1.0 cm in length and 0.6 cm in width (Table 3).

Section VI. *Stachyobium*

In Section *Stachyobium*, the floral bracts are minute, membranous, acute in *D. darjeelingense*, *D. denudans*, *D. monticola* and acuminate in *D. eriiflorum*, *D. porphyrochilum*. The shape of the floral bract varies: triangular (*D. darjeelingense*), lanceolate (*D. denudans*, *D. porphyrochilum*) and narrowly ovate (*D. monticola*). There are variations in vein no. and size. The floral bracts are 3-veined in *D. darjeelingense* and 1-veined in remaining species. The size ranges from 2.0-4.0 mm in length and 1.0-1.2 mm in width (*D. porphyrochilum*) to 4.0 mm in length and 2.0 mm in width (*D. darjeelingense*) (Table 3).

e. Sepals

Section I. *Aporum*

In *D. anceps* the dorsal sepal is elliptic, erect, subacute, tip folded inwards, 5-veined, 0.5 cm in length and 0.4 mm in width (Table 4). Lateral sepal is longer and broader

than dorsal sepal, falcate, elliptic, obtuse, tip folded inwards, pink spotted, 5-veined, 0.8 cm in length and 0.5 cm in width (Table 5).

Section II. *Crinifera*

In Section *Crinifera*, the dorsal sepal is 5-veined, elliptic-oblong with subacute apex in *D. fugax* and ovate-lanceolate with acuminate apex, rolled inside in *D. plicatile*. The size of dorsal sepal is 1.3 cm in length and 0.4 cm in width (*D. fugax*) and 0.9 cm in length and 0.25 cm in width (*D. plicatile*) (Table 4). Lateral sepals are slightly larger than dorsal sepal in *D. fugax* and similar to dorsal sepal in *D. plicatile*. Lateral sepals are 5-veined, oblong-elliptic and subacute in *D. fugax*, obliquely ovate-lanceolate and acuminate in *D. plicatile*. The size of lateral sepals is 1.4 cm in length and 0.5 cm in width in *D. fugax* and 0.9 cm in length and 0.25 cm in width in *D. plicatile* (Table 5).

Section III. *Dendrobium*

In Section *Dendrobium*, the dorsal sepal varies in shape ranging from lanceolate, oblong-lanceolate, oblong, ovate-oblong to elliptic in different species (Table 4). The dorsal sepals are 5-veined with obtuse apex in *D. amoenum*, *D. crepidatum*, *D. fimbriatum*, *D. gibsonii*, *D. transparens*; acute apex in *D. moniliforme*; subacute apex in *D. aphyllum*, *D. bicameratum*, *D. chryseum*, *D. heterocarpum*, *D. polyanthum*; 7-veined with obtuse apex in *D. chrysanthum*, *D. densiflorum*, *D. moschatum*, *D. nobile* and acuminate apex in *D. denneanum*. The size of dorsal sepal varies from 0.9 cm in length and 0.6 cm in width (*D. bicameratum*) to 3.2 cm in length and 1.6 cm in width (*D. moschatum*) (Table 4). Lateral sepals vary in shape ranging from lanceolate, oblong-lanceolate, oblong-elliptic, oblong, ovate-lanceolate, ovate-triangular to triangular in different species (Table 4). The lateral sepals are 5-veined with obtuse apex in *D. crepidatum*, *D. fimbriatum*, *D. gibsonii*; acute apex in *D. amoenum*, *D. moniliforme*, *D. nobile*; subacute apex in *D. aphyllum*, *D. bicameratum*, *D. chryseum*, *D. polyanthum*; 7-veined with obtuse apex in *D. chrysanthum*; acute apex in *D. heterocarpum*, *D. moschatum*, *D. nobile*; acuminate apex in *D. denneanum* and obtusely acute in *D. densiflorum*. The size of lateral sepal varies from 0.7 cm in length and 0.75 cm in width (*D. bicameratum*) to 3.3 cm in length and 0.5 cm in width (*D. transparens*) (Table 5).

Table 4: Comparative Structure of Dorsal Sepals in *Dendrobium*

S.N.	Taxa	Length (cm)	Width (cm)	Veins	Shape	Apex	Distinguished characters
1	<i>D. amoenum</i>	2.4	0.7	5	Oblong-lanceolate	Obtuse	White with tinged of purple
2	<i>D. amplum</i>	4.7	0.7	10	Lanceolate	Acuminate	Yellowish brown with dark brown spots
3	<i>D. anceps</i>	0.5	0.4	5	Elliptic	Sub-acute	Erect, tip folded inward
4	<i>D. aphyllum</i>	2.8	0.8	5	Oblong-lanceolate	Sub-acute	White with pale purplish red lines
5	<i>D. bicameratum</i>	0.9	0.6	5	Ovate-oblong	Sub-acute	Concave, broad
6	<i>D. chrysanthum</i>	2.2	1.2	7	Elliptic	Obtuse	Concave, entire, incurve apical half
7	<i>D. chryseum</i>	2.5	0.9	5	Oblong-lanceolate	Subacute	Concolor yellow
8	<i>D. crepidatum</i>	1.4	0.7	5	Oblong-lanceolate	Obtuse	Entire, spotted (tinged with light purple)
9	<i>D. darjeelingense</i>	0.8	0.2	3	Lanceolate	Acuminate	Entire, creamy tinged with light green
10	<i>D. denneanum</i>	1.8	1	7	Oblong	Acuminate	Entire, dark yellow
11	<i>D. densiflorum</i>	2	1.1	7	Ovate-oblong	Obtuse	Light yellow
12	<i>D. denudans</i>	1.2	0.25	3	Linear-lanceolate	Acuminate	Creamy to pale green
13	<i>D. eriiflorum</i>	1.2	0.25	5	Lanceolate	Acuminate	Light greenish white
14	<i>D. fimbriatum</i>	2.4	1	5	Elliptic-oblong	Obtuse	Entire, light orange-yellow
15	<i>D. formosum</i>	4.2	1.2	7	Elliptic-oblong	Acuminate	Erect, slightly concave
16	<i>D. fugax</i>	1.3	0.4	5	Elliptic-oblong	Sub-acute	White sprinkled with pink-purple spots
17	<i>D. fuscescens</i>	2.8	0.8	10	Ovate-lanceolate	Acuminate	Purplish-brown

18	<i>D. gibsonii</i>	1.6	1	6	Elliptic	Obtuse	Entire, slightly incurved, base slightly zigzag
19	<i>D. heterocarpum</i>	2.8	0.7	5	Oblong-lanceolate	Sub-acute	Pale yellow
20	<i>D. longicornu</i>	2.5	0.7	7	Ovate-lanceolate	Acuminate	Keeled
21	<i>D. moniliforme</i>	1.5	0.5	5	Broadly lanceolate	Acute	Subfalcate
22	<i>D. monticola</i>	1	0.2	3	Lanceolate	Acuminate	White
23	<i>D. moschatum</i>	3.2	1.6	7	Oblong	Obtuse	Pale yellow
24	<i>D. nobile</i>	3.1	0.9	7	Oblong-lanceolate	Obtuse	White at base mauve above
25	<i>D. plicatile</i>	0.9	0.25	5	Ovate-lanceolate	Acuminate	Rolled inside, milky yellow tinged with purple red spots
26	<i>D. polyanthum</i>	2.2	0.6	5	Lanceolate	Sub-acute	Pink-purple
27	<i>D. porphyrochilum</i>	0.6	0.15	3	Lanceolate	Obtuse	Creamish-green
28	<i>D. rotundatum</i>	3	1	7	Ovate-lanceolate	Acute	Pale yellowish brown
29	<i>D. transparens</i>	3.2	0.5	5	Lanceolate	Obtuse	White with pink flooded

Table 5: Comparative Structure of Lateral Sepals in *Dendrobium*

S.N.	Taxa	Length (cm)	Width (cm)	Veins	Shape	Apex	Distinguished Characters
1	<i>D. amoenum</i>	2.9	0.8	5	Lanceolate	Acute	Broader than dorsal sepal
2	<i>D. amplum</i>	4.6	0.7	10	Lanceolate	Acuminate	Falcate, broadly based
3	<i>D. anceps</i>	0.8	0.5	5	Elliptic	Obtuse	Tip folded inward, falcate, pink-spotted
4	<i>D. aphyllum</i>	2.9	0.7	5	Oblong-lanceolate	Subacute	White with pale purplish red lines
5	<i>D. bicameratum</i>	0.7	0.75	5	Triangular	Subacute	Concave
6	<i>D. chrysanthum</i>	2.2	1.1	7	Ovate-triangular	Obtuse	Concave, base broad and oblique, incurve apical half
7	<i>D. chryseum</i>	2.7	0.9	5	Oblong-lanceolate	Subacute	Concolor yellow
8	<i>D. crepidatum</i>	1.5	0.6	5	Ovate-oblong	Obtuse	Midrib thick, spotted (tinged with light purple)
9	<i>D. darjeelingense</i>	0.8	0.25	5	Ovate-lanceolate	Acute	Obliquely curved
10	<i>D. denneanum</i>	2.2	0.8	5	Oblong	Acuminate	Subfalcate
11	<i>D. densiflorum</i>	2.1-2.4	1.0-1.2	7	Oblong-elliptic	Obtusely acute	Light yellow
12	<i>D. denudans</i>	1.2	0.4	5	Lanceolate-triangular	Acuminate	Falcate
13	<i>D. eriiflorum</i>	1.2	0.3	5	Lanceolate	Acuminate	Falcate, broadly based
14	<i>D. fimbriatum</i>	2.4	1	5	Ovate-lanceolate	Obtuse	Small outgrowth at lower side of apex
15	<i>D. formosum</i>	4	1.6	7	Oblong-lanceolate	Acuminate	Subfalcate, keeled, spreading
16	<i>D. fugax</i>	1.4	0.5	5	Oblong-elliptic	Subacute	Adnate at base to form mentum
17	<i>D. fuscescens</i>	2.8	1.0	10	Ovate-lanceolate	Acuminate	Base broad, slightly falcate

18	<i>D. gibsonii</i>	1.6	0.9	5	Oblong	Obtuse	Slightly incurved, entire
19	<i>D. heterocarpum</i>	2.8	0.7	7	Lanceolate	Acute	Pale yellow
20	<i>D. longicornu</i>	5.5	1	7	Lanceolate	Acuminate	Adnate to form a long spur-like mentum, keeled, recurved
21	<i>D. moniliforme</i>	1.6	0.6	5	Lanceolate	Acute	Subfalcate
22	<i>D. monticola</i>	0.9	0.35	5	Falcate- lanceolate	Acute	Base broad, contracted above middle part
23	<i>D. moschatum</i>	3.2	1.6	7	Oblong	Acute	Pale yellow
24	<i>D. nobile</i>	3.2	0.8	7	Oblong- lanceolate	Acute	Base oblique, margin incurved slightly
25	<i>D. plicatile</i>	0.9	0.25	5	Ovate lanceolate	Acuminate	Obliquely ovate-lanceolate
26	<i>D. polyanthum</i>	2.3	0.5	5	Lanceolate	Subacute	Base oblique
27	<i>D. porphyrochilum</i>	0.8	0.2	3	Lanceolate	Obtuse	Slightly broader than dorsal sepal
28	<i>D. rotundatum</i>	3.0	1.3	7	Ovate	Acute	Subfalcate, adnate to column foot
29	<i>D. transparens</i>	3.3	0.5	5	Lanceolate	Acuminate	White with pink flooded

Section IV. *Formosae*

In Section *Formosae*, the dorsal sepals are 7-veined, elliptic-oblong, subacute in *D. formosum* and ovate-lanceolate, acuminate, keeled in *D. longicornu*. The size of dorsal sepal is 4.2 cm in length and 1.2 cm in width (*D. formosum*) and 5.5 cm in length and 1.0 cm in width (*D. longicornu*) (Table 4). Lateral sepals are 7-veined, oblong-lanceolate, subfalcate, acute, keeled in *D. formosum*, lanceolate, acuminate, keeled in *D. longicornu*. The size of lateral sepals is 4.0 cm in length and 1.6 cm in width in *D. formosum* and 5.5 cm in length and 1.0 cm in width in *D. longicornu* (Table 5).

Section V. *Sarcopodium*

In Section *Sarcopodium*, the dorsal sepals are 10 veined, acuminate, lanceolate in *D. amplum* and ovate-lanceolate in *D. fuscescens*. In *D. rotundatum* the dorsal sepal is 7-veined, ovate-lanceolate and acute. The size of dorsal sepal is 4.7 cm in length and 0.7 cm in width (*D. amplum*), 2.8 cm in length and 0.8 cm in width (*D. fuscescens*) and 3.0 cm in length and 1.0 cm in width (*D. rotundatum*) (Table 4). Lateral sepals are 10-veined, acuminate, lanceolate in *D. amplum* and ovate-lanceolate in *D. fuscescens*. In *D. rotundatum* the dorsal sepal is 7-veined ovate and acute. The size of lateral sepal is 4.6 cm in length and 0.7 cm in width (*D. amplum*), 2.8 cm in length and 1.0 cm in width (*D. fuscescens*) and 2.8 cm in length and 1.3 cm in width (*D. rotundatum*) (Table 5).

Section VI. *Stachyobium*

In Section *Stachyobium*, the dorsal sepals are 3 veined, lanceolate with acuminate apex in *D. darjeelingense*, *D. monticola* and obtuse apex in *D. porphyrochilum*; linear-lanceolate with acuminate apex in *D. denudans*. In *D. eriiflorum* the dorsal sepal is 5-veined, lanceolate with acuminate. The size of dorsal sepal ranges from 0.6 cm in length and .15 cm in width (*D. porphyrochilum*) to 1.2 cm in length and 0.25 cm in width (*D. denudans*, *D. eriiflorum*) (Table 4). Lateral sepals are 5-veined, lanceolate with acuminate apex in *D. eriiflorum*, acute apex in *D. monticola*; ovate-lanceolate with acute apex in *D. darjeelingense*, lanceolate triangular with acuminate apex in *D. denudans*. In *D. porphyrochilum* the lateral sepal is 3-veined, lanceolate with obtuse apex. The size of lateral sepal ranges from 0.8 cm in length and 0.2 cm in

width (*D. porphyrochilum*) to 1.2 cm in length and 0.4 cm in width (*D. denudans*) (Table 5).

f. Mentum

Lateral sepals adnate to the foot of column to form mentum.

Section I. *Aporum*

In *D. anceps* the mentum is saccate shaped (Fig. 2.14).

Section II. *Crinifera*

The mentum is broad, short, conical shaped in *D. fugax* (Fig. 2.7) and *D. plicatile* (Fig. 2.12).

Section III. *Dendrobium*

In Section *Dendrobium*, the mentum is conical shaped in *D. amoenum* (2.1), *D. aphyllum* (Fig. 2.2), *D. chryseum* (Fig. 2.3), *D. heterocarpum*, (Fig. 2.8) *D. moschatum* (Fig. 2.10), *D. nobile* (Fig. 2.11), *D. transparens* (Fig. 2.13); rounded shaped in *D. chrysanthum* (Fig. 2.17), *D. denneanum* (Fig. 2.18), *D. densiflorum* (Fig. 2.19) *D. fimbriatum* (Fig. 2.20), *D. moniliforme* (Fig. 2.21), *D. polyanthum* (Fig. 2.22); urceolate shaped in *D. bicameratum* (Fig. 2.25) and subglobose in *D. crepidatum* (Fig. 2.26), *D. gibsonii*(Fig. 2.27).

Section IV. *Formosae*

The mentum is conical shaped in *D. formosum* (Fig. 2.6) and funnel shaped in *D. longicornu* (Fig. 2.29).

Section V. *Sarcopodium*

The mentum is rounded shaped in *D. amplum* (Fig. 2.16), *D. rotundatum* (Fig. 2.24) and saccate shaped in *D. fuscescens* (Fig. 2.15).

Section VI. *Stachyobium*

The mentum is conical shaped in *D. denudans* (Fig. 2.4), *D. eriiflorum* (Fig. 2.5), *D. monticola* (Fig. 2.9), rounded shaped in *D. porphyrochilum* (Fig. 2.23) and spur shaped in *D. darjeelingense* (Fig. 2.28).

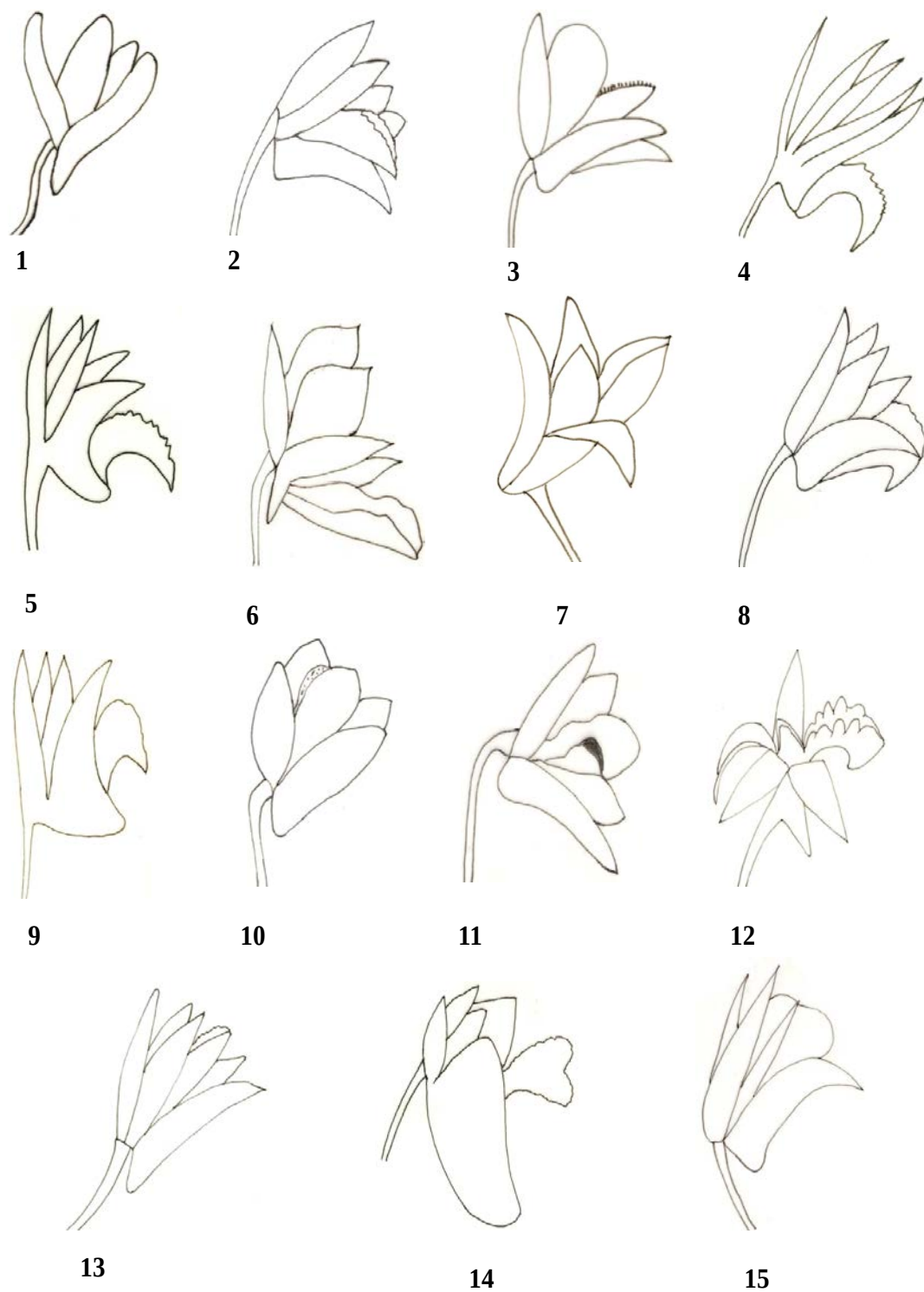


Fig. 2. Mentum of *Dendrobium* species.

Mentum conical shaped: 1. *D. amoenum* 2. *D. aphyllum* 3. *D. chryseum* 4. *D. denudans* 5. *D. eriiflorum* 6. *D. formosum* 7. *D. fugax* 8. *D. heterocarpum* 9. *D. monticola* 10. *D. moschatum* 11. *D. nobile* 12. *D. plicatile* 13. *D. transparens*; saccate shaped: 14. *D. anceps* 15. *D. fuscescens*.

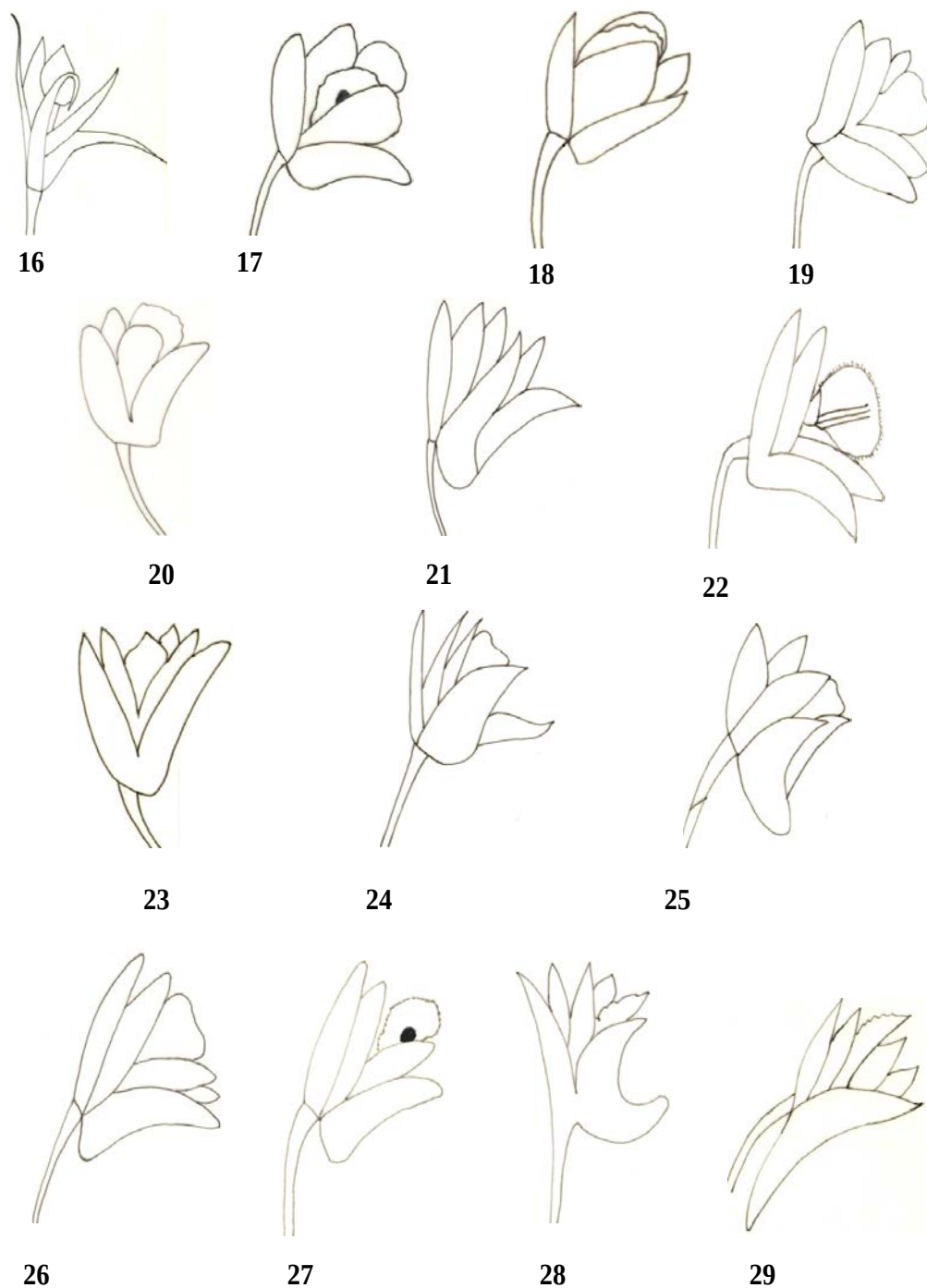


Fig. 2. (Contd.)

Mentum round shaped: 16. *D. amplum* 17. *D. chrysanthum* 18. *D. denneanum* 19. *D. densiflorum* 20. *D. fimbriatum* 21. *D. moniliforme* 22. *D. polyanthum* 23. *D. porphyrochilum* 24. *D. rotundatum*; urceolate shaped: 25. *D. bicameratum*; subglobose shaped: 26. *D. crepidatum* 27. *D. gibsonii*; spur shaped: 28. *D. darjeelingense*; funnel shaped: 29. *D. longicornu*.

g. Petals

Section I. Aporum

In *D. anceps* the petals are broadly elliptic, obtuse and 5-veined. The size of petal is 0.4 cm in length and 0.2 cm in width (Table 6).

Section II. *Crinifera*

In Section *Crinifera*, the petals are 3-veined, subacute, oblong in *D. fugax* and oblong-elliptic in *D. plicatile*. The size of petal is 1.1 cm in length and 0.2 cm in width in *D. fugax* and 0.9 cm in length and 0.2 cm in width in *D. plicatile* (Table 6).

Section III. *Dendrobium*

In Section *Dendrobium*, the petals vary in shape ranging from ovate, obovate, broadly ovate, ovate-orbicular, ovate-lanceolate, oblong, elliptic and broadly elliptic to oblong-elliptic in different species (Table 6). The petals are 5-veined with obtuse apex in *D. amoenum*, *D. aphyllum*, *D. bicameratum*, *D. crepidatum*, *D. fimbriatum*, *D. polyanthum*, *D. transparens*; acute apex in *D. heterocarpum*, *D. moniliforme*; emarginated apex in *D. gibsonii*; 7-veined with obtuse apex in *D. densiflorum*, *D. moschatum*, *D. nobile*; rounded apex in *D. chrysanthum*; 3-veined with obtuse apex in *D. chryseum*, *D. denneanum*. The size of petal varies from 0.9 cm in length and 0.5 cm in width (*D. bicameratum*) to 3.5 cm in length and 2.0 cm in width (*D. nobile*) (Table 6).

Section IV. *Formosae*

In Section *Formosae*, the petals are obovate, cuspidate, 7-veined in *D. formosum* and linear-lanceolate, acute, 3-veined in *D. longicornu*. The size of petal is 5.0 cm in length and 3.3 cm in width in *D. formosum* and 2.5 cm in length and 0.5 cm in width in *D. longicornu* (Table 6).

Section V. *Sarcopodium*

In Section *Sarcopodium*, the petals are linear-lanceolate, spreading, acute, 5-veined in *D. amplum*, *D. fuscescens* and oblong-lanceolate, acuminate, 7-veined in *D. rotundatum*. The size of petal ranges from 2.7 cm in length and 0.3 cm in width in *D. fuscescens* to 4.8 cm in length and 0.3 cm in width in *D. amplum* (Table 6).

Table 6: Comparative Structure of Petals in *Dendrobium*

S.N.	Taxa	Length (cm)	Width (cm)	Veins	Shape	Apex	Distinguished Characters
1	<i>D. amoenum</i>	2.6	1.2	5	Ovate	Obtuse	Broader than dorsal sepal, entire
2	<i>D. amplum</i>	4.8	0.3	5	Linear-lanceolate	Acute	Wide spreading
3	<i>D. anceps</i>	0.4	0.2	5	Elliptic	Obtuse	Much shorter than sepals, entire
4	<i>D. aphyllum</i>	3.1	1.2	5	Oblong-elliptic	Obtuse	Broader than sepals, entire
5	<i>D. bicameratum</i>	0.9	0.5	5	Elliptic	Obtuse	As long as sepal, yellowish with dull red spots and stripes
6	<i>D. chrysanthum</i>	2.4	1.7	7	Obovate	Rounded	Concave slightly, margin erose minutely
7	<i>D. chryseum</i>	2.5	1.4	3	Elliptic-obovate	Obtuse	Broader than sepal, major lateral veins branched
8	<i>D. crepidatum</i>	1.5	0.9	5	Obovate	Obtuse	Broader than sepal, entire, spotted (tinged with light purple)
9	<i>D. darjeelingense</i>	0.7	0.15	3	Oblong-lanceolate	Acute	Smaller than sepal
10	<i>D. denneanum</i>	2.5	1.2	3	Ovate	Obtuse	Broader than sepal, lateral veins branched
11	<i>D. densiflorum</i>	1.5-2.0	1.3-1.6	7	Ovate-orbicular	Obtuse	Shortly clawed, margin erose
12	<i>D. denudans</i>	1.3	0.12	3	Linear-lanceolate	Acuminate	Smaller than sepal in breadth
13	<i>D. eriiflorum</i>	1.1	0.18	3	Linear-lanceolate	Acute	Lying parallel above column

14	<i>D. fimbriatum</i>	2.4	1.5	5	Oblong-elliptic	Obtuse	Broader than sepal, margin slightly erose
15	<i>D. formosum</i>	5	3.3	7	Obovate	Cuspidate	Larger than sepal, truncate, margin undulate
16	<i>D. fugax</i>	1.1	0.2	3	Oblong-ovate	Subacute	Narrower than sepals
17	<i>D. fuscescens</i>	2.7	0.3	5	Linear-lanceolate	Acute	Petal spreading
18	<i>D. gibsonii</i>	1.7	1.3	5	Elliptic	Emarginate	Margin slightly undulate
19	<i>D. heterocarpum</i>	2.8	1	5	Ovate-lanceolate	Acute	Equal to dorsal sepal, entire, many secondary veins
20	<i>D. longicornu</i>	2.5	0.5	3	Linear-lanceolate	Acute	As long as dorsal sepal
21	<i>D. moniliforme</i>	1.6	0.7	5	Ovate-lanceolate	Acute	As long as sepal, entire
22	<i>D. monticola</i>	0.8	0.15	3	Linear-lanceolate	Acuminate	Smaller than sepal
23	<i>D. moschatum</i>	3.5	1.8	7	Ovate	Obtuse	Larger than sepal
24	<i>D. nobile</i>	3.5	2	7	Oblong-ovate	Obtuse	Margin slightly incurved
25	<i>D. plicatile</i>	0.9	0.2	3	Lanceolate	Subacute	Narrower than sepals , rolled inside
26	<i>D. polyanthum</i>	2.2	0.4	5	Oblong	Obtuse	Pink purple petals
27	<i>D. porphyrochilum</i>	0.5	0.1	3	Oblong-lanceolate	Acute	Pale yellow green with red veins
28	<i>D. rotundatum</i>	3.0	0.8	7	Oblong-lanceolate	Acuminate	As long as dorsal sepal
29	<i>D. transparens</i>	3.3	1.3	5	Oblong	Obtuse	White flushed with pink

Section VI. *Stachyobium*

In Section *Stachyobium*, the petals are 3-veined, oblong-lanceolate with acute apex in *D. darjeelingense*, *D. porphyrochilum*; linear-lanceolate with acute apex in *D. eriiflorum*, acuminate apex in *D. denudans*, *D. monticola*. The size of petal ranges from 0.5 cm in length and 0.1 cm in width (*D. porphyrochilum*) to 1.3 cm in length and 0.12 cm in width (*D. denudans*) (Table 6).

h. Lip

The lip is attached to the column foot. The lip varies greatly in shape, size and margins in all species of *Dendrobium*. The morphological characters of lip are of utmost important in taxonomy to distinguish the genus at infraspecific level. The lip characters are considered as most distinguishing characters for delimitation of species of *Dendrobium*. The lip is simple or tri-lobed. The lip can be distinguished into following types on the basis of structure of simple and trilobed lip of *Dendrobium*.

Type A. Lip simple without side lobes. There is variation in shape, margin and apex of lip in different species of *Dendrobium*. Following types are differentiated on the basis of shape, margin and apex of lip.

a. Lip orbicular-oblong, obovate, suborbicular and subglobular, margin denticulate and fimbriate with apex rounded in *D. chrysanthum* (Fig. 3.1), *D. polyanthum* (Fig. 3.4), *D. fimbriatum* (Fig. 3.2) and *D. moschatum* (Fig. 3.3) (Section *Dendrobium*).

b. Lip orbicular, suborbicular and subreniform, margin ciliolate, fimbriate and lacerate with apex emarginated and retuse in *D. crepidatum* (Fig. 3.7), *D. aphyllum* (Fig. 3.5), *D. chryseum* (Fig. 3.6), *D. denneanum* (Fig. 3.8), *D. densiflorum* (Fig. 3.9) and *D. gibsonii* (Fig. 3.10) (Section *Dendrobium*).

c. Lip trowel-shaped and elliptic, margin undulate and entire with apex acute and subacute in *D. heterocarpum* (Fig. 3.11) (Section *Dendrobium*) and *D. porphyrochilum* (Fig. 3.12) (Section *Stachyobium*).

d. Lip ovate-oblong, margin entire with apex obtuse in *D. nobile* (Fig. 3.13) (Section *Dendrobium*).

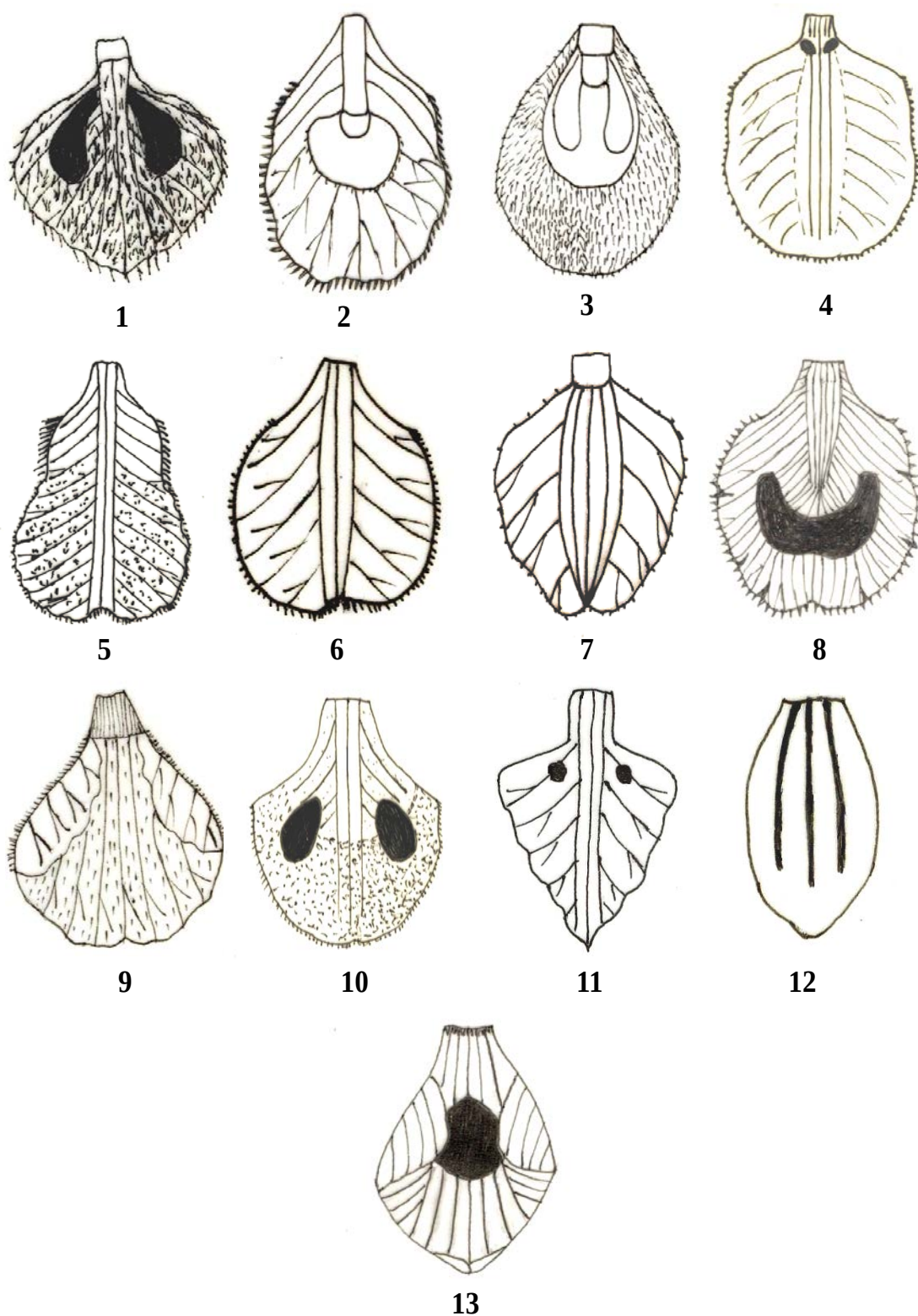


Fig. 3. Lip of *Dendrobium* species.

1. *D. chrysanthum*; 2. *D. fimbriatum*; 3. *D. moschatum*; 4. *D. polyanthum*; 5. *D. aphyllum*; 6. *D. chryseum*; 7. *D. crepidatum*; 8. *D. denneanum*; 9. *D. densiflorum*; 10. *D. gibsonii*; 11. *D. heterocarpum*; 12. *D. porphyrochilum*; 13. *D. nobile*.

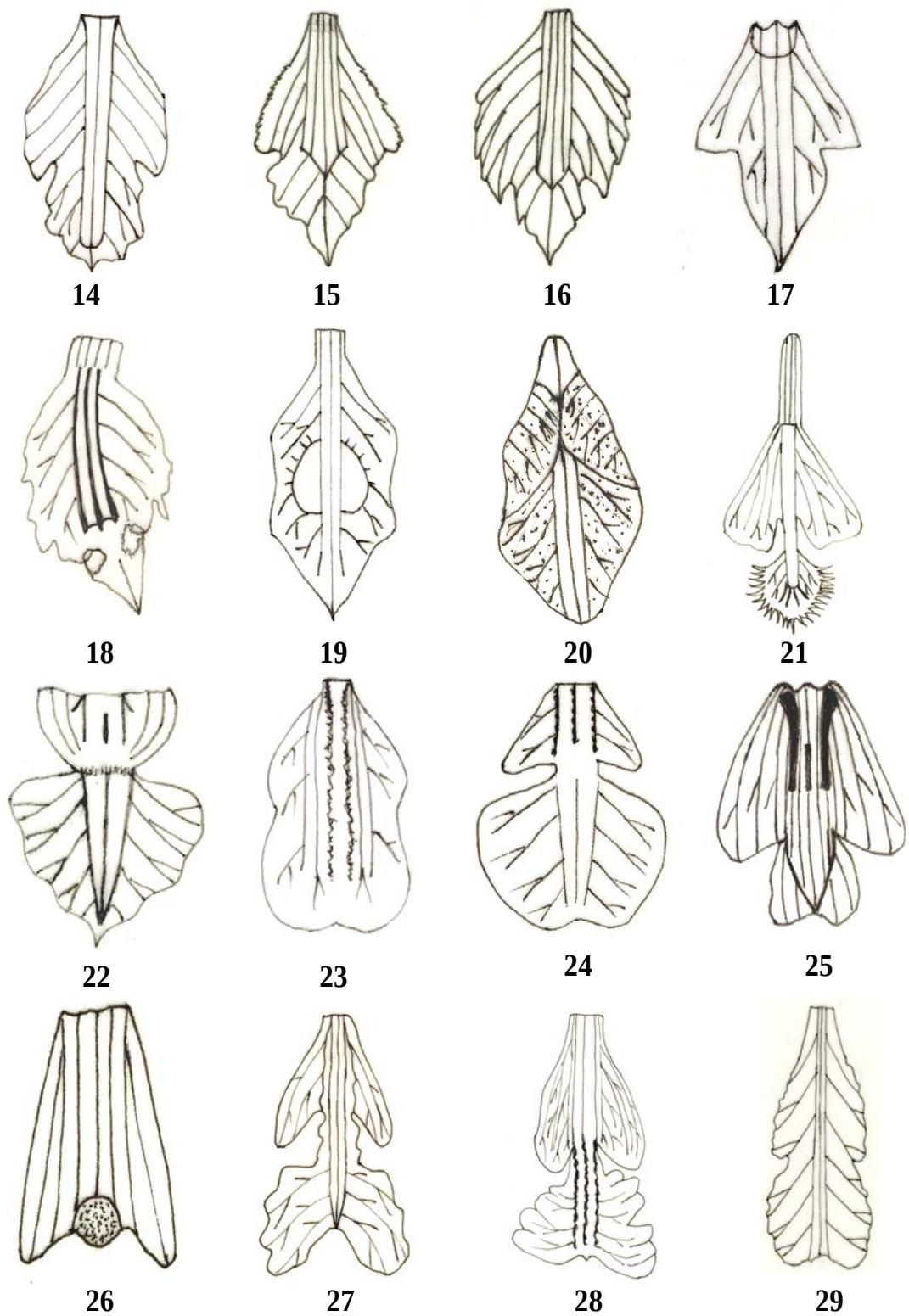


Fig. 3. contd.

14. *D. darjeelingense*; 15. *D. denudans*; 16. *D. eriiflorum*; 17. *D. moniliforme*; 18. *D. monticola*; 19. *D. transparens*; 20. *D. amoenum*; 21. *D. longicornu*; 22. *D. amplum*; 23. *D. formosum*; 24. *D. fuscescens*; 25. *D. rotundatum*; 26. *D. bicameratum*; 27. *D. fugax*; 28. *D. plicatile*; 29. *D. anceps*.

Type B. Lip trilobed with side lobes and midlobe. There is variation in shape, margin and apex of midlobe of lip in different species of *Dendrobium*. Following types are differentiated on the basis of shape, margin and apex of midlobe of lip.

a. Lip oblong-ovate, obovate, oblong-lanceolate, subeliptic and elliptic-obovate, margin crenulate, lacerate, undulate and entire with apex acute in *D. darjeelingense* (Fig. 3.14), *D. denudans* (Fig. 3.15), *D. eriiflorum* (Fig. 3.16) (Section *Stachyobium*), *D. moniliforme* (Fig. 3.17) (Section *Dendrobium*), *D. monticola* (Fig. 3.18) (Section *Stachyobium*), and *D. transparens* (Fig. 3.19) (Section *Dendrobium*).

b. Lip oblong-ovate and broadly triangular, margin undulate and fimbriate-lacerate with apex obtuse in *D. amoenum* (Fig. 3.20) (Section *Dendrobium*) and *D. longicornu* (Fig. 3.21) (Section *Formosae*).

c. Lip pandurate, margin crenulate with apex mucronate in *D. amplum* (Fig. 3.22) (Section *Sarcopodium*).

d. Lip ovate-oblong, obovate-oblong and ovate, margin undulate with apex emarginated and retuse in *D. fuscescens* (Fig. 3.24), *D. rotundatum* (Fig. 3.25) (Section *Sarcopodium*) and *D. formosum* (Fig. 3.23) (Section *Formosae*).

e. Lip oblong-obovate, subovate and broadly triangular, margin undulate and entire with apex truncate and subtruncate in *D. fugax* (Fig. 3.27), *D. plicatile* (Fig. 3.28) (Section *Crinifera*) and *D. bicameratum* (Fig. 3.26) (Section *Dendrobium*).

f. Lip wedge-shaped, margin crenulate with apex bilobed in *D. anceps* (Fig. 3.29) (Section *Aporum*).

Ornamentation on lip

Ornamentation on lip varies in different species of *Dendrobium*. Following types of ornamentation are found in lip of *Dendrobium*.

Type i. Without ornamentation on disc of lip: *D. moschatum*.

Type ii. Ridges on disc of lip: *D. chrysanthum*, *D. crepidatum*, *D. denudans*, *D. eriiflorum*, *D. formosum*, *D. longicornu* and *D. porphyrochilum*.

Type iii. Lamellae on disc of lip: *D. amplum*, *D. fugax*, *D. fuscescens*, *D. monticola* and *D. plicatile*.

Type iv. Callus on disc of lip: *D. bicameratum*, *D. moniliforme* and *D. polyanthum*.

Type v. Clawed at base of lip: *D. chryseum*, *D. denneanum*, *D. densiflorum*, *D. fimbriatum* and *D. nobile*.

Type vi. Sub-villous disc of lip: *D. amoenum*.

Type vii. Papillary hairs on disc of lip: *D. aphyllum*, *D. gibsonii*, *D. heterocarpum*.

Type viii. Central distinct veins from base to apex of lip: *D. transparens*.

Type ix. Shallow depression ending near apex of lip: *D. anceps*.

Type x. Keels from base to apex of lip: *D. darjeelingense* and *D. rotundatum*.

i. Column, Anther and Pollinia

Column is sub-terete to clavate, straight or curved in all species of *Dendrobium*. Column varies from 0.1 – 2.9 cm in length in different species of *Dendrobium*. Longer column is found in *D. longicornu*, *D. amplum*, *D. formosum*, *D. rotundatum*, *D. aphyllum* and *D. fuscescens*, shorter in remaining species of *Dendrobium*. Filaments are fused along the style length to form column. The base of column extends ventrally to form column foot. Lateral sepals are attached to column foot to form mentum. Column foot varies from 0.14 – 2.8 cm in length in different species of *Dendrobium*. Column foot is longer in *D. longicornu*, *D. formosum*, *D. amplum*, *D. anceps* and *D. transparens* and shorter in remaining species of *Dendrobium*. Column foot with 2 calli at lower end with thickened line is present in *D. amoenum*, at right angle to column in *D. amplum* and *D. eriiflorum*, bilocular in *D. bicameratum*, margin with fine papillose in *D. monticola*, transverse ridge at lower end in *D. chrysanthum*, slightly winged in *D. rotundatum* and simple in remaining species.

The anther is inserted on filament near stigma base with base of operculum. A single fertile anther is present at apex of column and attached by short connective on clinandrium. The anther is two chambered, oblong or bilobed, rounded, emarginated or retuse at the apex, surface glabrous or papillose, yellow or white, anther cap entire, dentate, erose, hairy.

The anther contains four pollinia in two pairs. Pollinia are oblong or ellipsoid, usually subequal. They are mostly yellow and pale-yellow in few species. The caudicle or viscidia is absent in pollinia.

The stigma is three-lobed: two lateral lobes are fertile while the posterior lobe is modified into rostellum. The rostellum is small, lamellate, narrow or wide. The stigmatic cavity is entire in most species of *Dendrobium* but bilobed in *D. amplum*, *D. formosum* and *D. porphyrochilum* and four-lobed in *D. densiflorum*.

Table 7: Comparative Structure of Lips in *Dendrobium*

S.N.	Taxa	Lip											Distinguished Characters on disc
		Structure					Side Lobe			Mid Lobe			
		Outline	Length (cm)	Width (cm)	Shape	Colour	Shape	Apex	Margin	Shape	Apex	Margin	
1	<i>D. amoenum</i>	Tri-lobed	2.8	1.4	Oblong-ovovate	White with purplish blotch at apex, greenish yellow at middle	Rounded	Obtuse	Convolute	Oblong-ovate	Obtuse	Undulate	Sub-villous on disc
2	<i>D. amplum</i>	Tri-lobed	2.7	1.7	Pandurate	Dark purple with bronze edges	Short, Rounded	Obtuse	Entire	Sub-rhomboid	Mucronate	Crenulate	Disc with 3 lamellae, outer 2 having an erect tooth at bases, middle one shorter and toothless
3	<i>D. anceps</i>	Tri-lobed	1.2	0.4	Cuneately oblong	Yellowish green with pink spotted	Oblong	Obtuse	Entire at lower part, crenulate at apex	Obovate	Bilobed	Crenulate	Shallow thickened depression ending near apex

4	<i>D. aphyllum</i>	Simple	3.4	2.6	Suborbicular	Pale yellow or cream at apex, purple veined at base	–	–	–	Convolute forming a tube at base	Rounded, emarginate	Fimbriate	Disc hairy
5	<i>D. bicameratum</i>	Tri-lobed	0.5	0.45	Triangular	Yellow marked with dull red	Triangular	Acute	Entire	Rectangular	Truncate	Entire	Disc with cushion-shaped callus
6	<i>D. chrysanthum</i>	Simple	2.2	2.4	Orbicular-oblong	Golden yellow with purplish red blotch	–	–	–	Reniform	Rounded	Denticulate	Thick and broad ridge extending from base to middle
7	<i>D. chryseum</i>	Simple	2.8	2.4	Suborbicular	Yellow orange with 2-lobed purple blotch	–	–	–	Suborbicular	Rounded	Fimbriate	Minutely pubescent to tomentose on adaxial side, clawed at base
8	<i>D. crepidatum</i>	Simple	1.4	1.1	Orbicular	Pale purplish-pink above middle, yellow below middle	–	–	–	Obovate, incurved sides at base	Retuse	Undulate, ciliate	A transverse ridge at the claw
9	<i>D. darjeelingense</i>	Tri-lobed	0.6	0.3	Oblong-ovate	Red lined in cream tinged with light green	Triangular	Acute	Entire	Obovate	Acute	Undulate, crenulate	3 keels from base to apex
10	<i>D. denneanum</i>	Simple	2.2	2	Orbicular	Dark yellow with dark purple reniform patch	–	–	–	Reniform, convolute in basal part	Retuse	Undulate, fimbriate	Clawed at base, tomentose
11	<i>D. densiflorum</i>	Simple	2.2	2.1	Orbicular-rhomboid	Orange yellow	–	–	–	Orbicular-rhomboid, convolute in basal half	Retuse	Revolute, lacerate	Clawed at base

12	<i>D. denudans</i>	Tri-lobed	1.1	0.5	Obovate	Pale green with radiating red-purple lines	Oblong	Acute	Lacerate	Obovate	Acute	Serrate-crisped	Disc with 3 ridges having a triangular apex ending at mid-lobe
13	<i>D. eriiflorum</i>	Tri-lobed	0.8	0.7	Oblong-ovate	Light greenish-white spotted with dull purple	Elongate, narrow	Acute	Pectinate-serrate	Orbicular	Acute	Undulate	Disc with a mesial ridge running from base to apex of mid-lobe
14	<i>D. fimbriatum</i>	Simple	3	2.2	Suborbicular	Deep orange yellow with dark purple blotch	–	–	–	Suborbicular	Rounded	Deeply fimbriate	Shortly clawed, base with purple red stripes, densely pubescent adaxially
15	<i>D. formosum</i>	Tri-lobed	6	3.5	Obcuneate	White with yellow marks	Rounded	Obtuse	Entire	Orbicular	Retuse, apiculate	Undulate	Disc with two yellow tuberculate central ridges
16	<i>D. fugax</i>	Tri-lobed	1.3	0.6	Oblong-obovate	White sprinkled with pink-purple spots	Oblong	Truncate	Erose-crisped	Oblong-elliptic	Truncate	Undulate	Disc with two plicate lamellae extending from base to apex
17	<i>D. fuscescens</i>	Tri-lobed	1.8	1.6	Ovate-oblong	Purplish-brown	Oblong	Obtuse	Undulate	Sub-orbicular	Emarginate to Mucronate	Undulate	Disc with 3 crenulate lamellae between side lobes, middle lamella shorter
18	<i>D. gibsonii</i>	Simple	1.5	1.7	Sub-reniform	Orange yellow with deep purple blotch on each side	–	–	–	Orbicular	Emarginate	Fimbriate	Deep purple blotch, papillary hairs with short fringed edges on both sides of disc
19	<i>D. heterocarpum</i>	Simple	2.8	1.6	Trowel-shaped	Pale yellow with reddish purple radiating lines	–	–	–	Ovate-oblong	Acute	Undulate	Disc papillose-pubescent
20	<i>D. longicornu</i>	Tri-lobed	5.1	2.3	Broadly triangular (spreading)	White streaked orange	Rounded	Truncate	Slightly wavy	Sub-orbicular	Obtuse	Fimbriate	A broad central ridge from base to mid-lobe ending into 4

						yellow							branches
21	<i>D. moniliforme</i>	Tri-lobed	1.5	0.9	Oblong-lanceolate	White with yellowish green central spots	Rounded, incurved near middle	Rounded	Entire, slightly wavy	Ovate-elliptic	Acute	Entire	Disc with an elongated callus
22	<i>D. monticola</i>	Tri-lobed	0.8	0.45	Subelliptic	White with purplish red stripes in side lobes	Rounded	Acuminate	Inciso-serrate	Ovate triangular	Acute	Undulate, recurved	disc with irregular, orbicular, triangular apex , 3 lamellate ridged projections in centre
23	<i>D. moschatum</i>	Simple	3	1.7	Calceolate	Pale yellow with purplish brown blotches on either sides	–	–	–	Sub-globular	Rounded	Cucullate, fimbriate	No callus
24	<i>D. nobile</i>	Simple	3.5	2.2	Ovate-oblong	White at base becoming mauve at apex with large purple blotch	–	–	–	Ovate-oblong	Obtuse	Cucullate, entire	Shortly clawed, upper half cucullate, lower half incurved, densely pubescent
25	<i>D. plicatile</i>	Tri-lobed	1.5	0.8	Subovate	White with yellowish white lamellae	Subovate	Rounded	Entire	Flabellate	Sub truncate	Undulate	Disc with two or three lamellae extending from base to apex of mesochile.
26	<i>D. polyanthum</i>	Simple	2.5	2	Obovate, convolute at base	Pinkish yellow at apex white at base with purple veins	–	–	–	Obovate	Rounded	Denticulate	Short claw, callus at base,

27	<i>D. porphyrochilum</i>	Simple	0.4	0.25	Elliptic	Purplish brown with yellowish green margin	—	—	—	Elliptic	Subacute	Entire	3 obscure ridges of variable lengths from base to apex
28	<i>D. rotundatum</i>	Tri-lobed	1.9	1.2	Obovate-oblong	Brownish yellow	Sub-ovate	Obtuse	Slightly undulate	Sub-reniform	Emarginate	Undulate	Midlobe with a triangular thickened keel adaxially, disc with 3 crenulate lamellae between side lobes, middle one shorter
29	<i>D. transparens</i>	Tri-lobed	3.6	1.8	Elliptic-obovate	White with purple patch at middle	Broad, convolute	Rounded	Erose	Sub-orbicular	Acute	Undulate	Disc hairy with 3 distinct veins running from base to apex

4.1.1.3. Taxonomic Treatment of *Dendrobium* Sw.

4.1.1.3.1. Description of *Dendrobium* Sw.

Dendrobium Sw., Nova Acta Reg. Soc. Upsal 2, 6: 82 (1799), nom. cons.

Type: *Dendrobium moniliforme* (L.), Sw. (type cons.), *fide* Holttum *et al.* (Taxon 28, 4: 409, 1979).

Basionym: *Epidendrum moniliforme* L. Sp. Pl. 954. 1753.

Habit of different species of *Dendrobium* is sympodial with elongated cane-like stems or pseudobulbs. All species are perennial, epiphytic, erect or pendulous herbs and some are lithophytic also. The height of plant ranges from a centimeter to 70 cm, the smallest plant being *D. porphyrochilum* (1 cm) and the largest being *D. amplum* (70 cm). **Stem** or **pseudobulb** is erect or pendant, many noded, one to several internodes swollen at or near base or along entire length to form canelike pseudobulbs covered with or without sheathing leaf bases, sheaths hirsute or glabrous. Most species of *Dendrobium* has elongated cane-like stems and few species had pseudobulbs like *D. amplum*, *D. fugax*, *D. fuscescens*, *D. plicatile*, *D. rotundatum*.

Leaves one to many, alternate, apical from pseudobulb or distichously arranged along stem, lanceolate, linear, oblong or ovate, membranous, fleshy or coriaceous, apex bilobed or emarginated, acute, obtuse. **Inflorescence** is axillary or terminal, racemose, erect, horizontal or pendulous, one to many flowered, solitary or many flowered borne on nodes of foliate or defoliate stems, rachis long or short, slender, peduncle slender, short or long, sheathed. **Flowers** are very showy, solitary or in fascicles, small (1.0 cm across in *D. porphyrochilum*) to large (10 cm across in *D. formosum*), variation in colour and shape, resupinate or not resupinate, spreading, ephemeral or long-lived. **Floral bract** is 1, oblong, ovate, lanceolate, triangular, acute, obtuse, acuminate, entire, glabrous or hirsute. **Sepals** are free, dorsal sepal lanceolate, oblong, ovate, acute, obtuse, emarginated apex and nerved, lateral sepals lanceolate, triangular, ovate, acute or obtuse, adnate to column foot forming a mentum. The shape of mentum varies in all species of *Dendrobium*. The mentum is conical shaped, rounded, saccate, subglobose, urceolate, spur-like or funnel shaped indifferent species of *Dendrobium*. **Petals** are free, lanceolate, oblong, ovate, acute, obtuse, emarginated apex, nerved, free from the dorsal sepal. **Lip** is simple to 3-lobed, entire or fimbriate, base adnate to column foot, sessile or narrowly clawed at base, with or without callus at base. **Column** is free, short, the anterior part with a large

depression occupied by the stigma, foot short or long, broad, hollowed or not hollowed at the base, a nector-secreting depression or cavity at its extremity. **Anther** is 2-celled, attached by a short process, ovate or conic-shaped, emarginated or retuse apex, glabrous or papillose, frontage entire, erose, dentate, hairy. **Pollinia** are 4 arranged in 2 pairs, ovoid or oblong, slightly compressed, mostly yellow.

4.1.1.3.2. Synopsis of Classification of *Dendrobium* Sw. (Chase *et al.*, 2015)

Family : Orchidaceae

Subfamily: Epidendroideae

Tribe : Malaxideae

Subtribe : Dendrobiinae

Genus : *Dendrobium*

Sections of *Dendrobium* Sw. (Schuitman & Adams, 2014)

Schuitman and Adams (2014) rearranged the sections and divided *Dendrobium* into 30 sections. They included 2 genera *Epigeneium* F. Gagnepain and *Flickingeria* A. D. Hawkes into *Dendrobium*. *Dendrobium* is divided into number of sections: *Amblyanthus*, *Aporum*, *Biloba*, *Brevisaccata*, *Cadetia*, *Calyptrochilus*, *Conostalix*, *Crinifera*, *Dendrobium*, *Dendrocoryne*, *Diplocaulobium*, *Distichophyllae*, *Eleutheroglossum*, *Formosae*, *Fugacia*, *Fytchianthe*, *Grastidium*, *Herpethophytum*, *Latouria*, *Lichenastrum*, *Macrocladium*, *Microphytanthe*, *Monophyllaea*, *Pedilonum*, *Phalaenanthe*, *Pleianthe*, *Rhizobium*, *Sarcopodium*, *Spatulata*, *Stachyobium* on the basis of nature of stem or pseudobulb, leaves, inflorescence, flower, lip and column characters. In the present study, out of these 30 sections only 6 sections have been accepted for the species of *Dendrobium* of Nepal. The sections are *Aporum*, *Crinifera*, *Dendrobium*, *Formosae*, *Sarcopodium* and *Stachyobium*.

4.1.1.3.3. Key to sections of *Dendrobium* Sw.

- 1a. Plants with cane-like stems ----- 2
- 1b. Plants with pseudobulbs ----- 4
- 2a. Stems with internodes, swollen, laterally compressed, leaves equitant, compressed, persistent, flower small ----- **I. *Aporum***
- 2b. Stems with most internodes, fleshy and swollen ----- 3
- 3a. Stems with deciduous black or brownish hairs on leaf sheaths, flower solitary or in racemose, mentum usually long and funnel-shaped, straight or curved-- -----
----- **IV. *Formosae***

- 3b. Stems without black or brownish hairs on leaf sheaths, elongate, stout, fusiform to clavate, leaves deciduous or persistent, flowers small to large in lateral pairs, fascicled or many flowered, rarely solitary, highly coloured ----- **III. *Dendrobium***
- 4a. Pseudobulbs clustered with few internodes, leaves many, leafy throughout or at apical part, flowers small, few to many arising apically or laterally-----
----- **VI. *Stachyobium***
- 4b. Pseudobulbs with one or few internodes, leaves one or two, flower solitary or two in between leaves or at apex of pseudobulb, flower long-lived or ephemeral ----- 5
- 5a. Pseudobulbs with one internode, leaves two, flower solitary in between leaves, flower long-lived ----- **V. *Sarcopodium***
- 5b. Pseudobulbs with few internodes, leaves one, one to three flowers at apex of pseudobulb, flower ephemeral ----- **II. *Crinifera***.

4.1.1.3.4. Keys for the identification of species of *Dendrobium* Sw.

- 1a. Plants with pseudobulbs ----- 2
- 1b. Plants with cane-like stems ----- 11
- 2a. Pseudobulbs with few internodes, leaves 2 or 3 to many, flowers few to many arising apically or laterally ----- 3
- 2b. Pseudobulbs with one or few internodes, leaves one or two, flower solitary or two in between leaves or at apex of pseudobulb ----- 7
- 3a. Plants with elongate stems ----- 4
- 3b. Plants with cylindrical or elongate pseudobulbs ----- 6
- 4a. Stems 4-15 cm long, leaves deciduous, 8-many flowered, lip ob-ovate, margin of sidelobes lacerate ----- ***D. denudans***
- 4b. Stems 7-21 cm long, leaves deciduous or persistent, flowers more than ten, lip oblong-ovate, margin of sidelobes entire or pectinate-serrate ----- 5
- 5a. Stems 20-21 cm long, leaves deciduous, flowers 16-20, lip with 3 keels from base to apex, side lobes margin entire ----- ***D. darjeelingense***
- 5b. Stems 7-12 cm high, leaves persistent, flowers many, lip with a mesial ridge from base to apex, side lobes margin pectinate-serrate ----- ***D. eriiflorum***
- 6a. Plants 1-2 cm high, pseudobulb cylindrical, flowers 7-12, lip simple with 3 obscure ridges of variable lengths from base to apex, margin entire -----
----- ***D. porphyrochilum***

- 6b. Plants 4-6 cm high, pseudobulb elongate, flowers 3-8, lip 3-lobed with irregular, orbicular and triangular apex, margin inciso-serrate ----- ***D. monticola***
- 7a. Pseudobulbs with one internode, leaves two, flower solitary in between leaves, flower long-lived ----- 8
- 7b. Pseudobulbs with few internodes, leaves one, one to three flowers at apex of pseudobulb, flower ephemeral ----- 10
- 8a. Flowers 2.0-3.4 cm across, midlobe of lip suborbicular to subreniform ----- 9
- 8b. Flowers 7.5 cm across, midlobe of lip subrhomboid, disc with 3 parallel mesial ridges ----- ***D. amplum***
- 9a. Flowers 5.0 cm across, midlobe of lip suborbicular, disc with 3 crenulate lamellae between side lobes ----- ***D. fuscescens***
- 9b. Flowers 3.4 cm across, midlobe of lip subreniform, disc with a triangular thickened keel ----- ***D. rotundatum***
- 10a. Leaf 14.0-16.0 x 2.0-2.5 cm, flower white with pink purple spots, lip oblong ovate, 1.3 x 0.6 cm ----- ***D. fugax***
- 10b. Leaf 10.0–20.0 x 3.0-5.0 cm, flower milky yellow tinged with purplish red spots, lip subovate, 1.5 x 0.8 cm ----- ***D. plicatile***
- 11a. Stems compressed, flattened with fleshy and equitant leaves throughout, flowers small, 1.2 cm across, lip simple ----- ***D. anceps***
- 11b. Stems tufted, erect, cylindrical, clavate, subclavate, pendulous, leaves membranous, subleathery or leathery, flower small to large, lip simple or trilobed ----- 12
- 12a. Stems erect, suberect, cylindrical, clavate, subclavate, leaves membranous, leathery ----- 13
- 12b. Stems pendulous, cylindrical, leaves membranous, fleshy, leathery & subleathery ----- 24
- 13a. Stems clavate, subclavate, inflorescence one-many flowered, flower 1.0–4.5 cm across ----- 14
- 13b. Stems erect, suberect, cylindrical, stout, fractiflex, inflorescence 1-12 flowered, flower 2.5-10.0 cm across ----- 17
- 14a. Stems subclavate, leaves leathery, deciduous, inflorescence axillary, 1-3 flowered, flower 4.5 cm across, pale yellow, lip simple ----- ***D. heterocarpum***

- 14b. Stems clavate, leaves membranous & leathery, deciduous & persistent, inflorescence lateral & axillary, 4-many flowered, flower 1.0-4.0 cm across, lip simple, trilobed----- 15
- 15a. Leaves membranous & leathery, persistent & deciduous, inflorescence lateral, subterminal, 4-6 flowered, flower 1.0-5.5 cm across, lip simple, trilobed ----- 16
- 15b. Leaves leathery, persistent, inflorescence axillary, many flowered, flower 2.5 – 4.0 cm across, flower light yellow, lip simple ----- ***D. densiflorum***
- 16a. Leaves membranous, deciduous, inflorescence lateral, 4-6 flowered, flower 1.0 cm across, flower yellow with dull red in circular heads, lip trilobed -----
----- ***D. bicameratum***
- 16b. Leaves leathery, persistent, inflorescence subterminal, 5 flowered, flower 4.0-5.5 cm across, flower dark yellow, lip simple ----- ***D. denneanum***
- 17a. Stems erect, fractiflex, leaves leathery, persistent, inflorescence lateral, axillary, terminal & subterminal, 1-12 flowered, flowers 3.5-19.0 cm across ----- 18
- 17b. Stems erect & suberect, cylindrical, leaves membranous & leathery, deciduous & persistent, inflorescence lateral & axillary, 1-8 flowered, flowers 1-6 cm across----- 21
- 18a. Stems fractiflex, inflorescence axillary, lateral or terminal, 1-5 flowered, flower 3.5-10.0 cm across, lip trilobed ----- 19
- 18b. Stems stout, inflorescence lateral, 1-12 flowered, flowers 4.0-7.0 cm across, lip simple, trilobed ----- 20
- 19a. Stems fractiflex covered by short coarse deciduous black hairs, inflorescence axillary, 1-3 flowered, flower 3.5 cm across, white with orange yellow lip, margin fimbriate ----- ***D. longicornu***
- 19b. Stems stout, young stem clothed in fine black hairs, inflorescence lateral or terminal, 1-5 flowered, flower 8.0-10.0 cm across, white with yellow inner lip, margin undulate ----- ***D. formosum***
- 20a. Inflorescence 8-12 flowered, flower 6.5-7.0 cm across, lip with purplish brown blotches on either sides, margin cucullate and fimbriate ----- ***D. moschatum***
- 20b. Inflorescence 1-4 flowered, flower 6.0-7.0 cm across, lip with large purple blotch in the center, margin cucullate and entire ----- ***D. nobile***
- 21a. Stems, erect, cylindrical, leaves membranous, leathery, deciduous, 1-3 flowered, flowers 2.5-3.4cm across, lip trilobed ----- 22

- 21b. Stems erect & suberect, leaves leathery, deciduous & persistent, 2-8 flowered, flowers 4.0-6.0 cm across, lip simple ----- 23
- 22a. Inflorescence lateral, 1-3 flowered, flower 2.5 cm across, lip white with yellowish green central spot near the base of mid-lobe, margin entire -----
----- ***D. moniliforme***
- 22b. Inflorescence axillary, 2-3 flowered, flower 3.4 cm across, lip white with purple patch at middle, margin fimbriate ----- ***D. transparens***
- 23a. Stems erect, leaves deciduous, inflorescence lateral, 2-4 flowered, flowers 4.0-6.0 cm across, lip with 2-lobed purple blotch, margin denticulate -----
----- ***D. chryseum***
- 23b. Stems suberect, leaves persistent, inflorescence axillary, 6-8 flowered, flowers 4.5-5.5 cm across, lip deep orange-yellow with dark purple blotch on the disc, margin deeply fimbriate ----- ***D. fimbriatum***
- 24a. Leaves membranous & fleshy, inflorescence lateral & axillary, 1-4 flowered, flowers 2.0-5.0 cm across, lip simple, trilobed ----- 25
- 24b. Leaves leathery & subleathery, inflorescence lateral, 2-12 flowered, flowers 2.0 - 5.0 cm across, lip simple ----- 28
- 25a. Leaves membranous, deciduous & persistent, inflorescence lateral & axillary, 1-4 flowered, flowers 2.0-5.0 cm across, lip simple, trilobed ----- 26
- 25b. Leaves fleshy, deciduous, inflorescence lateral, 1-3 flowered, flowers 4.0 cm across, lip simple, pale yellow or cream with purple veins at base -- ***D. aphyllum***
- 26a. Leaves deciduous & persistent, inflorescence lateral, 2-4 flowered, flowers 2.0-5.0 cm across, lip simple ----- 27
- 26b. Leaves deciduous, inflorescence axillary, 1-3 flowered, flowers 2.0-3.0 cm across, lip trilobed, white with purplish blotch at apex and green yellow at centre ----- ***D. amoenum***
- 27a. Leaves persistent, inflorescence 2-4 flowered, flowers 5.0 cm across, lip golden yellow with purplish red blotch on each side ----- ***D. chrysanthum***
- 27b. Leaves deciduous, inflorescence 2-3 flowered, flowers 2.0-5.0 cm across, lip pinkish yellow at apex and white at base with purple veins ----- ***D. polyanthum***
- 28a. Leaves leathery, persistent, inflorescence 6-12 flowered, flowers 3.0 cm across, lip orange yellow with a rounded deep purple blotch on each side, margin fimbriate ----- ***D. gibsonii***

28b. Leaves subleathery, deciduous, inflorescence 2-3 flowered, flowers 2.0-5.0 cm across, lip pale purplish pink above middle, yellow below middle, margin undulate ----- ***D. crepidatum***

4.1.1.3.5. Description of Taxa

Section I. *Aporum* Blume, *Tab. Pl. Jav. Orchid.*, in *Clavis generum* (1825).

Type: *Dendrobium lobatum* (Blume) Miq., *Fl. Ned. Ind.* 3: 631 (1859).

Basionym: *Aporum lobatum* Blume.

Sectional Characters:

Roots slender, smooth and shiny, wiry, white surface. Stems cane-like, wiry, without swollen internodes, laterally compressed, covered with leaf sheaths. Leaves fleshy or coriaceous, equitant, broadest near base and tapering towards apex. Inflorescence one-flowered, lateral on leafy stem, sometimes on leafless stem. Flower small, white sometimes yellowish green, lasting only a few days. Labellum with expanded midlobe. Mentum usually long, spur-like or saccate-like.

Distribution: About 170 species distributed largely in South-East Asia, Malaysia, East to New Guinea but not in Japan or New Zealand. Only one species *Dendrobium anceps* is present in Nepal Himalaya.

Notes: *Aporum* was a section of *Dendrobium* in Blume's *Clavis generum* (1825a). Afterwards he raised the rank of section into genus in the text of *Bijdragen* (1825b) which was published later that year. Lindley (1830) maintained the genus outside *Dendrobium* but moved it back to sectional level (Lindley, 1850b). Reichenbach (1861) maintained the section *Aporum* with genus *Oxystophyllum* listed by Blume. Seidenfaden (1985) preferred to keep the section *Aporum* excluding *Oxystophyllum*. Based on molecular studies, Clements (2003) proposed that *Oxystophyllum* should be recognized at generic rank within subtribe Podochileae. *Oxystophyllum* is no longer accepted in subtribe Dendrobiinae.

Dendrobium anceps Swartz in *Kongl. Vetensk. Acad. Nya. Handl.* **21:** 246 (1800).

Type: India or., not on sheet, # s.n., (Holotype: S, S03-2120), *Kungl. Vetensk. Nya. Handl.* **21:** 246, 1800. Appendix II A.

Herb, epiphytic, 15-56 cm high. **Stem** erect, slender, branched, compressed, flattened, 0.2-0.3 cm broad at base, 0.7-1.2 cm broad at apex, leaves present all along stem,

covered by leaf sheaths, leaf sheath many-veined, broad, noded, internodes not swollen, internode 2.0-2.5 cm long. **Leaves** exstipulate, simple, distichous, fleshy, overlapping, sessile, jointed, equitant sheathing bases, lanceolate, acute, without apparent veins when young, striated when dry, 2.5-3.5 cm x 0.8-1.2 cm. **Inflorescence** axillary, 1-flowered, borne at nodes between the leaf axils, erect, peduncle attenuate, sheathed, short, 2.0 mm long. **Flowers** bracteate, bisexual, zygomorphic, epigynous, pedicel with ovary slender, 0.6 cm long, yellowish-green with pink lines on lateral sepals, lip and mentum, boat-shaped, 1.2 cm across. **Bract** oblong, obtuse, 5-veined, much shorter than the ovary, 3.5 mm x 2.0 mm. **Sepals** unequal, dorsal sepal elliptic, erect, sub-acute, tip folded inward, 5-veined, 5.0 mm x 4.0 mm, lateral sepals longer and broader than dorsal sepal, falcate, elliptic, obtuse, tip folded inward, pink spotted, 5-veined, adnate at base to form mentum, 8.0 mm x 5.0 mm at broader region, saccate. **Petals** much shorter than sepals, broadly elliptic, obtuse, entire, 5-veined, 4.0 mm x 2.0 mm. **Lip** wedge-shaped or cuneately oblong, yellowish-green with pink spotted, obscurely 3-lobed, side lobes oblong, concave, obtuse, margin entire in the lower part, crenulate in the upper especially at broad apex, mid-lobe with a broad 2-lobed apex, disc occupied by shallow thickened depression ending near the apex, 1.2 cm x 0.4 cm. **Column** flat, 0.2 cm x 0.4 cm long, foot elongate with a narrow nectar-secreting cavity at its extremity, mentum as long as lateral sepals, column with foot 1.0 cm x 0.4 cm. **Anther** orbicular with a lip, 1.5 mm long. **Pollinia** 4 in 2 pairs, oblong-lanceolate, 1.0 mm x 0.8 mm (Fig. 5).

Habitat: On tree trunks of *Schima wallichii*.

Distribution: Nepal (CE. 200-1400 m), Bhutan, Myanmar, Cambodia, Laos, Thailand and Vietnam (Fig. 4).

Status: Threatened due to deforestation and overexploitation for ornamental and medicinal value.

Flowering: April-May.

Etymology: Derived from Latin word “anceps” meaning plant having double-edged leaves.

Specimens Examined: Appendix III 1.

Notes: *Dendrobium anceps* is notable as Swartz species. While establishing *D. anceps*, Swartz (1800) gave ambiguous description which will suffice most of the *Aporum* section members. Because of lack of illustrations for the species, later

workers gave the name to different species in the section *Aporum*. It is impossible to retrace the structure of flowers and to illustrate from type specimen. In 1829 Lindley first illustrated a specimen and approved the name *anceps* as specific epithet. Hence the illustration which has clear structure of lip is followed as proper *D. anceps*. In Curtis Magazine pl. 3608 (1837), Lindley illustrated another specimen and ascribe the same name *anceps*. It is due to fact that Lindley overlooked the lip character and ascribe pl. 3608 also as *anceps*.

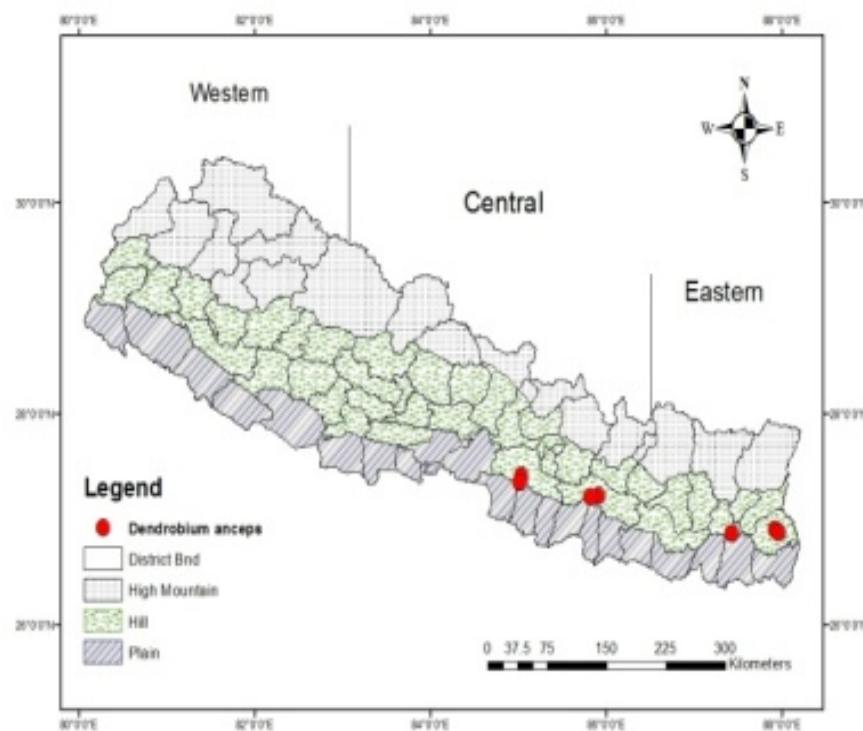


Fig. 4. Distribution map of *Dendrobium anceps* Swartz in Nepal Himalaya.

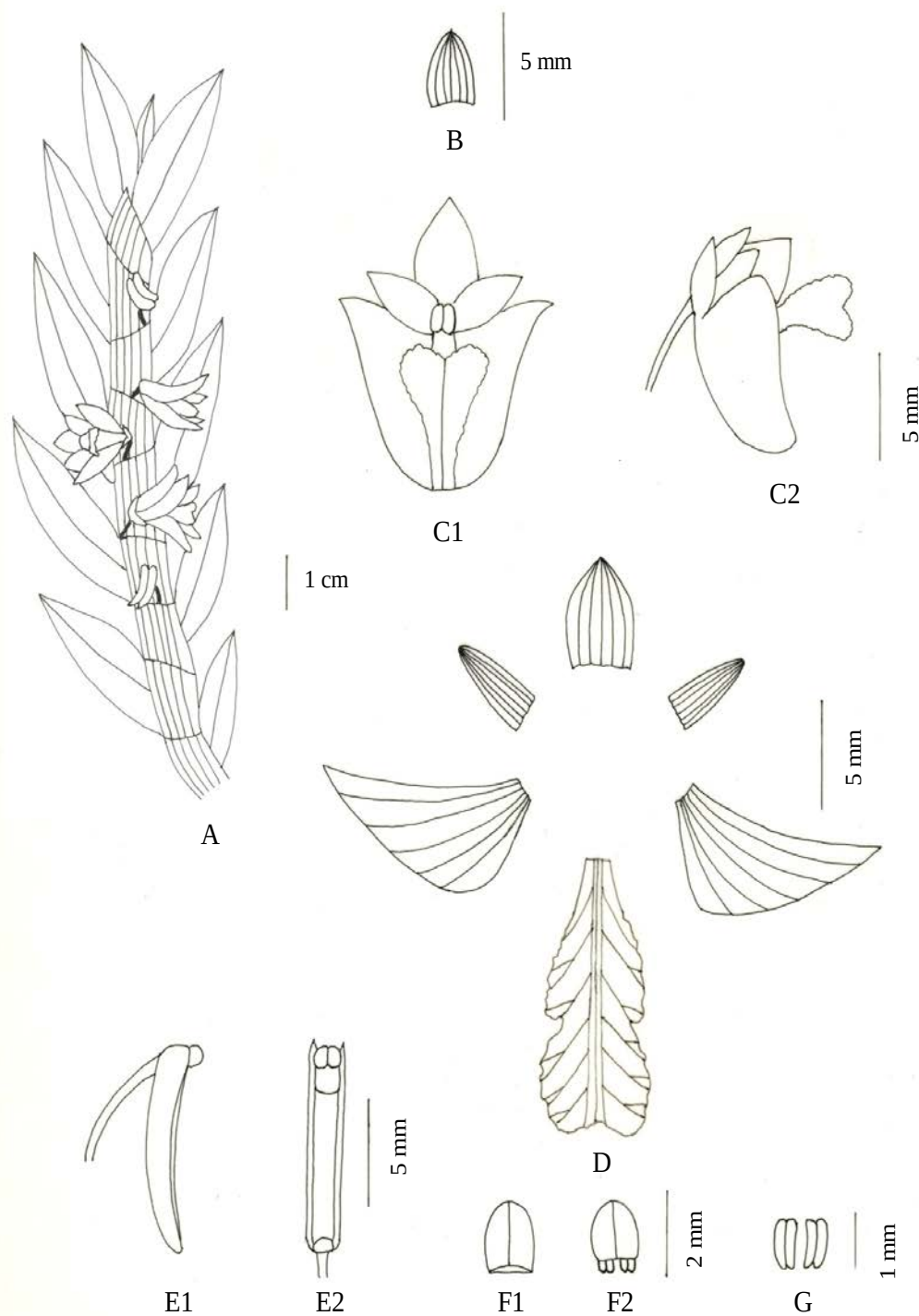


Fig. 5. *Dendrobium anceps* Swartz; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia

Section II. *Crinifera* Pfitzer in Engl. & Prantl., Nat. Pflanzenfam. II, 6, 175 (1889).

Type: *Dendrobium criniferum* Lindl., Edward's Bot. Reg. 30 (Misc.): 41 (1844).

Basionym: *Flickingeria comata* (Blume) A.D. Hawkes

Sectional Characters: Rhizome elongate, branched, erect, rooting mainly in basal part, sometimes creeping and rooting along its length, sometimes thin and pendulous. Pseudobulb distant, with one or few internodes of which upper one is swollen, laterally flattened, highly reduced and slightly swollen, 1-leaved at apex. Leaves coriaceous, glabrous, without leaf sheath. Inflorescence one-flowered, terminal or subterminal or lateral just below the apex of pseudobulb. Flower ephemeral, lasting one day or less. Mentum well developed, but not spur-like. Labellum attached to the apex of column foot, distinctly 3-lobed, usually with lamellae and often wavy keels.

Distribution: About 70 species are distributed in Southeast Asia, Malaysia, Singapore, Brunei, the Philippines, Indonesia, Papua New Guinea, Australia, Solomon Islands, Vanuatu, New Caledonia, Fiji and Samoa. Only 2 species *Dendrobium fugax* and *Dendrobium plicatile* are present in Nepal Himalaya.

Notes: Pfitzer (1889) established this section *Crinifera* with species having different habit, flat leaves and lip with 3 limbs and middle lobe with fringes. In the taxonomic history, Blume (1825a) in *Clavis generum* proposed Section *Desmotrichum* in the genus *Dendrobium*. But after in the same year he raised this section to genera in *Bijdragen* in 1825b. Lindley (1847) mixed *Desmotrichum* with *Sarcopodium* in *Dendrobium* Section *Dendrocoryne*. Hawks (1961) find out that *Desmotrichum* was the conserved name for another genus and renamed it as *Flickingeria*. Hunt and Summerhayes (1957) made same discovery as that of Hawks and proposed the name *Ephemerantha*. Later on Seidenfaden (1980) denied this idea and the name *Flickingeria* has been adopted. Schuitman and Adams (2014) introduced this Section *Crinifera* with species having bushy habit with stiff and branching rhizomes that grow upwards and their roots at the base, 1-leaved pseudobulbs and flowers that last only a single day (or less).

Key to the species:

- Leaf 14.0-16.0 x 2.0-2.5 cm, flower white with pink purple spots, lip oblong ovate, 1.3 x 0.6 cm ----- *D. fugax*

- Leaf 10.0–20.0 x 3.0-5.0 cm, flower milky yellow tinged with purplish red spots, lip subovate, 1.5 x 0.8 cm ----- ***D. plicatile***

Dendrobium fugax Rchb.f., *Gard. Chron.*: 1257 (1871).

Type: Singapore, Ridley, # s.n. (*Dendrobium roseopunctatum*, Holotype: SING).
Appendix II B.

- *Flickingeria fugax* (Rchb.f.) Seidenf., *Dansk Bot. Ark.* 34: 46 (1980).

Herb, epiphytic, 21-29 cm high. **Rhizome** creeping, producing long, pendant stems. Stem pendulous, branched, yellow, noded, sheathed, internodes 2.0-3.0 cm long. **Pseudobulb** borne on stem nodes at irregular distances, narrowly fusiform, compressed or terete, grooved, 3.5-5.0 cm x 1.3-1.5 cm. **Leaf** solitary, terminal on pseudobulb, sessile, ovate-lanceolate, bifid, glabrous, coriaceous, 14.0-16.0 cm x 2.0-2.5 cm. **Inflorescence** terminal raceme, 1-2 flowered, borne at apex of pseudobulb at base of leaf, peduncle short, 1 cm long, covered with sheaths upto 8 mm, sheaths overlapping, membranous, lanceolate, acute. **Flowers** bracteate, white sprinkled with pink-purple spots, 2.0 cm across, pedicel with ovary 0.6 cm long, fugacious. **Bract** triangular, membranous, small, acute, 1-veined, 1.0 mm x 1.2mm. **Sepals** unequal, dorsal sepal elliptic-oblong, sub-acute, spreading, 5-veined, 1.3 cm x 0.4 cm, lateral sepals slightly larger than dorsal sepal, oblong-elliptic, sub-acute, 5-veined, adnate at base to form mentum, 1.4 cm x 0.5 cm, mentum broad, short, conical. **Petals** narrower than sepals, oblong, sub-acute, 3-veined, 1.1 cm x 0.2 cm. **Lip** complex, 3-lobed, oblong-obovate, hypochile wedge-shaped, side lobes oblong, erect, sprinkled with pink-purple spots, mesochile narrow, contracted at the base, margins erose-crisped, epichile broadly oblong-elliptic, margins undulate, apex truncate, disc with two plicate lamellae extending from hypochile to epichile, 1.3 cm x 0.6 cm. **Column** erect, 2 mm x 1.3 mm, apex denticulate, foot 3 mm x 1.3 mm. **Anther** ovate, minutely denticulate lip, 1.4 mm x 1.3 mm. **Pollinia** 4 in 2 pairs, oblong, 1.1 mm x 1.0 mm (Fig. 7).

Habitat: Ontree trunks of *Syzygium cumini*.

Distribution: Nepal (C. 500-1600 m), Bhutan, India, Myanmar and Thailand (Fig. 6).

Status: Threatened due to deforestation and overexploitation for medicinal uses.

Flowering: May-June.

Etymology: Derived from Latin word “fugax” meaning ephemeral referring to flower of the plant.

Specimens Examined: Appendix III 2.

Notes: *Dendrobium fugax* was established by Reichenbach in 1871. Later on Seidenfaden (1980) adopted the name *Flickingeria fugax* for *Dendrobium fugax* which becomes synonym now. Schuiteman and Adams (2014) condensed genus *Flickingeria* into *Dendrobium*. Now *D. fugax* is accepted name and *Flickingeria fugax* is synonym.

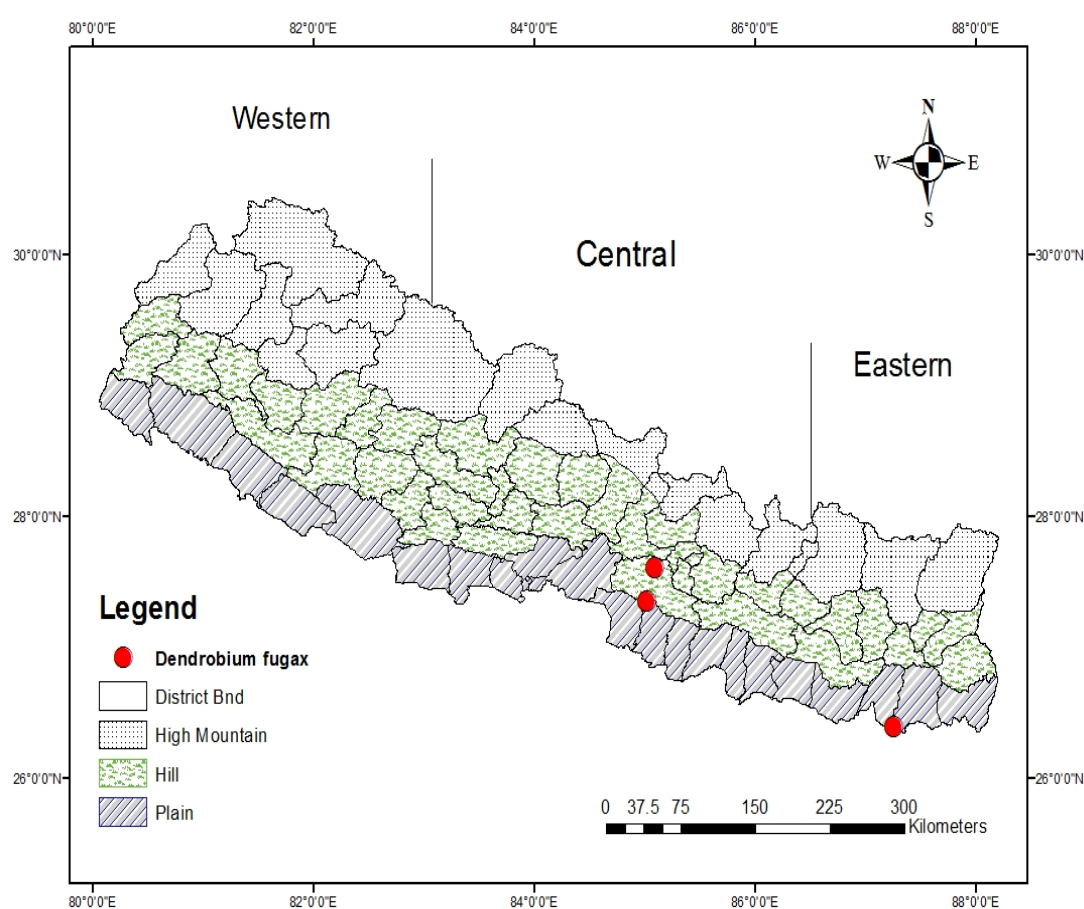


Fig. 6. Distribution map of *Dendrobium fugax* Rchb.f. in Nepal Himalaya.

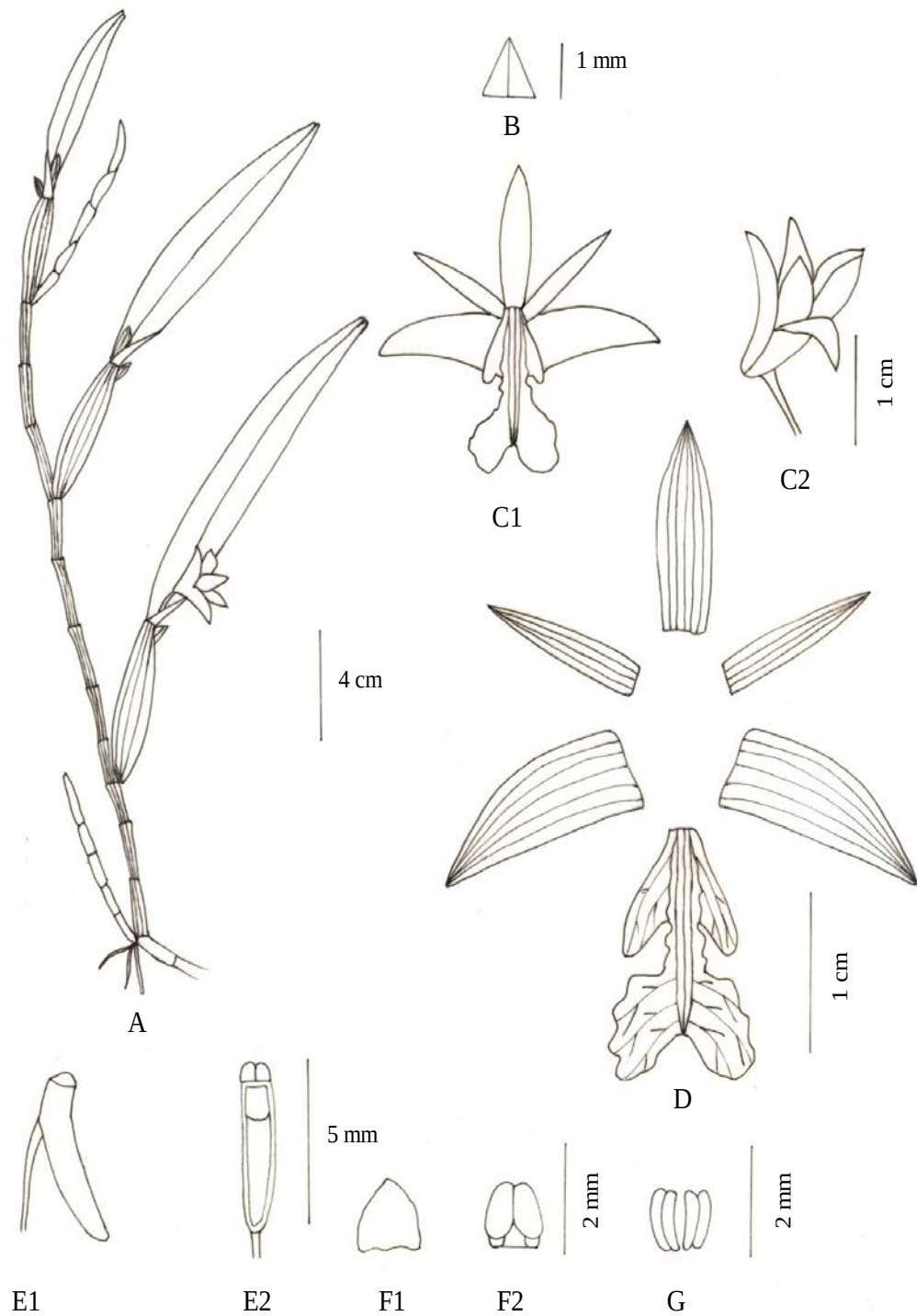


Fig. 7. *Dendrobium fugax* Rchb. f.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia

Dendrobium plicatile Lindl., Edward's Bot. Reg. 26 (Misc.): 10 (1840)

Type: Phillipines, Quisumbing, # 84713 (Isotype: AMES). Appendix II C.

Basionym: Desmotrichum fimbriatum Blume, Bijdr. Fl. Ned. Ind. 7: 329 (1825)

Herb, epiphytic and lithophytic, 20-28 cm high. **Rhizome** creeping, producing long, pendant stems. Stem pendulous, branched, noded, sheathed, internodes 0.7-0.8 cm long. **Pseudobulb** borne on stem nodes at irregular distances, narrowly fusiform, compressed or terete, grooved, golden yellow, 3.5-5.0 cm x 1.0-2.0 cm. **Leaf** solitary, terminal on pseudobulb, sessile, oblong-elliptic, bifid, glabrous, coriaceous, 10.0-20.0 cm x 3.0-5.0 cm. **Inflorescence** terminal raceme, 1-3 flowered, borne at apex of pseudobulb at base of leaf, erect, peduncle short, 0.7 cm long, covered with sheaths, sheaths overlapping, membranous, lanceolate, acute. **Flowers** bracteate, short-lived, sepals and petals milky yellow tinged with purplish red spots, lip white with purple red spots on lateral lobes and yellowish white central lamellae, 2.0 cm across, pedicel with ovary 0.6 cm long. **Bract** triangular, membranous, small, acute, 1-veined, 1.0 mm x 1.2 mm. **Sepals** dorsal sepal ovate-lanceolate, acuminate, rolled inside, 5-veined, 9.0 mm x 2.5 mm, lateral sepals obliquely ovate-lanceolate, similar to dorsal sepal size, acuminate, 5-veined, mentum broad, short, at acute angle to ovary, conical. **Petals** oblong-elliptic, narrower than sepals, sub-acute, rolled inside, 3-veined, 9.0 mm x 2.0 mm. **Lip** complex, 3-lobed, subovate, base narrowed and connate, crisped, side lobes erect, subovate, entire, margin rounded, midlobe flabellate, margin undulate-crisped, apex subtruncate, margins undulate, disc with two or three lamellae extending from base to apex of midlobe, lamellae crisped to apical half, 1.5 cm x 0.8 cm at middle. **Column** stout, 4.0 mm x 3.0 mm, foot 7.0 mm long. **Anther** and **Pollinia** not seen (Fig. 8).

Habitat: On tree trunks of *Syzygium cumini*.

Distribution: Nepal (E. 500 - 2400 m), India, Nepal, Vietnam, Thailand, Malaysia, Phillipines and Indonesia.

Status: Threatened due to deforestation.

Flowering: April - June.

Etymology: Derived from Latin word "plicatilis" meaning folding lengthwise referring to flower of plant.

Specimens Examined: Appendix III 3.

Notes: *Dendrobium plicatile* was formerly treated as *Flickingeria fimbriata* of genus *Flickingeria*. After merging genus *Flickingeria* into *Dendrobium* and now it becomes *D. plicatile*. *D. plicatile* is accepted name and *Flickingeria fimbriata* is synonym.

D. plicatile is epiphytic and lithophytic herb plant. This species resembles with *D. fugax* in pseudobulb shape, shape of leaf and size of flower. But it differs from latter in smaller size of leaf (10-20 x 3-5 cm), greater no. of flowers (1-3), flower colour (milky yellow tinged with purplish red spots) and plicate sepal and petal in contrast to larger size of leaf (14-16 x 2-2.5 cm), lesser no. of flowers (1-2), flower colour (white sprinkled with pink purple spots) and nonplicate sepal and petal of *D. fugax*.

This species was collected from Eastern Nepal by Stainton. But the voucher specimen could not be traced in KATH, TUCH, K, BM, E and TI. With this, the species could not be collected from field and other sources. It may be due to extraction of species from their natural habitat for commercial purposes and export them outside the country illegally or by deforestation. So this species was described on the basis of image of species with high resolution acquired by personal contact. As the locality of specimen could not trace due to unavailable of voucher specimen, the distribution map was not given in the present study.

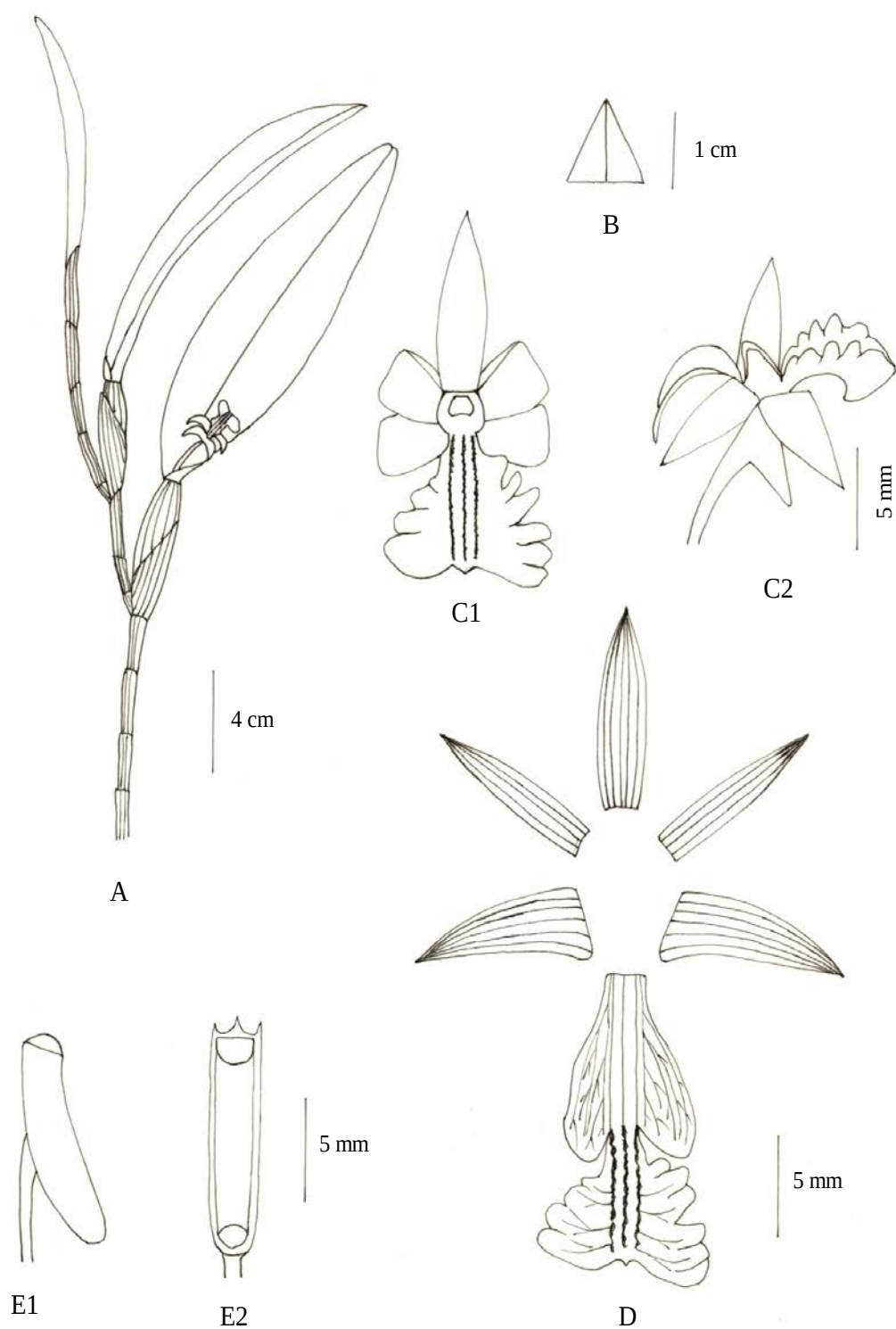


Fig. 8. *Dendrobium plicatile* Lindl.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view.

Section III. *Dendrobium*

Type: *Dendrobium moniliforme* (L.) Sw., Nova Acta Regiae Soc. Sci. Upsal. 6: 85 (1799).

Basionym: *Epidendrum moniliforme* L.

Sectional Characters:

Stems or pseudobulbs usually cane-like, fleshy or rarely wiry, branched or not, many-leaved, rarely with distinct, ovoid to fusiform, one-few leaved pseudobulbs. Leaves usually short-lived, tubular leaf sheath at the base or absent. Inflorescences racemose, usually short, when elongate pendulous, one to many flowered, lateral or apical on the upper part of the leafy or leafless stem, more often on the leafless stem of the previous year. Flowers medium-sized to large, often showy, long-lived, mentum short, sac-like, chin-like or less often narrowly conical. Labellum usually rigidly attached to the apex of the column foot but not adnate to it, with its basal part clasping the column, entire or weakly lobed, often darker coloured in the centre adaxially, often densely and finely pubescent, often with finely fringed margins with a linear basal claw, without keels or sometimes with a single callus or with a single longitudinal keel.

Distribution: About 100 species are distributed in Sri Lanka, tropical continental Asia, Japan, Malaysia, Brunei, Indonesia, the Philippines, Papua New Guinea and Australia. Only 16 species are present in Nepal Himalaya. This section includes *D. amoenum* Wall. ex Lindl., *D. aphyllum* (Roxb.) C.E.C. Fisch, *D. bicameratum* Lindl., *D. chrysanthum* Wall. ex Lindl., *D. chryseum* Rolfe, *D. crepidatum* Lindl. & Paxton, *D. denneanum* Kerr, *D. densiflorum* Wall., *D. fimbriatum* Hook., *D. gibsonii* Paxton, *D. heterocarpum* Wall. ex Lindl., *D. moniliforme* (L.) Sw., *D. moschatum* (Buch.-Ham.) Sw., *D. nobile* Lindl., *D. polyanthum* Wall. ex Lindl. and *D. transparens* Wall. ex Lindl. from Nepal Himalaya.

Notes: After the recommendation of the Committee for Spermatophyta (Taxon 31, 3: 542, 1982), consequent to the proposal by Holttum *et al.* (Taxon 28, 4: 409, 1979) that *Dendrobium moniliforme* (L.) Sw. is being considered as type species of the genus. Hence the sectional name *Dendrobium* is applied for this important section for which earlier authors used the names such as *Eudendrobium* or *Eugenanthe*.

The section *Dendrobium* was formerly known as *Onychium*, *Eudendrobium*, *Eugenanthe* and so on. Blume established this section as *Onychium* in *Clavis generum* (1825). Lindley in 1844 first introduced the concept *Eudendrobium* in his unfinished

system and the section remained more or less unchanged in his finalized system in 1851 (Paxt. Fl. Gard. 1: 135). Reichenbach f.'s system (Walp. Ann. 6, 1861) seems difficult to understand and unworkable. Bentham & Hooker (1883) followed Lindley. After Bentham & Hooker, Pfitzer in 1889 did not add any new viewpoints. Hooker f. in 1890 has *Eudendrobium* with 12 sections. Kranzlin in 1910 created subgenus *Dendrobium* with 9 sections. Schleeters' system (1912) has been followed till today. In his system, he called it section *Eugenanthe* in subgenus *Eudendrobium* with 17 sections, the first of which he calls *Eugenanthe*, indicating that it more or less covers the old section *Eudendrobium*. He has limited the subgenus *Eudendrobium* to species with distinct leaf sheaths. Schlechter system has been accepted by later authors and remained untouched in Brieger's system in 1981.

Section *Holochrysa* of Lindley (1859), sections *Chrysantha* and *Planifolia* of Reichenbach (1861), section *Breviflores* of Hooker (1890), section *Densiflora* of Finet (1903), sections *Aurea*, *Aquea*, *Chrysotaxa*, *Herbacea*, *Macrostachya*, *Nobilis* and *Stuposa* in subgenus *Eudendrobium* of Krazlin (1910), section *Goldschmidtia* of Dammer (1910), sections *Brachyanthe*, *Callista* and *Eugenanthe* of Schletcher (1912) were all synonyms of section *Dendrobium*.

Key to the species:

- 1a. Stems erect, suberect, stout, clavate, subclavate, leaves membranous, leathery, flower 1.0-10.0 cm----- 2
- 1b. Stems pendulous, leaves membranous, fleshy, leathery, subleathery, flower 2.0-5.0 cm ----- 11
- 2a. Stems clavate, subclavate, one-many flowered, flower 1.0–4.5 cm across ----- 3
- 2b. Stems erect, suberect, cylindrical, stout, 1-12 flowered, flower 2.5-10.0 cm across, ----- 5
- 3a. Stems subclavate, leaves leathery, deciduous, inflorescence axillary, 1-3 flowered, flower 4.5 cm across, pale yellow, lip simple ----- ***D. heterocarpum***
- 3b. Stems clavate, leaves membranous, leathery, deciduous, persistent, inflorescence lateral, axillary, 4-many flowered, flower 1.0-4.0cm across, lip simple, trilobed- 4
- 4a. Leaves membranous, deciduous, inflorescence lateral, 4-6 flowered, flower 1.0 cm across, yellow with dull red in circular heads, lip trilobed ----- ***D. bicameratum***
- 4b. Leaves leathery, persistent, inflorescence axillary, many flowered, flower 2.5 – 4.0 cm across, light yellow, lip simple ----- ***D. densiflorum***

- 5a. Stems erect, leaves leathery, persistent, inflorescence lateral, subterminal, 1-12 flowered, flowers 3.5-19.0 cm across ----- 6
- 5b. Stems erect, suberect, leaves membranous, leathery, deciduous, persistent, inflorescence lateral, axillary, 1-8 flowered, flowers 1-6 cm across, ----- 8
- 6a. Inflorescence subterminal, 5 flowered, flower 4.0-5.5 cm across, lip simple with dark purple reniform patch, margin fimbriate ----- ***D. denneanum***
- 6b. Inflorescence lateral, 1-12 flowered, flower 6.0-7.0 cm across, lip simple, trilobed- ----- 7
- 7a. Inflorescence 8-12 flowered, flower 6.5-7.0 cm across, lip with purplish brown blotches on either sides, margin cucullate and fimbriate ----- ***D. moschatum***
- 7b. Inflorescence 1-4 flowered, flower 6.0-7.0 cm across, lip with large purple blotch in the center, margin cucullate and entire ----- ***D. nobile***
- 8a. Stems erect, leaves membranous, leathery, deciduous, inflorescence 1-3 flowered, flowers 2.5-3.4 cm across, lip trilobed ----- 9
- 8b. Stems erect, suberect, leaves leathery, deciduous, persistent, inflorescence 2-8 flowered, flowers 4.0-6.0 cm across, lip simple ----- 10
- 9a. Inflorescence lateral, 1-3 flowered, flower 2.5 cm across, lip white with yellowish green central spot near the base of mid-lobe, margin entire ----- ***D. moniliforme***
- 9b. Inflorescence axillary, 2-3 flowered, flower 3.4 cm across, lip white with purple patch at middle, margin fimbriate ----- ***D. transparens***
- 10a. Stems erect, leaves deciduous, inflorescence lateral, 2-4 flowered, flowers 4.0-6.0 cm across, lip with darker shade in the centre, margin fimbriate --- ***D. chryseum***
- 10b. Stems suberect, leaves persistent, inflorescence axillary, 6-8 flowered, flowers 4.5-5.5 cm across, lip deep orange-yellow with dark purple blotch on the disc, margin deeply fimbriate ----- ***D. fimbriatum***
- 11a. Leaves membranous, fleshy, inflorescence lateral, axillary, 1-4 flowered, flowers 2.0-5.0 cm across, lip simple, trilobed ----- 12
- 11b. Leaves leathery, subleathery, inflorescence lateral, 2-12 flowered, flowers 2.0 - 5.0 cm across, lip simple ----- 15
- 12a. Leaves membranous, deciduous, persistent, inflorescence lateral, axillary, 1-4 flowered, flowers 2.0-5.0 cm across, lip simple, trilobed ----- 13
- 12b. Leaves fleshy, deciduous, inflorescence lateral, 1-3 flowered, flowers 4.0 cm across, lip simple, pale yellow or cream with purple veins at base -- ***D. aphyllum***

- 13a. Leaves deciduous, persistent, inflorescence lateral, 2-4 flowered, flowers 2.0-5.0 cm across, lip simple ----- 14
- 13b. Leaves deciduous, inflorescence axillary, 1-3 flowered, flowers 2.0-3.0 cm across, lip trilobed, white with purplish blotch at apex and green yellow at centre, margin undulate ----- ***D. amoenum***
- 14a. Leaves persistent, inflorescence 2-4 flowered, flowers 5.0 cm across, lip golden yellow with purplish red blotch on each side, margin denticulate-----
----- ***D. chrysanthum***
- 14b. Leaves deciduous, inflorescence 2-3 flowered, flowers 2.0-5.0 cm across, lip pinkish yellow at apex and white at base with purple veins, margin denticulate --
----- ***D. polyanthum***
- 15a. Leaves leathery, persistent, inflorescence 6-12 flowered, flowers 3.0 cm across, lip orange yellow with a rounded deep purple blotch on each side, margin fimbriate ----- ***D. gibsonii***
- 15b. Leaves subleathery, deciduous, inflorescence 2-3 flowered, flowers 2.0-5.0 cm across, lip pale purplish pink above middle, yellow below middle, margin undulate ----- ***D. crepidatum***

Dendrobium amoenum Wall. ex Lindl., Gen. Sp. Orch. Pl.: 78 (1830).

Type: s.coll., s.n. (*Dendrobium egertoniae* Lindl., Syntype: K). Appendix II D.

Dendrobium egertoniae Lindl., Edward's Bot. Reg. 33: t.36 (1847).

Herb, epiphytic or lithophytic, 24-75 cm high. **Stem** slender, pendulous, compressed, flattened and slightly swollen at the node, internode 2.5-3.0 cm long. **Leaves** exstipulate, simple, membranous, distichous, oblong-lanceolate, smooth, acute, slightly oblique, leaf base sheathing around stem, withered during flowering, 4.4-10.9 cm x 0.6-1.8 cm. **Inflorescence** axillary raceme, 2-3 flowered, borne at nodes of leafless stem, pendulous, peduncle short, 6.0 mm long, sheathed at base, sheath membranous, 4.0 mm long. **Flowers** bracteate, bisexual, zygomorphic, epigynous, pedicel and ovary slender, 2.8-3.0 cm long, sepals and petals purplish white with faint purplish tinge towards apex of sepals, pink-purple spots at petal and lip apex, lip with a large lemon-yellow blotch at the center, rarely flowers white with only lemon-yellow blotch inside lip, delightfully perfumed, 2-3 cm across. **Bract** ovate-

lanceolate, membranous, acute, much shorter than the ovary, 3-veined, 0.7 cm x 0.2 cm. **Sepals** dorsal sepal oblong-lanceolate, obtuse, 5-veined, 2.4 cm x 0.7 cm, lateral sepal lanceolate, acute, broader than dorsal sepal, 5-veined, 2.9 cm x 0.8 cm, mentum conical. **Petals** ovate, obtuse, entire, 5-veined, 2.6 cm x 1.2 cm. **Lip** as long as lateral sepal, tri-lobed, oblong-obovate when spread out, white with purplish blotch at the apex and greenish yellow towards the middle, 2.8 cm x 1.4 cm, side lobes broad, rounded, convolute, obtuse, mid-lobe oblong-ovate with undulate margin, obtuse, pubescent on both surfaces, disc sub-villous. **Column** broad at the apex, foot long, tapering, flat at the upper part, nectar large, 2 calli in the lower part with thickened line at the centre, 1.2 cm x 0.25 cm. **Anther** orbicular, slightly emarginate at apex, minutely papillose, 2 mm long. **Pollinia** elliptic, 4 in 2 pairs, 1.45 mm x 1.25 mm (Fig. 10).

Habitat: On the rock and tree trunks of *Alnus nepalensis*.

Distribution: Nepal (CE. 200 – 2000 m), India, Bhutan, Myanmar and Thailand (Fig. 9).

Status: Endangered.

Flowering: May.

Etymology: Derived from Latin word “amoenum” referring to plants found in pleasant places.

Specimens Examined: Appendix III 4.

Notes: Lindley (1830) established *Dendrobium amoenum* based upon Wallich collection from Nepal. From protologue, it is evident that the flowers are white and sepal and petal are tipped with light violet. But in the specimens collected from Makawanpur and Ilam districts, sepals and petals are purplish white with faint purplish tinge towards apex of sepals, petals and lip have pink-purple spots at apex, lip with a large lemon-yellow blotch at the center. Whereas, in the specimens collected from Sindhuli and Lalitpur districts, sepals and petals are purplish white, petals and lip do not have pink-purple spots at apex.

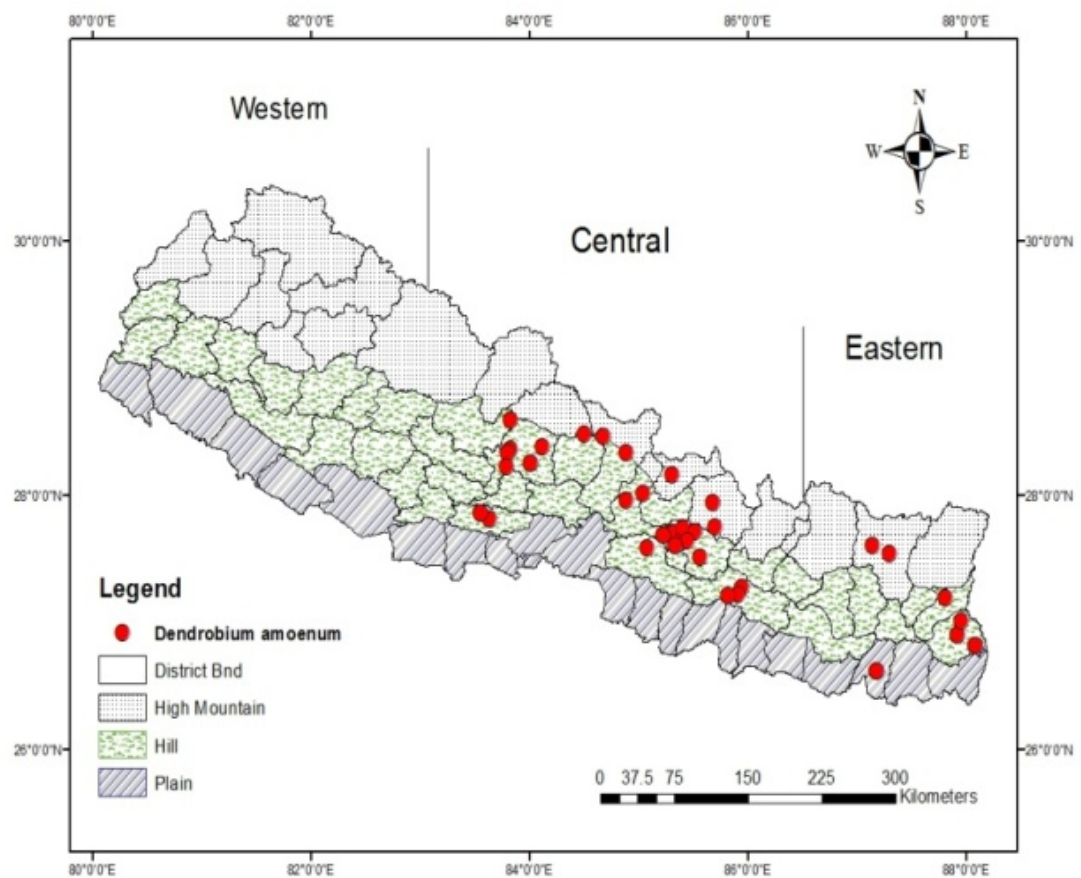


Fig. 9. Distribution map of *Dendrobium amoenum* Wall. ex Lindl. in Nepal Himalaya.

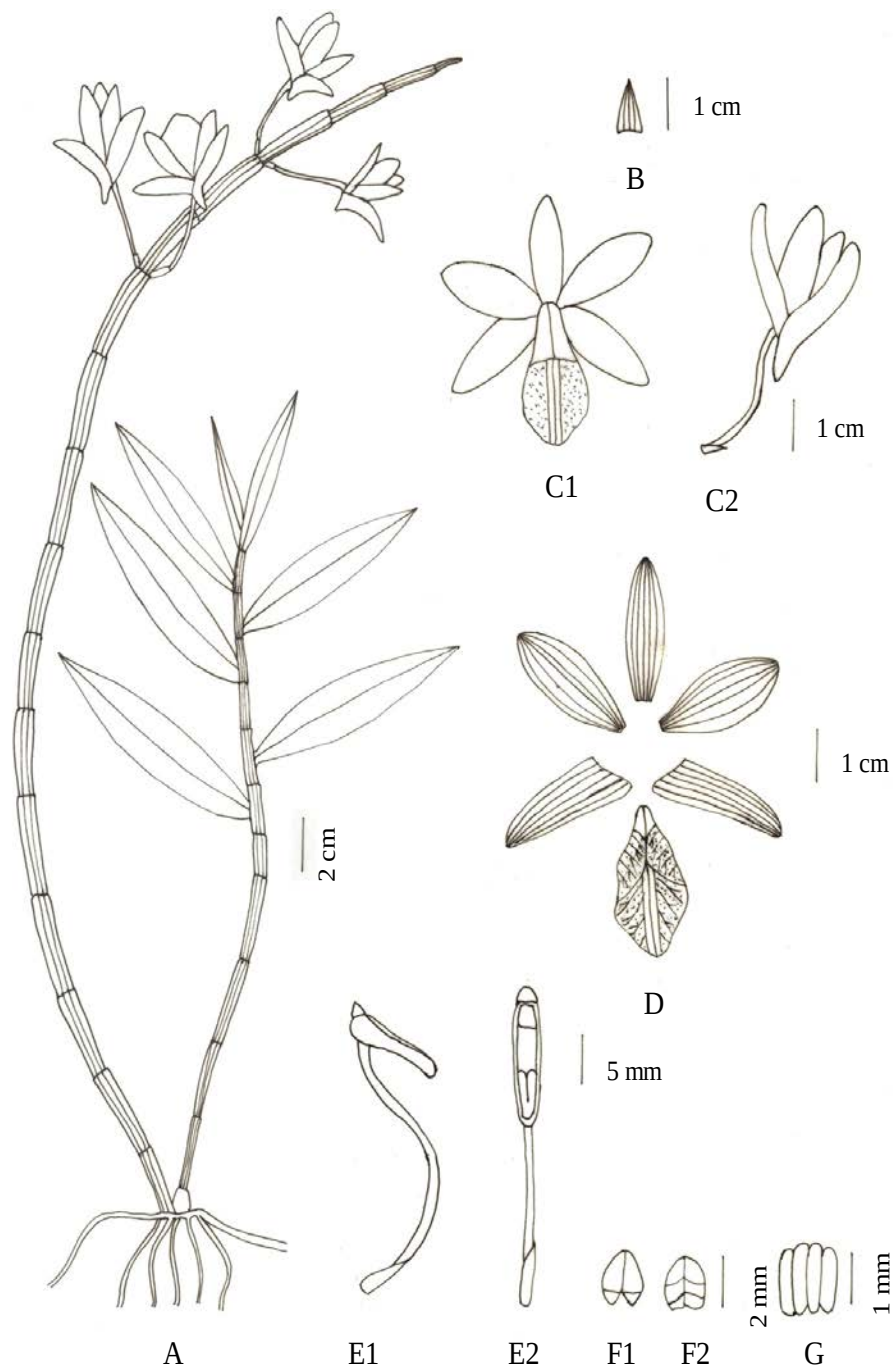


Fig. 10. *Dendrobium amoenum* Wall. ex Lindl.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia.

Dendrobium aphyllum (Roxb.) G. E. C. Fischer in Gamble, Fl. Presid. Madras **8**: 1416 (1928).

Type: Bangladesh, Wallich 2007.3 (*Dendrobium pierardi* Roxb. Syntype: K).

Appendix II E.

Herb, epiphytic, 20-50 cm high. **Stem** pendulous, slender, unbranched with many nodes, slightly swollen at nodes, covered by leaf sheaths, internode 2.5-3.0 cm long, pendant, smooth. **Leaves** linear-lanceolate, sessile, distichous, deciduous, acuminate, fleshy, 4.0-6.0 cm x 1.5-3.0 cm. **Inflorescence** axillary raceme, 1-3 flowers in fascicle, flowers arising at nodes of leafless old stem, pendulous, peduncle short, 2.0 mm. **Flower** bracteate, pendulous, 1-3 flowered, white with pale purplish red, fragrant 4.0 cm across, pedicel with ovary 3 cm long. **Bract** ovate, acute, deciduous, membranous, pale white, 1-veined, 3.0 mm x 2.5 mm. **Sepals** dorsal sepal oblong-lanceolate, sub-acute, 5-veined, 2.8 cm x 0.8 cm, lateral sepals oblong-lanceolate, sub-acute, 5-veined, 2.9 cm x 0.7 cm, mentum short, narrowly conic. **Petals** oblong-elliptic, broader than sepals, entire, obtuse, 5-veined, 3.1 cm x 1.2 cm. **Lip** simple, suborbicular, trumpet shaped, shortly clawed at base, apical part pale yellow or cream with purple-veined at base, convolute forming a tube at base, margin fimbriate in lower part and erose at upper part, shortly ciliate on anterior half, apex rounded, emarginated at apex, densely pubescent on the exterior surface and along the margins except in basal part, disc hairy, side lobes absent, 3.4 cm x 2.6 cm. **Column** broad at apex, 0.4 cm long, tapering foot, transverse nectary at base of foot, column with foot 1.2 cm long. **Anther** with erose curved lip, emarginate front margin, 4.0 mm x 2.5 mm. **Pollinia** 4 in 2 pairs, elliptic, yellow, 2.3 mm x 2.3 mm (Fig. 12).

Habitat: On tree trunks of *Castonopsis indica*.

Status: Endangered due to deforestation.

Flowering: April-June.

Distribution: Nepal (CE. 200-1500 m), Bhutan, China, India, Laos, Malaysia, Myanmar, Sri-Lanka, Vietman, Thailand and Australia (Fig. 11).

Etymology: Derived from Latin word “aphyllum” meaning leafless referring the plant having leafless stem.

Specimens Examined: Appendix III 5.

Notes: William Roxburgh (1795) discovered *Dendrobium aphyllum* from Southern India and described in his book “Plants of the coast of Coromandel” under the name

Limodorum aphyllum. The illustration provided by Roxburgh was not accurate and led to argument over true identity of this species for the following two centuries. *D. aphyllum* was best known as *D. pierardii* during nineteenth and twentieth centuries because Sir William Hooker (1822) had much better illustrated *D. pierardii*. Robert Brown (1821) had given the name *D. cucullatum* to *D. aphyllum* but this name had been forgotten. The name *D. aphyllum* came into general use after 1985 when Gunnar Seidenfaden had reviewed the history of this taxon and confirmed that *D. aphyllum* and *D. pierardii* are same species. Since then the name *D. aphyllum* has come into use. Later in 2003, Eric Christenson and Howard Wood pronounced that *D. aphyllum* was not the same species as *D. pierardii*. They asserted that *Limodorum aphyllum* of Roxburgh was a related but rather different species which was widely known as *D. macrostachyum* in 2003. They also pointed that *D. cucullatum* was now the right name for *D. pierardii*. Andre Schuiteman (2011) cleared up the identity of the plant with the result that the name *D. aphyllum* must be reinstated for the species which are formerly known as *D. pierardii* or *D. cucullatum*. *D. macrostachyum* should be used for smaller flowered species.

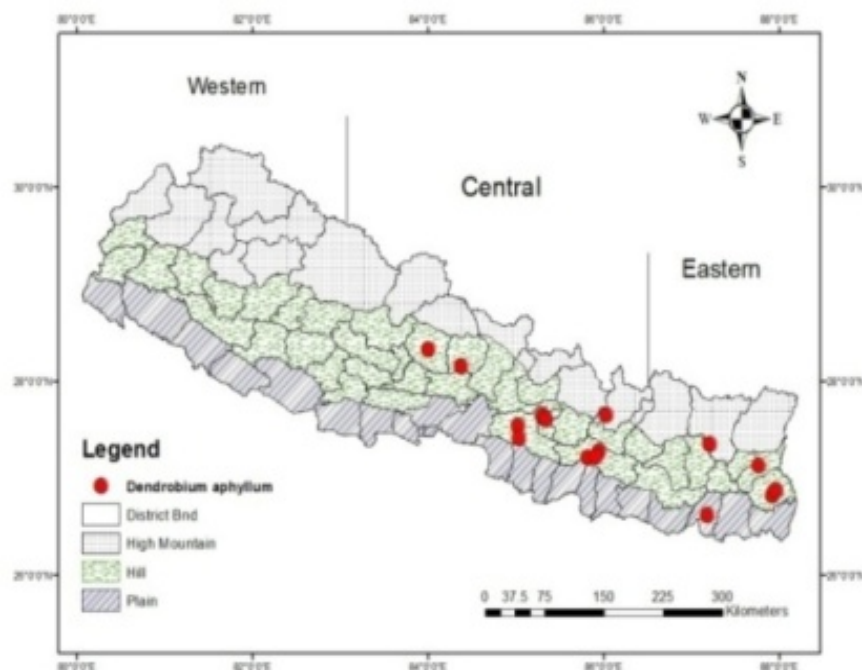


Fig. 11. Distribution map of *Dendrobium aphyllum* (Roxb.) G.E.C.Fischer in Nepal.

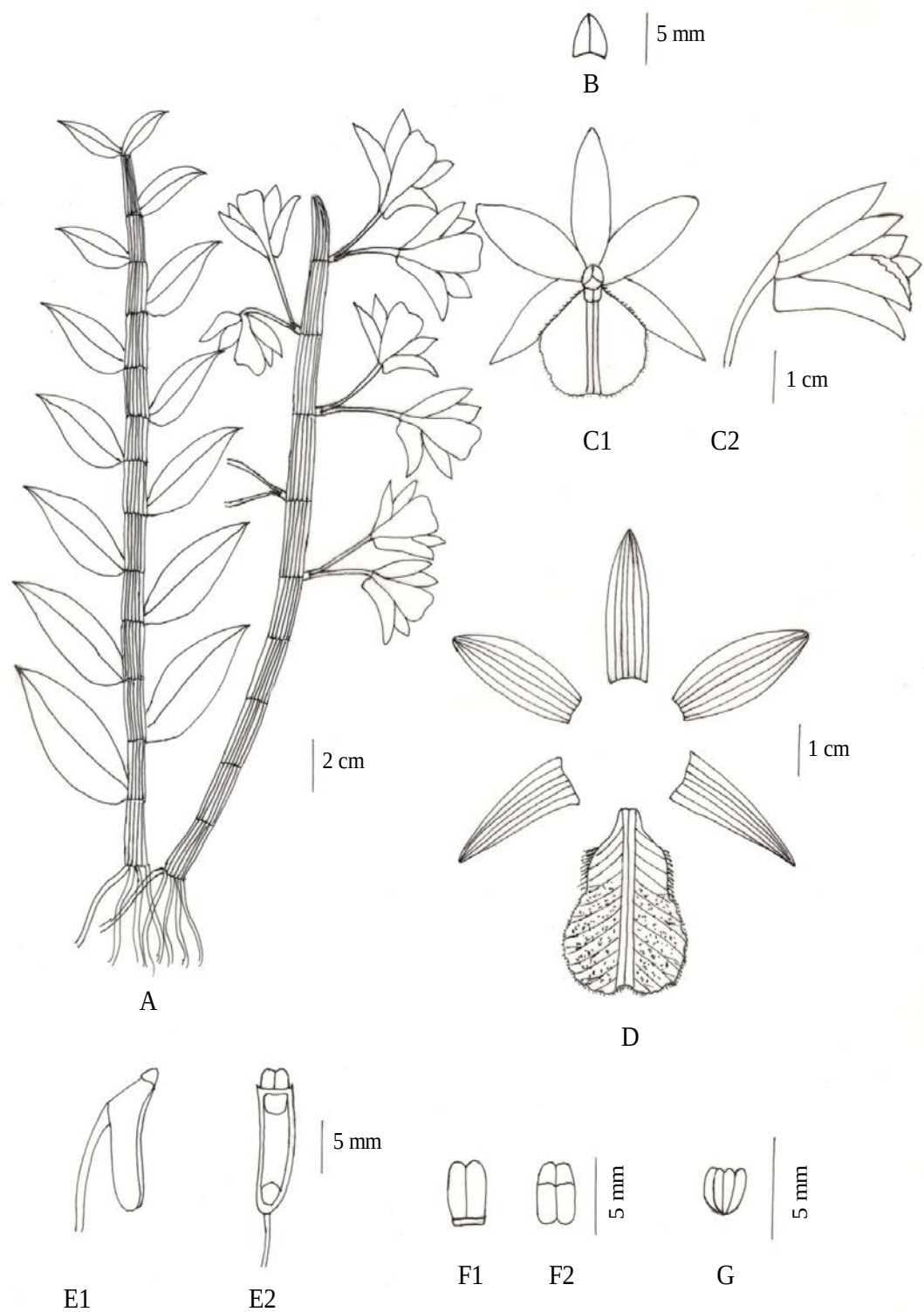


Fig. 12. *Dendrobium aphyllum* (Roxb.) G.E.C. Fischer; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia

Dendrobium bicameratum Lindl., Edward's Bot. Reg. 25: 59 (1839).

Type: Sikkim, Gamble, # 10510 (*Dendrobium bolboforum* Falc., Syntype: K).

Appendix II F.

Herb, epiphytic, 10-26 cm high. **Stem** erect, clavate or fusiform, elongate, 1.2-2.4 cm thick, unbranched with nodes, leaf sheathed, internodes swollen above the base, internode 1.7-3.0 cm long. **Leaves** exstipulate, elliptic-oblong to elliptic-lanceolate, distichous, smooth, acute, membranous, unequally bifid at apex, 2 or more leaves clustered at the apex of stem, 5.0-8.0 cm x 1.2-2.5 cm. **Inflorescence** subdensely 4-6 clustered flowers on a short rachis forming a capitate raceme either lateral or sub-terminal on leafless stem, erect, rachis weakly zigzag, 0.3-0.8 cm long, peduncle sheathed, 0.5 cm long, sheath overlapping, 0.2-0.3 cm long. **Flowers** bracteate, pedicellate, pedicel with ovary, 0.8 cm long, fleshy, 1-4 flowers from short sheathed peduncle, yellow marked with dull red in circular heads, arise on old stem from leaf node sites, 1.0 cm across. **Bract** sheathing the shortly stalked ovary, ovate-oblong, acute, 3-nerved, 0.6 cm x 0.4 cm. **Sepals** dorsal sepal broadly ovate-oblong, concave, sub-acute, 5-veined, 0.9 cm x 0.6 cm, lateral sepals triangular, concave, sub-acute, 5-veined, 0.7 cm x 0.75 cm, mentum urceolate,. **Petals** broadly elliptic, as long as sepals, obtuse, yellowish with dull red spots and stripes, 5-veined, 0.9 cm x 0.5 cm. **Lip** small, fleshy, concave, broadly triangular, 3-lobed, side lobes triangular, acute, erect, entire, mid-lobe short, rectangular, truncate, entire, disc with cushion-shaped callus, 0.5 cm x 0.45 cm. **Column** short, 0.17 cm x 0.3 cm, 2 - large oblong nectar secreting cells, bilocular column foot, foot 0.66 cm long. **Anther** fleshy, 2 mm x 1.5 mm. **Pollinia** 4 in 2 pairs, oblong, 1.2 mm x 0.7 mm (Fig. 14).

Habitat: On tree trunks of *Schima wallichii*.

Locality: Tistung, Makawanpur; Alt.: 1900 m; Coll. Date: June 9, 2012.

Distribution: Nepal (WC. 1400-2400 m), India (Sikkim), Bhutan, Myanmar (Fig. 13).

Status: Endangered.

Flowering: July-August.

Etymology: Derived from Latin word “bi (two) and camera (chamber, vault)” in reference to the characteristic bilocular column foot of the taxa.

Specimens Examined: Appendix III 6.

Notes: *D. bicameratum* was established by Lindley (1839) on the basis of the plant which is the native of the north of India, whence it was brought by Mr. Gibson for the Duke of Devonshire. This species was characterized by clavate stems, persistent leaves and lateral inflorescence with 4-6 flowers, trilobed lip and characteristic bilocular column foot.

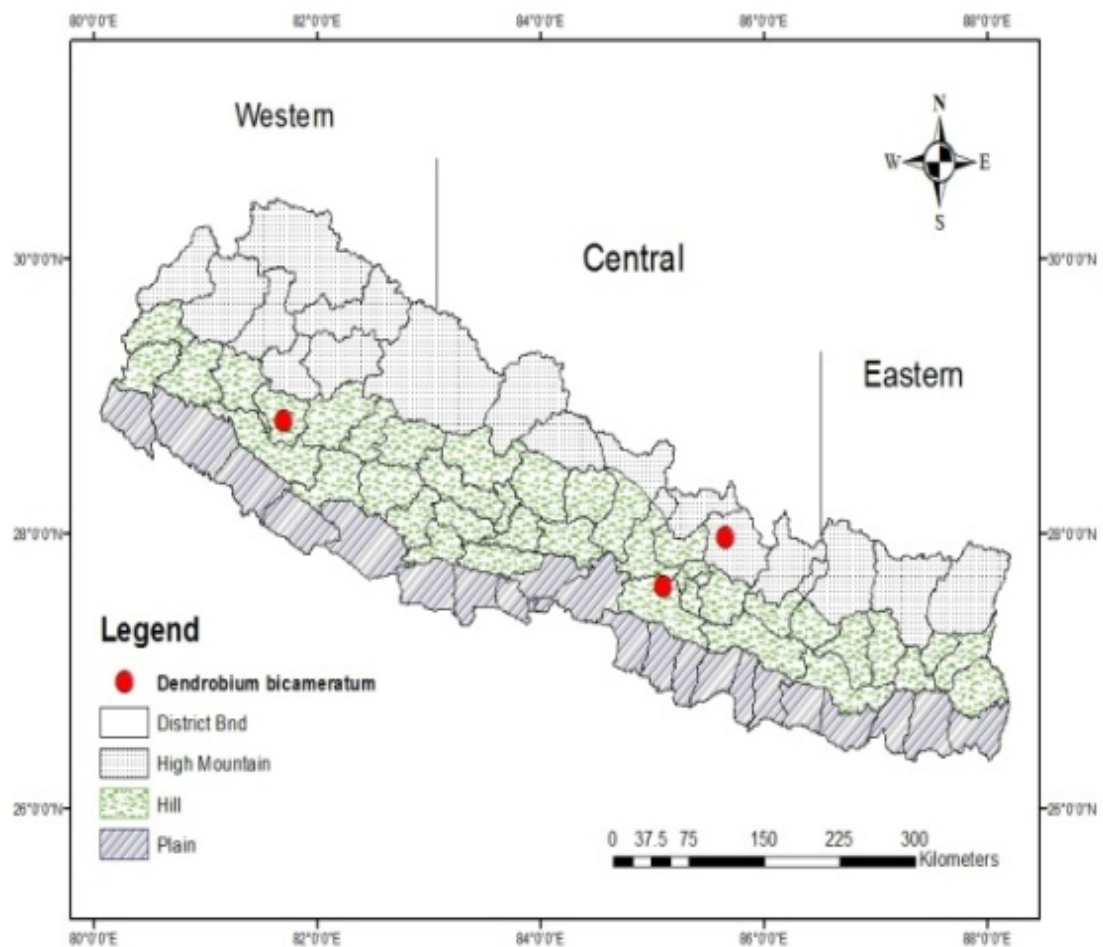


Fig. 13. Distribution map of *Dendrobium bicameratum* Lindl. in Nepal Himalaya.

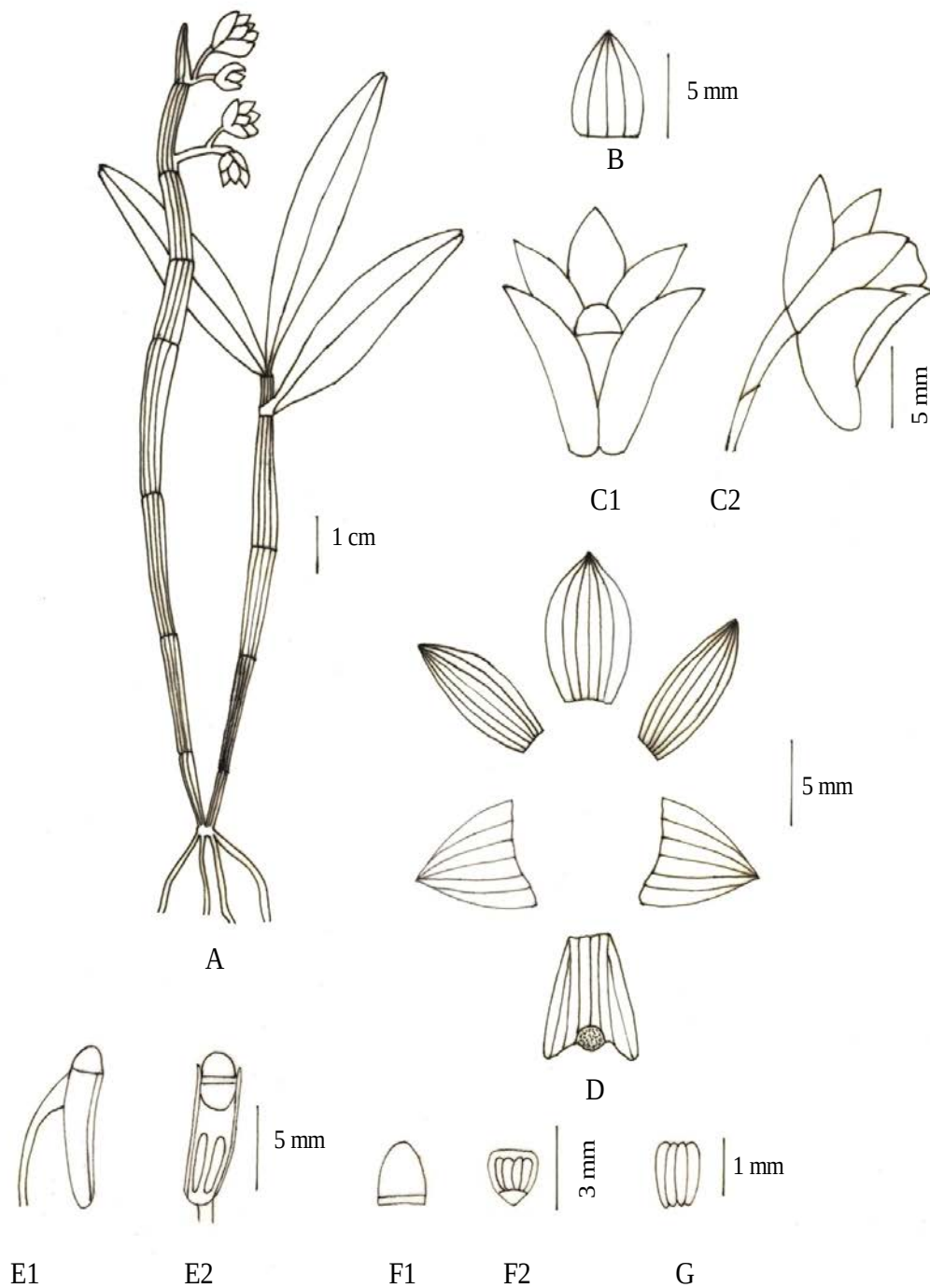


Fig. 14. *Dendrobium bicameratum* Lindl.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia

Dendrobium chrysanthum Wall. ex Lindl. in Edward's Bot. Reg. **15**: t.1299 (1829).

Type: Nepal, Wallich, # 2012 (Syntype: K). Appendix II G.

Herb, epiphytic, 25-70 cm high. **Stem** cylindrical, sulcate, pendulous, 2.0-3.0 cm thick, unbranched with many nodes, covered by leaf sheaths, internodes fleshy at middle than at base and apex, internode 3.0-3.2 cm long. **Leaves** simple, distichous, alternate, sessile, caducous, membranous, ovate-lanceolate, base rounded and sheathing, leaf sheath papery, margin smooth, apex acuminate, bright shiny green leaves, surface smooth, 7-veined with many smaller veins, leaves start falling off after flowering period, 8.5-20.0 cm x 2.5-4.5 cm. **Inflorescence** lateral raceme, borne on leafy stem, arise opposite of leaves, in fascicles of 2-4 flowers, pendulous, peduncle very short, almost sessile, sheathed, sheath membranous, 0.1 cm long. **Flowers** bracteate, in fascicles of 2-4, fleshy, fragrant, golden yellow, lip with purplish red blotch on each side, 5.0 cm across, pedicel with ovary 7.0 cm long. **Bract** small, ovate-triangular, scarious, acute, 1-veined, 4.0 mm x 2.5 mm. **Sepals** dorsal sepal elliptic, concave, apex obtuse, margin entire, incurve apical half, 7-veined, 2.2 cm x 1.2 cm, lateral sepals ovate-triangular obliquely, concave slightly, apex obtuse, base broad and oblique, margin entire, incurve apical half, 7-veined, 2.2 cm x 1.1 cm, mentum short, rounded. **Petals** obovate, concave slightly, apex rounded, 7-veined, margin erose minutely, 2.4 cm x 1.7 cm. **Lip** simple, orbicular-oblong or reniform, concave, undivided, densely barbellate adaxially except at basal part, barbellate abaxially except at middle part with 2 sub-orbicular purplish red blotches on each side, base with short claw, oblong callus at base, disk with thick and broad ridge extending from base to middle, apex rounded, margin denticulate, involute, 2.2 cm x 2.4 cm (spreading). **Column** concave, broad, 0.4 cm long, foot with a transverse ridge at lower end, 0.6 cm long. **Anther** conic, 3 ridged on the front surface, 3.0 mm x 2.5 mm. **Pollinia** 4 in 2 pairs, oblong, 1.6 mm x 1.2 mm (Fig. 16).

Habitat: On tree trunk of *Castonopsis indica*.

Status: Endangered due to deforestation.

Flowering: August-October.

Distribution: Nepal (CE. 1300-2000 m), Bhutan, China, India, Laos, Myanmar, Vietman and Thailand (Fig. 15).

Etymology: Derived from Latin word "chrysanthum" meaning golden flower. The plant can be differentiated from other species by the presence of golden flower.

Specimens Examined: Appendix III 7.

Notes: *D. chrysanthum* was described by Wallich but the name was validly published by Lindley in 1830. This species is native to Nepal. This plant is characterized by long pendulous stem, flower golden yellow with 2 dark maroon spots in the labellum. According to Seidenfaden (1985) *D. chrysanthum* is related to *D. ochreatum* Lindl. and the differences were less. Main differences were found in labellum, in *D. chrysanthum* there is presence of 2 dark maroon spots in labellum whereas in *D. ochreatum* a single maroon spot is present.

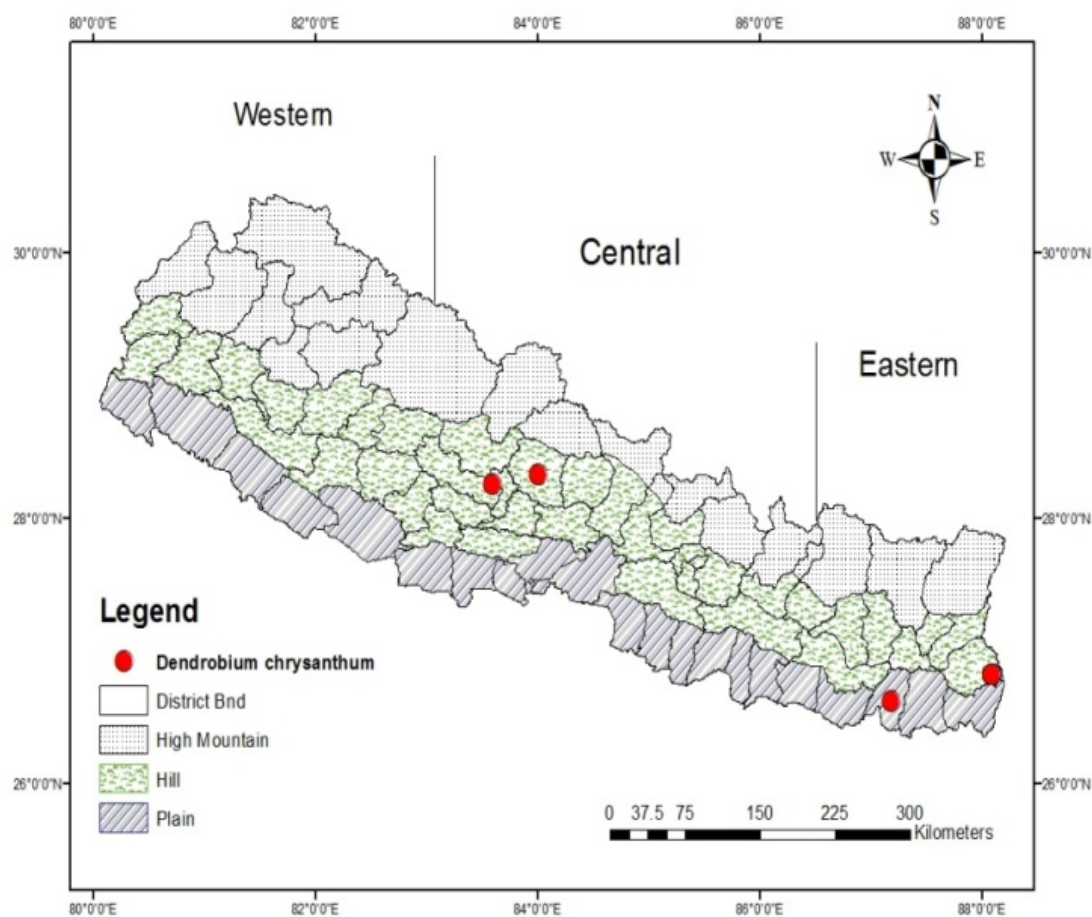


Fig. 15. Distribution map of *Dendrobium chrysanthum* Wall. ex Lindl. in Nepal.

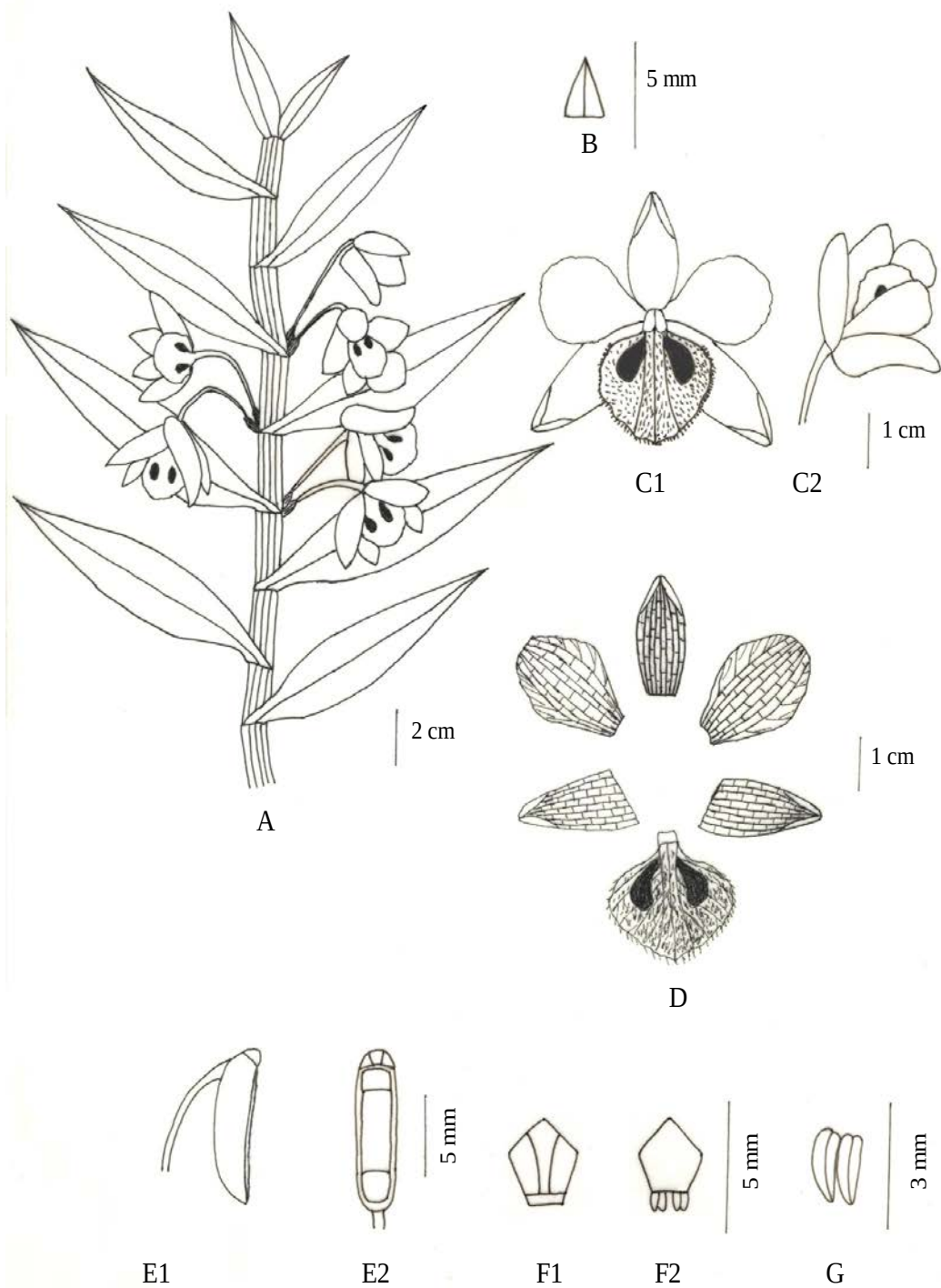


Fig. 16. *Dendrobium chrysanthum* Wall. ex Lindl.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia.

Dendrobium chryseum Rolfe, Gard. Chron. ser. 3, 3: 233 (1888).

Type: Lao People's Democratic Republic, Kerr, # 0965 (Syntype: K). Appendix II H.

Herb, epiphytic, 25-50 cm high. **Stem** erect to arching, cylindric, slender, 1.8-2.4 cm thick, noded, unbranched, striated, yellowish, internodes fleshy at middle than at base and apex, internode 2.0-5.0 cm long, leaf sheaths tightly enclosing internodes. **Leaves** 10-12, oblong-lanceolate, distichous, coriaceous, sheathing at bases, sessile, margin entire, apex obtuse to emarginated or subacute and obliquely hooked, leaf sheath membranous, 10.0-14.0 cm x 2.0-4.0 cm. **Inflorescence** lateral raceme arising from old leafless stem, 2-4 flowered, erect, peduncle sheathed, 4.0-6.0 cm long, basal sheaths 3 or 4, overlapping, tubular or funnel shaped, basal one short, distal one elongate, 0.5-2.0 cm long, rachis glabrous, 3.0-10.0 cm long. **Flowers** bracteate, fragrant, concolor yellow with centre a darker shade, 4.0-6.0 cm across, pedicel with ovary 3.5-5.0 cm long. **Bract** ovate-lanceolate, obtuse, 5-veined, membranous, glabrous, 1.5-2.0 x 0.4-0.5 cm. **Sepals** similar, dorsal sepal oblong-lanceolate, apex subacute apiculate, glabrous, 5-veined, 2.5 x 0.9 cm, lateral sepals oblong-lanceolate, apex subacute apiculate, glabrous, 5-veined, 2.7 x 0.9 cm, mentum conic. **Petals** broadly elliptic, apex obtuse, 3-veined, major lateral veins branched, glabrous, 2.5 cm x 1.4 cm. **Lip** simple, suborbicular, minutely pubescent to tomentose on adaxial side, margin shortly fimbriate and emarginated at apex, sometimes with faint crimson streaks at base, clawed at base, 2.8 x 2.4 cm. **Column** 0.8 cm x 0.4 cm, slightly curved, foot 0.3 cm long with a cavity. **Anther** narrowly conic, apex subtruncate, 5.0 x 3.0 mm. **Pollinia** not seen (Fig. 17).

Habitat: On tree trunks of *Castanopsis* sp.

Distribution: Nepal (C. 1200-2100 m), N.E. India, China and Myanmar.

Status: Threatened due to deforestation and over exploitation for ornamental plants.

Flowering: May-June.

Etymology: Derived from Greek word “chryseus” meaning golden-yellow referring the flower colour of specimen.

Specimens Examined: Appendix III 8.

Notes: The specimen could not be collected from field visits and other sources. The voucher specimen of *D. chryseum* (Lalitpur District, Phulchoki, 7000 ft., 1979.6.1, R. Bahadur 803, KATH) was mentioned in “A Handbook of The Flowering Plants of

Nepal Vol. 1” by Rajbhandari and Rai, 2017 and in “An annotated checklist of the orchids of Nepal” by Rokaya *et al.*, 2013. But the voucher specimen could not be traced in KATH so this specimen was described according to high resolution image acquired from Kew Herbarium. The distribution map was not given due to unavailability of voucher specimen in the present study.

D. chryseum was described by Rolfe in 1888. The synonyms of *D. chryseum* are *D. clavatum* Lindl. (1852) and *D. aurantiacum* Rchb.f. (1887). These two species seem to be identical in all characters except for the colour of the lip. The difference is that Lindley’s plant has a deep red blotch on the lip which is absent in Reichenbach’s plant. *D. clavatum* is first mentioned in Wall. Cat. 1829 as a nom. nud. In 1852 Lindley finally described *D. clavatum* where he could addendum Wallich’s insufficient collection with materials imported by Denne. The name *D. clavatum* sensu Lindley (1852) has been used by most authors till today.

D. aurantiacum was proposed for an Assam plant in 1887. In 1888, the type of *D. chryseum* Rolfe which came from Assam was abridged by Rolfe himself to a synonym of *D. aurantiacum*. A.F.G. Kerr found a plant in Laos in 1933 which he considered identical with *D. clavatum* Lindl. (1852) and realized that this name was a later homonym. Then he proposed the new name *D. denneanum*. According to Kerr, *D. clavatum* Lindl. 1852 was considered as basionym and the plant imported by Denne must be considered type specimen. But Kerr has no reference to *D. aurantiacum* and it is of importance that Kerr working on sheets of Laotian plant gives the information that the lip has no dark blotch and it must be considered identical with *D. aurantiacum*.

King and Pantling (1898) reported this species as *D. clavatum* Lindl. where as Seidenfaden (1985) replaced both synonyms *D. clavatum* and *D. aurantiacum* with *D. chryseum* Rolfe. In 1951 Tang & Wang took the view that Reichenbach’s *D. aurantiacum* should be considered as spotless variety of *D. clavatum* and coined the name *D. clavatum* var. *aurantiacum* (Rchb.f.) Tang & Wang. They referred this variety as a synonym *D. denneanum* with spotless lip.

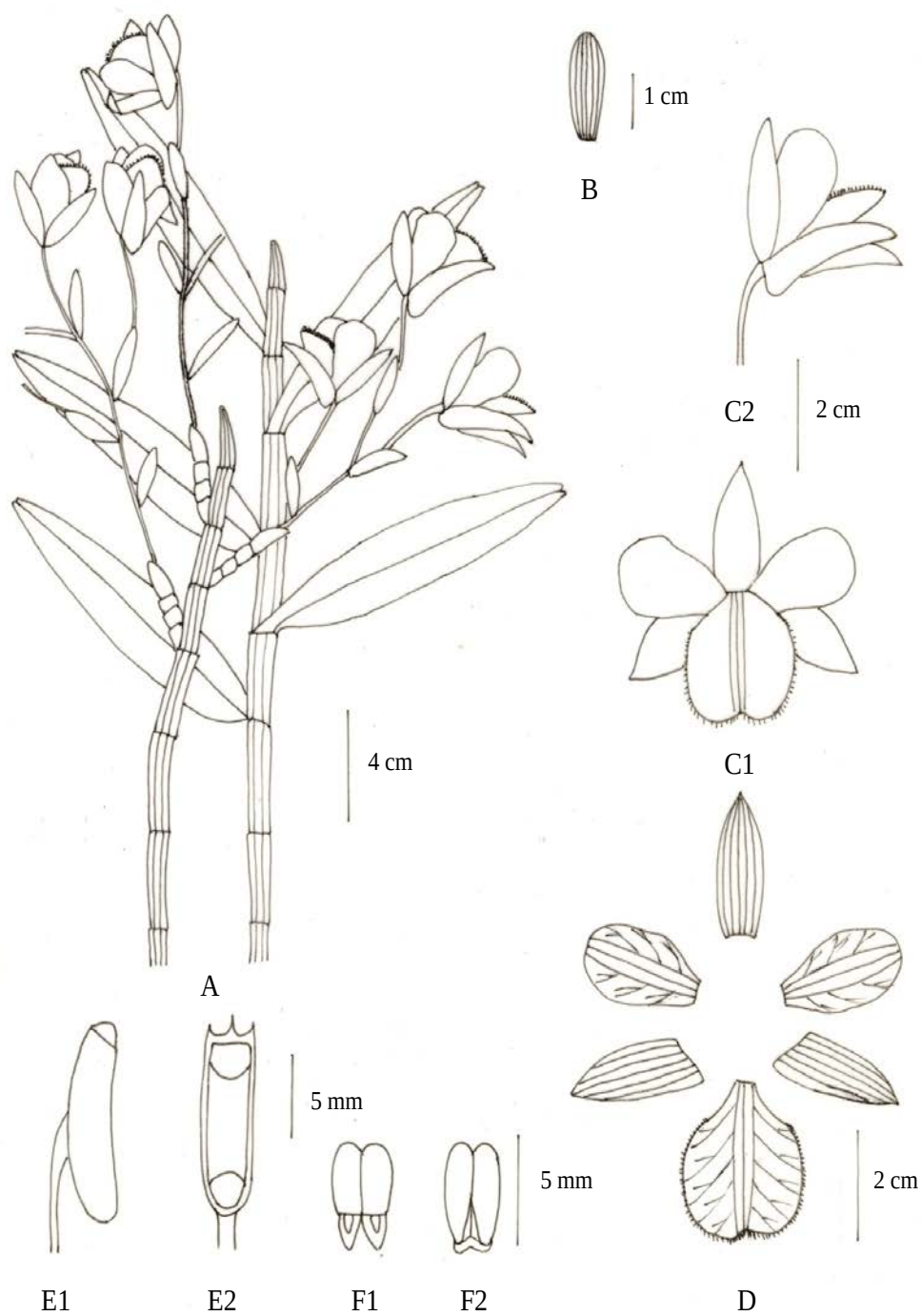


Fig. 17. *Dendrobium chryseum* Rolfe; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view: F: Anther: F1: Dorsal view F2: Ventral view.

Dendrobium crepidatum Lindl. & Paxton, Paxton's Fl. Gard. 1: 63 (1850).

Type: s.coll., # s.n. (Syntype: K). Appendix II I.

Herb, epiphytic, 14-20 cm high. **Stem** pendulous, cylindric, 2.0- 2.2 cm thick, noded, unbranched, striated, internodes slightly swollen and fleshy at middle than at base and apex, internode 2.0-2.5 cm long with green-white striped sheaths, thin, loose, scarious sheaths along old parts. **Leaves** 4-8, linear-lanceolate, distichous, subleathery, base with clasping sheath, apex acuminate, leaf sheath membranous, 5.5-9.5 cm x 1.0-1.6 cm. **Inflorescence** lateral raceme arising from old leafless stem, 2-3 flowers from each node, pendulous, basal sheaths scarious, peduncle short, 3.0 mm long. **Flowers** bracteate, fragrant, sepals and petals white with pale purplish-pink above middle, lip pale purplish-pink above middle, yellow below middle, waxy, pedicel with ovary purplish-pink, 3.5 cm long, 2.5 cm across. **Bract** small, ovate, acute, 1-veined, 4 mm x 2 mm. **Sepals** unequal, dorsal sepal oblong-lanceolate, apex obtuse, margin entire, spotted (tinged with light purple), 5-veined, 1.4 cm x 0.7 cm, lateral sepals oblong-lanceolate, as long as dorsal sepal, apex obtuse, 5-veined, midrib thick, spotted (tinged with light purple), 1.5 cm x 0.6 cm, mentum short, subglobose. **Petals** obovate, broader than sepals, apex obtuse, 5-veined, spotted (tinged with light purple), entire, 1.5 cm x 0.9 cm. **Lip** orbicular or broadly obovate with a narrow and slightly convoluted lower part ending into claw, base with incurved sides, margin slightly undulate, ciliolate and glandular papillose, apex rounded with a notch, disc with a transverse ridge at claw, 1.4 cm x 1.1 cm. **Column** very short and broad, 0.6 cm x 0.4 cm, curved at the lower end, excavated,. **Anther** subconic, apex narrowed and arching forward, denticulate at front margin, 2.5 mm x 2.0 mm. **Pollinia** 4 in 2 pairs, oblong, 2.0 mm x 1.6 mm (Fig. 19).

Habitat: On tree trunks of *Shorea robusta*.

Distribution: Nepal (C. 600-1400 m), Bhutan, China, India, Laos, Myanmar, Thailand and Vietnam (Fig. 18).

Status: Threatened due to deforestation and over exploitation for ornamental plants.

Flowering: April-May.

Etymology: Derived from Latin word “crepidatum” meaning shoe (lip-shaped) referring plants with shoe-lip shaped cavity at the base of the column foot.

Specimens Examined: Appendix III 9.

Notes: This species occurs in two different forms: one with normal flowers, the other with smaller, more or less actinomorphic and self pollinating flowers. The latter form was described as *D. lawianum* Lindl. (Deccan Peloric form, originally *D. lawanum* Lindl.). It is the widespread form in Deccan and Sikkim and also in Nepal while the form with normal flowers is the common forms towards northeast and east.

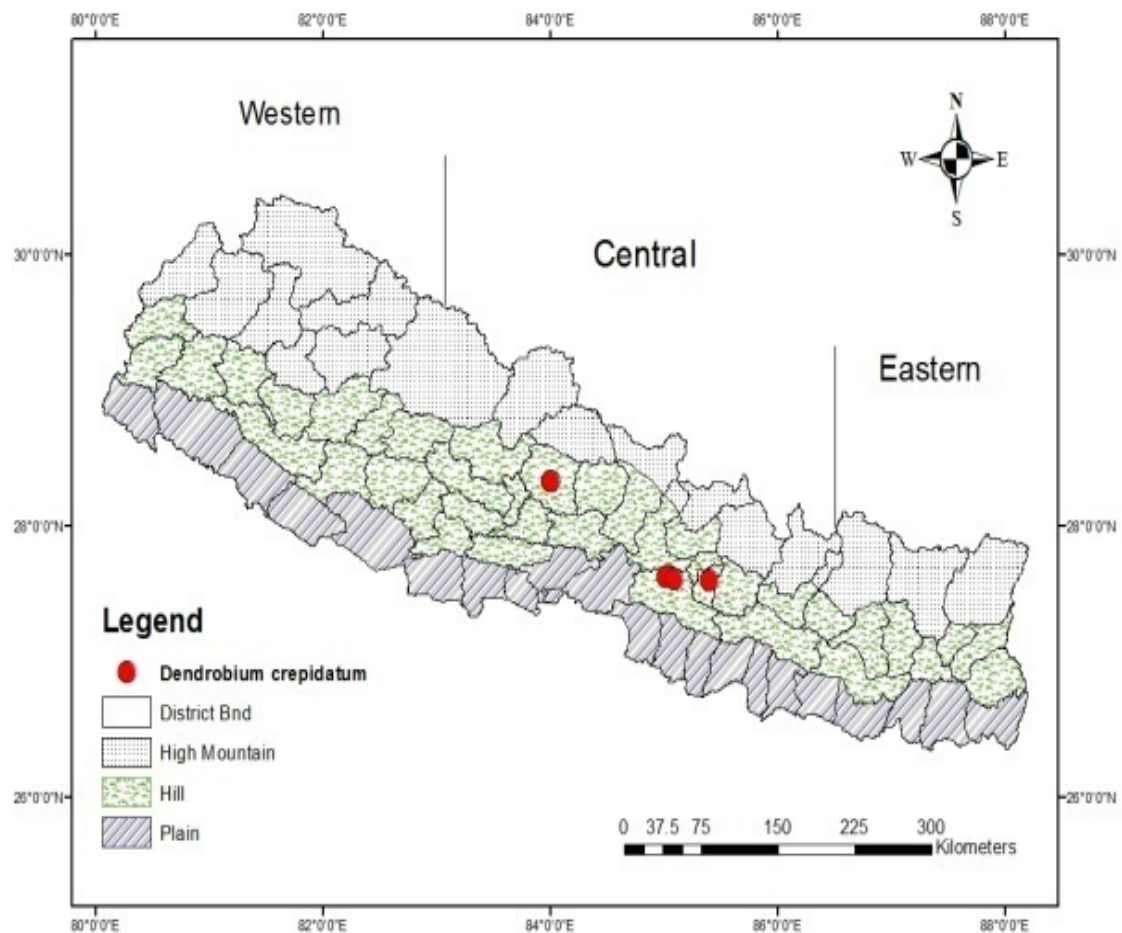


Fig. 18. Distribution map of *Dendrobium crepidatum* Lindl. & Paxton in Nepal Himalaya.

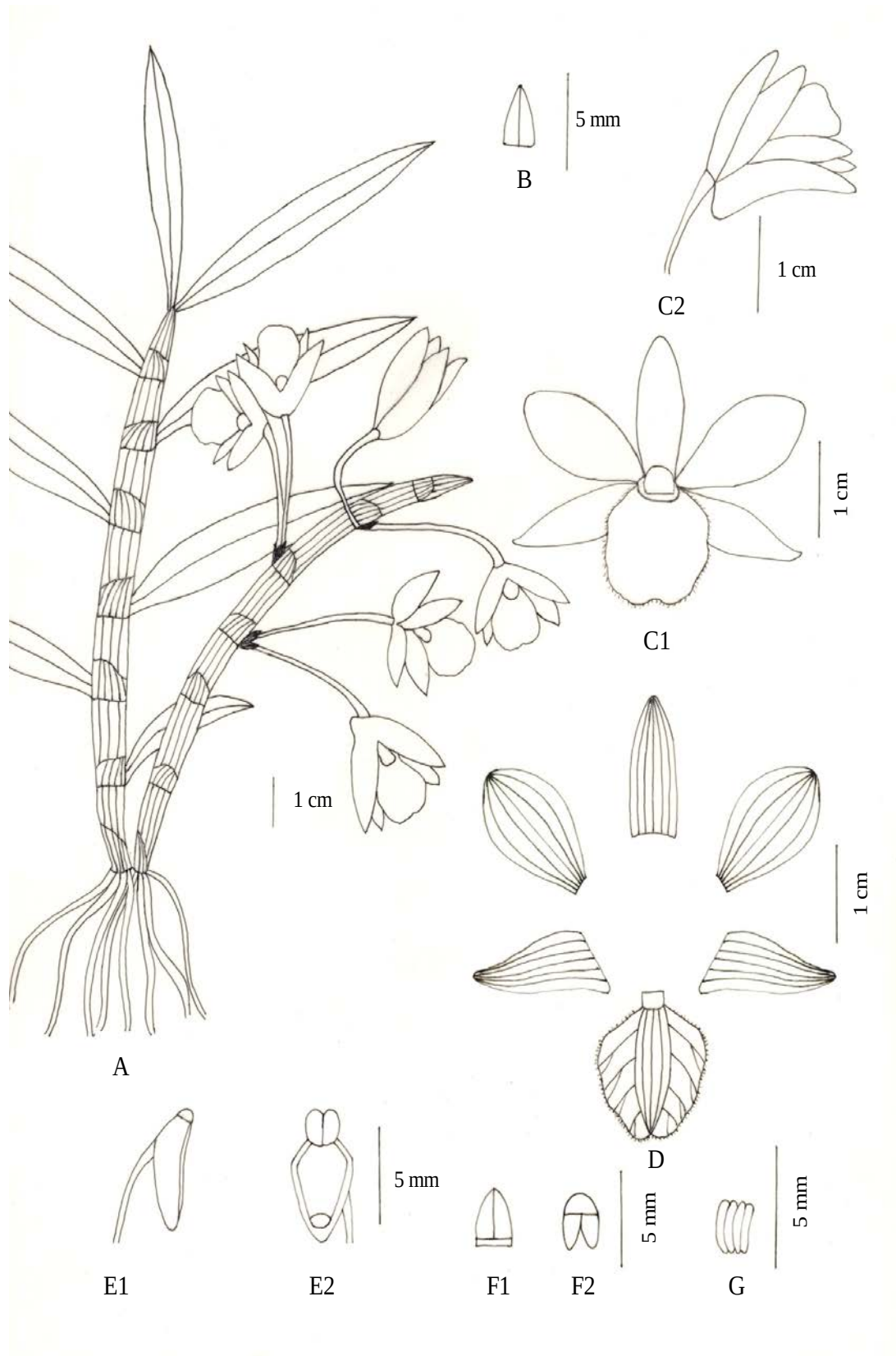


Fig. 19. *Dendrobium crepidatum* Lindl. & Paxton; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia.

Dendrobium denneanum Kerr. J., Siam Soc. Nat. Hist. Suppl. **9**: 229 (1933).

Type: Nepal, s.coll., # 2004 (*D.clavatum* Wall. ex Lindl., Syntype: K). Appendix II J.

Herb, epiphytic or lithophytic, 40-65 cm high. **Stem** erect, stout, clavate, cylindrical, 0.5-0.8 cm thick, thinner towards base and thicker towards apex, leafy portion smooth, leafless portion vertically ribbed, noded, surrounded by leaf sheaths, internodes slightly swollen at middle than at base and apex, internode 2.0-3.0 cm long. **Leaves** 8, narrowly lanceolate, distichous, obtuse, notched, entire, coriaceous, 8.5- 12.0 cm x 1.5-2.5 cm. **Inflorescence** raceme from leafy stem, subterminal, 5-flowered, borne towards the apex of stem, decurved with several tubular membranous sheaths, sheaths 2 or 3, 0.5-1.5 cm long, pendulous, peduncle stout, sheathed, 1.5-2.0 cm long, rachis 7.0-12.0 cm long. **Flowers** bracteate, large, dark yellow, pedicel with ovary 2.0-4.0 cm long, 4.0-5.5 cm across. **Bract** large, oblong, acute, 7-veined, membranous, 2.0 cm x 0.6 cm. **Sepals** dorsal sepal oblong, acuminate, margin entire, 7-veined, 1.8 cm x 1.0 cm, lateral sepals oblong and subfalcate, acuminate, margin entire, 5-veined, 2.2 cm x 0.8 cm, mentum short, rounded. **Petals** broader than sepals, broadly ovate, obtuse, glabrous, 3-veined, branched on lateral veins, 2.5 cm x 1.2 cm. **Lip** simple, orbicular or reniform, narrow lower part, spreading in anterior part, convolute in basal part, retuse apex, clawed at base, margin undulate and fimbriate, adaxial surface tomentose with dark purple reniform patch in the center, abaxial surface slightly raised in middle, 2.2 cm x 2.0 cm. **Column** short, 0.5 cm long, nectary at base, foot 0.4 cm long. **Anther** conical, 4 mm x 0.2 mm. **Pollinia** 4 in 2 pairs, ovate-oblong, lemon yellow, 2.0 mm x 1.8 mm (Fig. 21).

Habitat: On the rock

Distribution: Nepal (C. 600-2500 m), China, India, Myanmar, Laos, Vietnam and Thailand (Fig. 20).

Status: Threatened due to deforestation and over exploitation for medicinal values.

Flowering: May-June.

Etymology: Not found.

Specimens Examined: Appendix III 10.

Notes: The specimen could not be collected from field visits and other sources. So this specimen was described from voucher specimen deposited at KATH.

D. denneanum was first described by Kerr in 1933. In Laos he found a plant identical with *D. clavatum* Lindl. and he named it *D. denneanum*. *D. clavatum* Lindl. was synonym of *D. denneanum*. *Dendrobium aurantiacum* var. *denneanum* was also synonym.

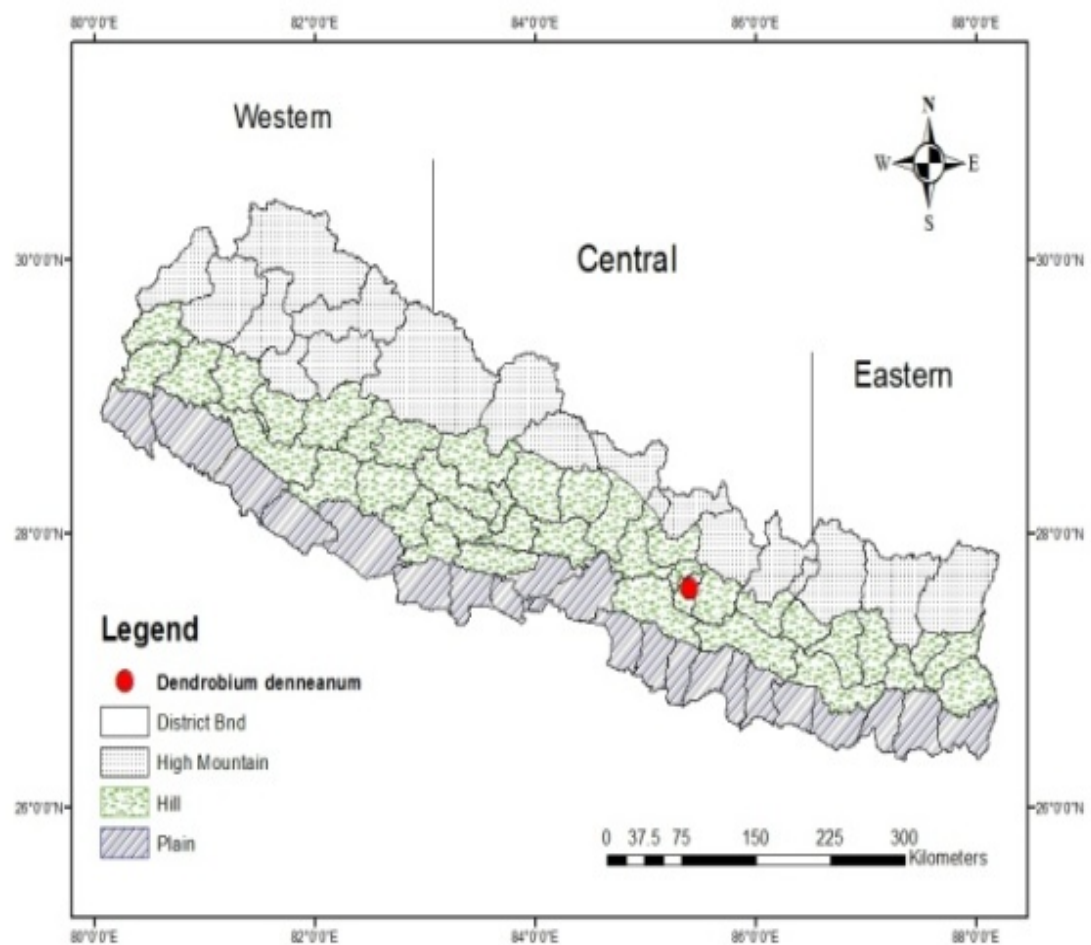


Fig. 20. Distribution map of *Dendrobium denneanum* Kerr in Nepal Himalaya.

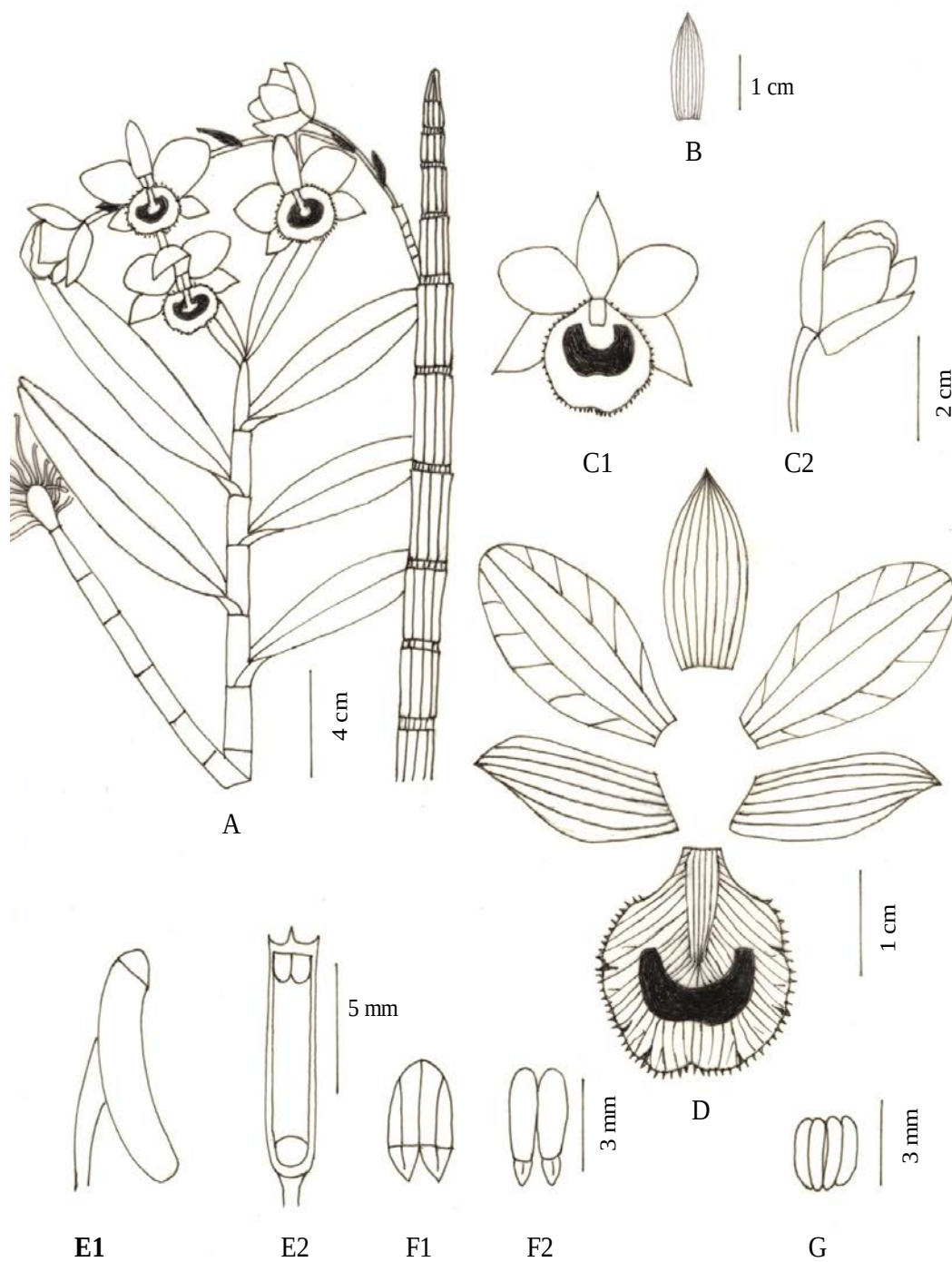


Fig. 21. *Dendrobium denneanum* Kerr; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia.

Dendrobium densiflorum Lindl. in Wallich., Pl. Asiat. Rar. **1**: 34, t. 40, (1830).

Type: Nepal, Wallich, # 2000 (Syntype: K). Appendix II K.

Herb, epiphytic, 20-40 cm high. **Stem** erect, arise in tufts, stout, fusiform or clavate, quadrangular, 2.0-2.5 cm thick, 7-12 noded, thickest at node and smaller towards base, each node covered with white sheath upto half, internodes swollen towards apex than at base, internode 2.5-3.8 cm long, 3-5 leaved at apex,. **Leaves** 3-5, subterminal, ovate-lanceolate or ovate-oblong-lanceolate, narrowed at base, acute, entire, coriaceous, persistent, 10.0-16.0 cm x 2.0-3.5 cm. **Inflorescence** axillary raceme with short-lived scented flowers, borne towards the apex of stem, pendulous, densely many-flowered having pine apples like appearance, cylindrical, peduncle sheathed at base, 4.0 cm long, sheaths 2 or 3, 0.5-1.0 cm long, rachis 10-12 cm long. **Flowers** bracteate, fragrant, light yellow, pedicel with ovary 2.5-3.0 cm long, 2.5-4.0 cm across. **Bract** large, oblong, obtuse, twisted, membranous, margins revolute, 7-veined, 1.9 cm x 1.0 cm. **Sepals** dorsal sepal ovate-oblong, obtuse, 7-veined, 2.0 cm x 1.1 cm, lateral sepals oblong-elliptic, obtusely acute, 7-veined, 2.1-2.4 cm x 1-1.2 cm, mentum large and slightly rounded,. **Petals** broader than sepals, ovate-orbicular, obtuse, shortly clawed, 7-veined, erose at margin, 1.5-2.0 cm x 1.3- 1.6 cm. **Lip** simple, orbicular-rhomboid, convolute in basal half, spreading in apical half, retuse apex, surface glandular pubescent, clawed at base, margin slightly revolute, lacerate, orange yellow, 2.2 cm x 2.1 cm. **Column** short and broad, 4 mm long, large concavity with nectaries, foot 5 mm long. **Anther** conical, lemon yellow, 2 mm x 1.5 mm. **Pollinia** 4 in 2 pairs, ovate-oblong, 1.6 mm x 1.1 mm (Fig. 23).

Habitat: On tree trunks of *Schima wallichii*.

Distribution: Nepal (CE. 900-1500 m), Bhutan, Burma, China, India, Myanmar and Thailand (Fig. 22).

Status: Threatened due to deforestation and over exploitation for ornamental plants.

Flowering: April-May.

Etymology: Derived from Latin word “densiflorus” referring plants with dense flowers.

Specimens Examined: Appendix III 11.

Notes: *D. densiflorum* comes under Section *Dendrobium* (Schuitman & Adams 2014). Before this it comes under Section *Densiflora* Finet (1903). The sectional

name *Densiflora* predates the Section *Callista* (Lour.) Schltr. Brieger (1981) reestablished *Callista* as a genus but Schelpe (1981) and Seidenfaden (1935) preferred to retain its sectional rank. Hooker f. (1980) treated whole section into section *Eudendrobium* where he placed about 65 species.

D. densiflorum is based on a Nepalese plant collected by Wallich in 1821. It was published as nom. nud. under no. 2000 in Wall. cat. 1829. In 1830 Lindley validated the Wall. cat. no. 2000 for *D. densiflorum*. But according to Kerr (1933) the plant of Wallich cat. no. 2000 in Lindley herbarium should be considered as type for this taxon. This taxon is identical with the plant found under no. 2004 in Wallich herbarium. That one by Wallich is labeled *D. clavatum* Roxb. (1832). This taxon is considered conspecific with *D. densiflorum*.

King & Pantling (1898) noted that the unexpected raceme with a curious cone-like appearance, which occurs in no other *Dendrobium*. This is caused by the flower buds being concealed by the floral bracts. *D. densiflorum* is related to *D. thyrsiflorum* Rchb. f. ex E. Andre but differs in that the sepals and petals are white or pale pink in latter species. Tsi (1980) and other Chinese authors treated them as conspecific.

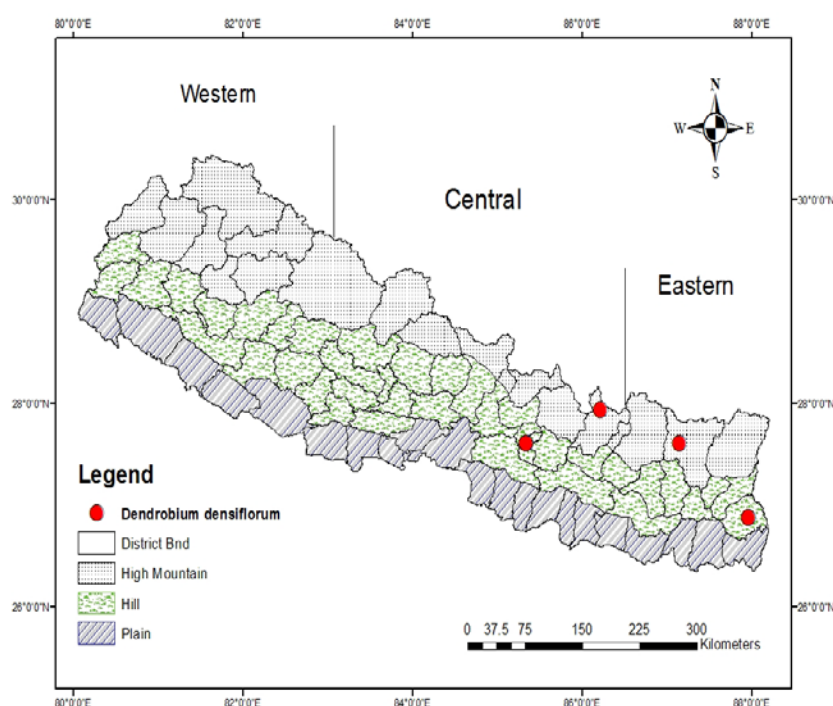


Fig. 22. Distribution map of *Dendrobium densiflorum* Lindl. in Nepal Himalaya.

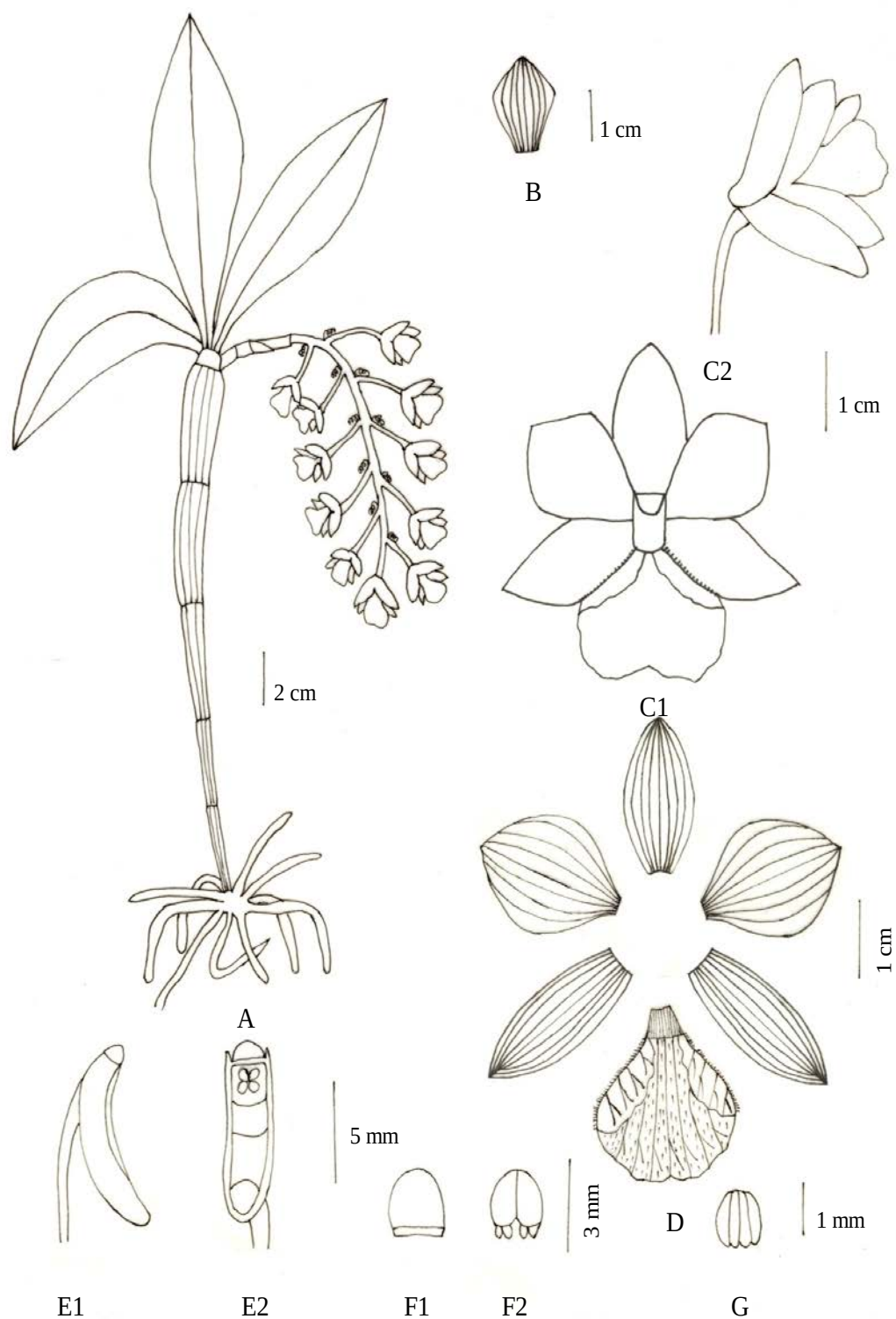


Fig. 23. *Dendrobium densiflorum* Lindl.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia.

Dendrobium fimbriatum Hook., Exot. Fl. **1**: t, 71 (1823); Hooker f., Fl. Brit. Ind. **5**: 745 (1890).

Type: Nepal, Wallich, # 2011 (Syntype: K). Appendix II L.

Herb, epiphytic or lithophytic, 55-70 cm high. **Stem** suberect, many leaved, arching to pendant, cylindrical or somewhat fusiform above base, unbranched, noded, internodes swollen at middle than at base and apex, internodes 2.5-5.0 cm long, covered with white and membranous sheaths up to half of stem, longitudinally grooved, yellowish green when old. **Leaves** lanceolate to oblong lanceolate, distichous, apex acute sometimes slightly bilobed or acuminate, sessile, alternate, coriaceous, 12.5-14.0 cm x 1.4-3.5 cm. **Inflorescence** axillary raceme pendulous, with 6-8 flowers from apex of leafy or leafless stem, peduncle 2.0 cm long, rachis slightly curved, 5.0-8.0 cm long, thin, sheathed, basal sheaths several, overlapping, tubular, membranous, basal sheath 3.0 mm up to terminal 1.0 cm. **Flower** bracteate, 6-8 flowers, orange-yellow, spreading, thin texture, 4.5-5.5 cm across, pedicel with ovary slender, 2.5-3.0 cm long, lip with orbicular dark purple blotch in the centre. **Bract** ovate-triangular, small, acute, membranous, 5-veined, 4.0 mm x 3.0 mm. **Sepals** sub-equal, light orange-yellow, dorsal sepal elliptic-oblong, obtuse, margin entire, 5-veined, 2.4 cm x 1.0 cm, lateral sepals similar in size to dorsal sepal, ovate-lanceolate, obtuse, margin entire, 5-veined, small outgrowth at lower side of apex, 2.4 cm x 1.0 cm, mentum short, rounded, 4.0 mm long. **Petals** oblong-elliptic, broader than sepal, obtuse, margin slightly erose, light orange-yellow, 5-veined, 2.4 cm x 1.5 cm. **Lip** simple, suborbicular, deep orange-yellow with dark purple blotch on the disc, apex rounded, margin deeply fimbriate, undulate, base with purple-red stripes on both sides, shortly clawed, densely pubescent adaxially, 3.0 cm x 2.2 cm. **Column** broad, 4.0 mm long, foot 4.0 mm long, nectary, suborbicular at lower end. **Anther** obliquely conical, yellow, fine teeth at front edge, 3.0 mm x 2.0 mm. **Pollinia** 4 in 2 pairs, oblong, yellow 2.0 mm x 1.5 mm (Fig. 25).

Habitat: On tree trunks of *Schima wallichii*.

Distribution: Nepal (WCE. 500-1000 m), India, Bhutan, China, Myanmar, Thailand and Vietnam (Fig. 24).

Status: Endangered.

Flowering: April-May.

Etymology: Derived from Latin word “fimbriatus” referring to the fringed margin of lip.

Specimens Examined: Appendix III 12.

Notes: In 1823, Hooker established *D. fimbriatum* without any blotch in lip. He collected a specimen which was similar to *D. fimbriatum*, but with a blotch in the lip in 1845. This made him to propose a new variety of *D. fimbriatum* as *D. fimbriatum* var. *oculatum* (Bot. Mag.: 71 t. 4160, 1845). Seidenfaden (1985) treated *D. fimbriatum* var. *oculatum* (species found in our country) which has purple blotch, as conspecific with *D. fimbriatum* without blotch. *D. fimbriatum* var. *oculatum* Hook. is placed as synonym under *D. fimbriatum* Hook. This species is closely related to *D. hookerianum* which also has purple blotches but with longer fimbriae on the lip margin. The specimen collected from Nepal is *D. fimbriatum* var. *oculatum* with dark purple blotch in the disc.

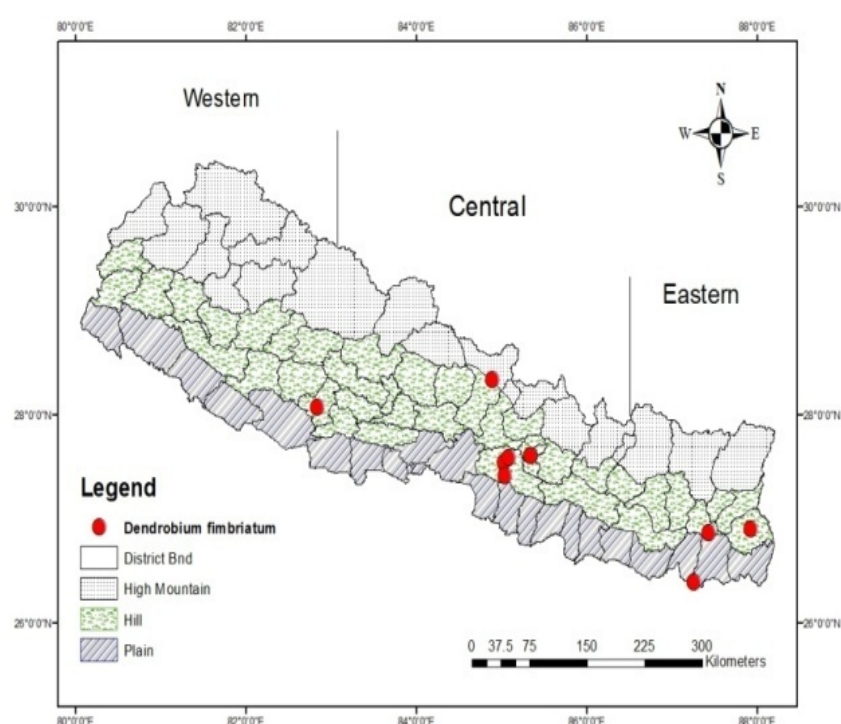


Fig. 24. Distribution map of *Dendrobium fimbriatum* Hook. in Nepal Himalaya.

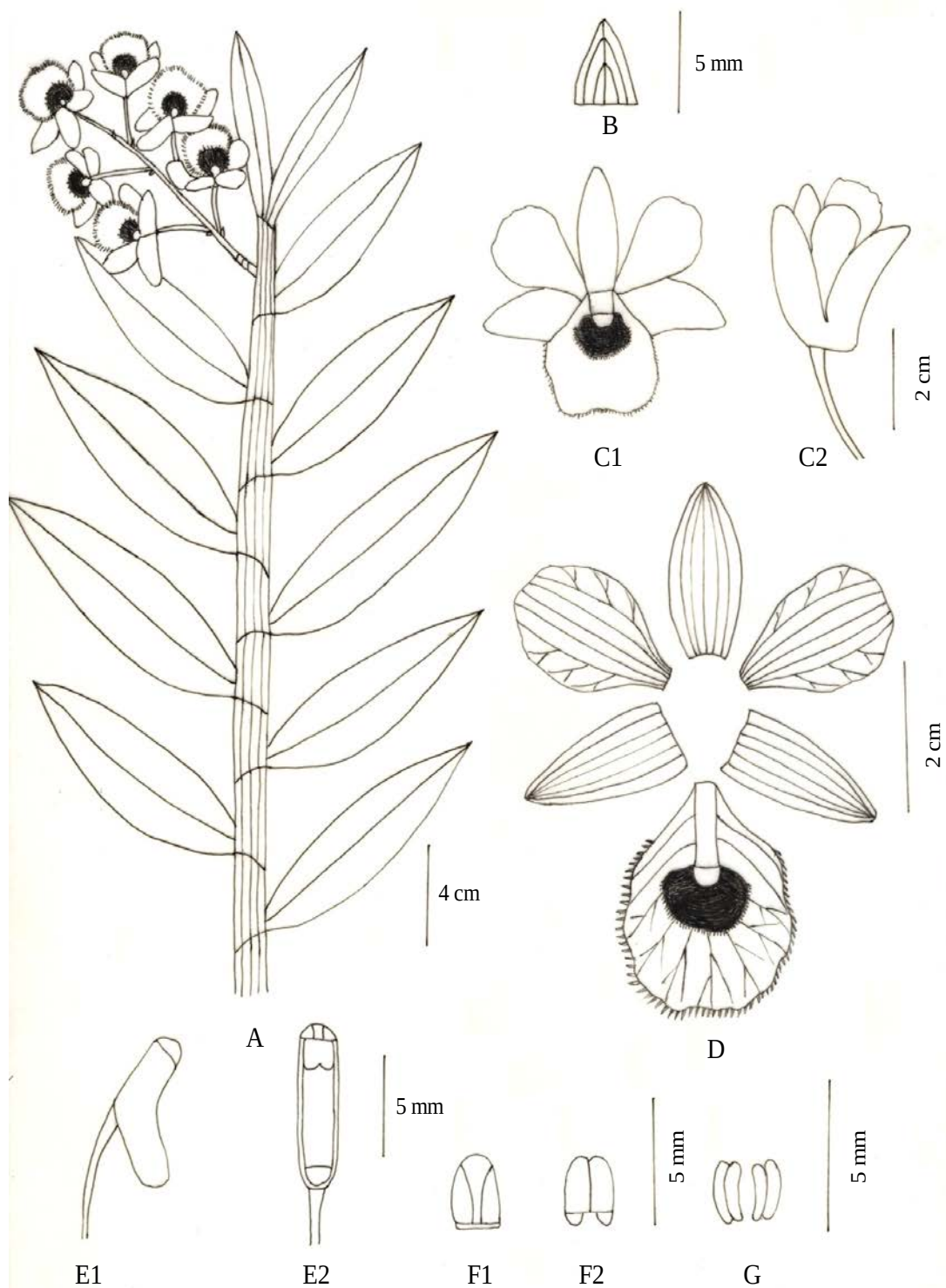


Fig. 25. *Dendrobium fimbriatum* Hook.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view: F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia.

Dendrobium gibsonii Paxton, Paxton' Mag. Bot. 5: 169 (1838); Hooker f., Fl. Brit. Ind. 5: 746 (1890).

Type: India, Hooker, # s.n. (*Dendrobium fuscatum* Lindl. Isotype: P, Isosyntype M). Appendix II M.

Herb, epiphytic, 25-48 cm high. **Stem** pendulous, cylindrical, zigzag slightly, many alternate leaved, tapering from base to apex, swollen at base, unbranched with many nodes and longitudinal grooves, internodes 2.0-3.0 cm apart, covered with green sheaths. **Leaves** ovate-lanceolate, distichous, sessile, apex acute, many-veined, coriaceous, base with papery sheaths, 9.0-18.5 cm x 2.0-4.0 cm. **Inflorescence** lateralraceme, lateral, arising from nodes of leafy stem, apical on old leafless stem, pendant, 6-12 flowered, peduncle slender, sheathed, 1.0-2.0 cm long, rachis slender, 9.0-13.0 cm long, basal sheaths 4-5, tubular, overlapping, basal sheath 3.0 mm, up to upper sheath 1.0 cm, papery. **Flower** bracteate, orange yellow, disk with a rounded deep purple blotch on each side, 3.0 cm across, pedicel with ovary 4.7 cm long. **Bract** lanceolate, acute, cymbiform, minute, membranous, 5-veined, 5.0-7.0 mm x 2.0-3.0 mm. **Sepals** dorsal sepal elliptic, apex obtuse, slightly incurved, base slightly zigzag, margin entire, 5-veined, 1.6 cm x 1.0 cm, lateral sepals fused to form mentum, oblong, apex obtuse, slightly incurved, margin entire, 5-veined, 1.6 cm x 0.9 cm, mentum subglobose. **Petals** broadly ovate or nearly elliptic, apex emarginate, margin slightly undulate, 5-veined, 1.7 cm x 1.3 cm. **Lip** subreniform, apex emarginate, claw at base, margin fimbriate, disc with deep purple blotch on each side, papillary hairs with short fringed edges on both sides, 1.5 cm x 1.7 cm. **Column** short, broad, 4 mm, foot 4 mm long. **Anther** cap conic, subglobose, glabrous, front margin slightly erose, 3 mm x 2 mm. **Pollinia** 4 in 2 pairs, slightly yellow, oblong, 2.0 mm x 1.5 mm (Fig. 27).

Habitat: On tree trunks of *Schima wallichii*.

Distribution: Nepal (W. 900-2000 m), India, Bhutan, Myanmar, Thailand, China and Vietnam (Fig. 26).

Status: Endangered.

Flowering: June-July.

Etymology: Derived from Latin word "gibson" referring to name of English collector John Gibson who collected orchids in North east India.

Specimens Examined: Appendix III 13.

Notes: There is no voucher specimen deposited in KATH and TUCH. This specimen has been reported from East Nepal by Stainton. In the present study this specimen was collected from Panchase, Kaski, Central Nepal.

Finet (1903) was of opinion that *D. gibsonii* should be considered as a variety of *D. fimbriatum* i.e. *D. fimbriatum* var. *oculatum*. Seidenfaden (1985) considered this specimen to be distinct on the basis of colour, lip margins and flexuose raceme. It is distinguished from *D. fimbriatum* by 2-well separated dots on lip as well as type of fringe. A taxonomic complication is that leafy stems from *D. gibsonii* appear on Lindley's type sheet for *D. polyanthum* but it was disagreeing with protologues and they are unrelated.

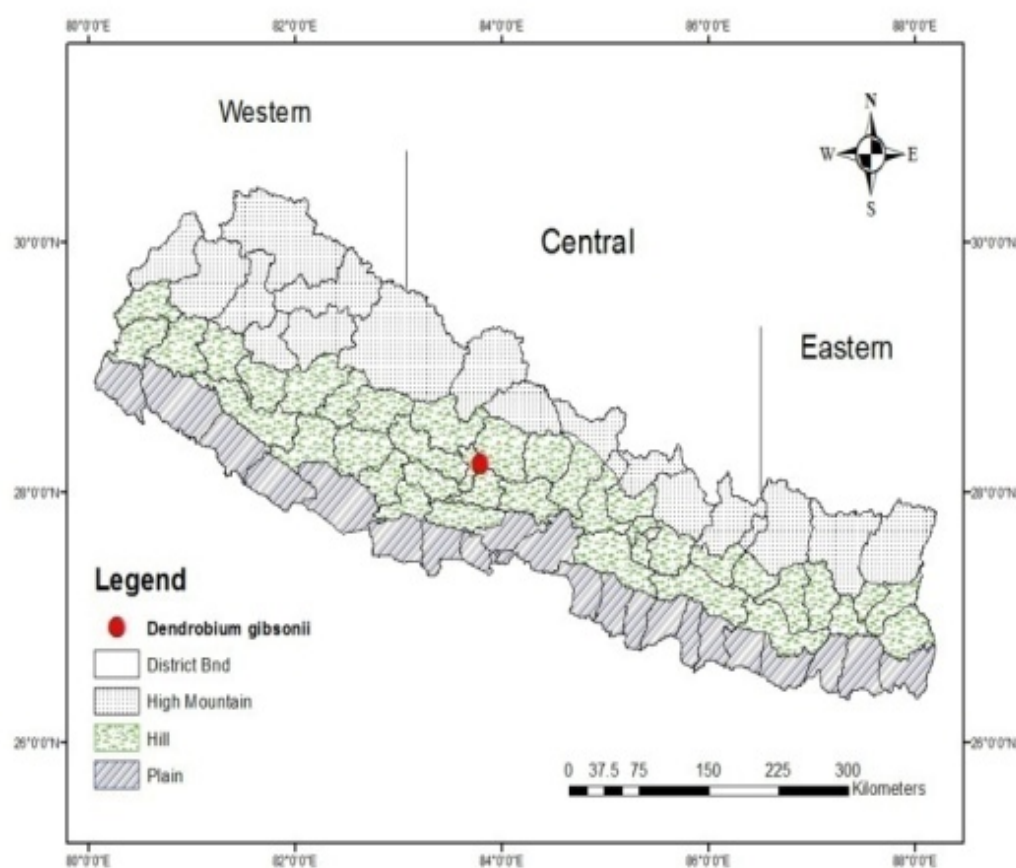


Fig. 26. Distribution map of *Dendrobium gibsonii* Paxton in Nepal Himalaya.

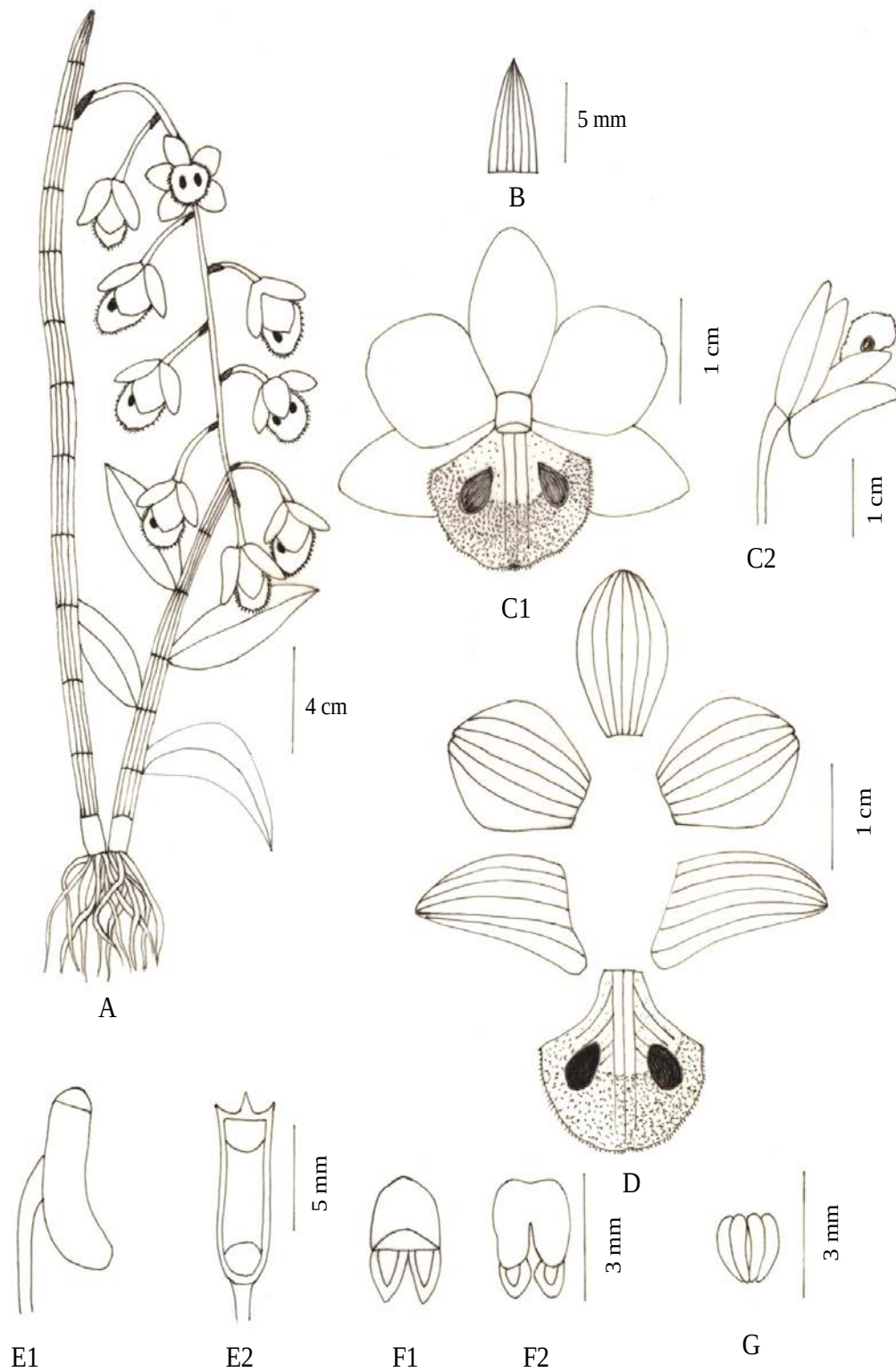


Fig. 27. *Dendrobium gibsonii* Paxton; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia

Dendrobium heterocarpum Wall. ex Lindl., Gen. Sp. Orch. Pl.: 78 (1830).

Type: Sri Lanka, Macrae, # 68 (Syntype: K). Appendix II N.

Herb, epiphytic, 15-25 cm high. **Stem** erect, subclavate, ribbed, 2.0-2.2 cm thick, swollen at nodes tapering towards base, internodes swollen at middle than at base and apex, internodes sheathed, 2.0-3.0 cm long. **Leaves** narrowly oblong-lanceolate, distichous, subacute, coriaceous, withered at flowering time, 7.0-12.0 cm x 1.0-2.0 cm. **Inflorescence** axillary raceme arising from nodes at the apical part of old leafless stem, 1-3 flowered, erect, peduncle very short, sheathed, 4.0 mm long, sheaths tubular, 3.0 mm long. **Flower** bracteate, pale yellow, sweet scented, 4.5 cm across, pedicel with ovary 2.5 cm long. **Bract** broad, ovate, convolute, obtuse, 3-veined, 0.6 cm x 0.4 cm. **Sepals** dorsal sepal oblong-lanceolate, subacute, 5-veined, 2.8 cm x 0.7 cm, lateral sepals lanceolate, acute, 7-veined, 2.8 cm x 0.7 cm, mentum short, conical. **Petals** equal to dorsal sepal, ovate-lanceolate, entire, acute, 5-main veined, many secondary veins, 2.8 cm x 1.0 cm. **Lip** pale yellow with yellow disc, reddish purple radiating lines, trowel-shaped, clawed, acute, decurved, margin undulate, side of base convolute, disc papillose-pubescent, 2.8 cm x 1.6 cm. **Column** short, 4 mm long, broad above foot, foot 9 mm long, tapering, excavated with median raised line, **Anther** cap-like, grooved on upper surface, erose edges, 2.0 cm x 1.8 cm. **Pollinia** 4 in 2 pairs, very narrow, oblong, 2.0 mm x 1.6 mm (Fig. 29).

Habitat: On tree trunk of *Quercus glauca*.

Distribution: Nepal (C. 900-2130 m), Sikkim, Bhutan, India, Myanmar, Sri Lanka, Thailand, Vietnam, Phillipines & Indonesia (Fig. 28).

Status: Endangered.

Flowering: March-April.

Etymology: Derived from Latin word “heterogenous” meaning different and Greek word “karpos” meaning fruit referring the plant having different fruit.

Specimens Examined: Appendix III 14.

Notes: Lindley in 1830 published both taxa together, *D. aureum* based on Macrae collection from Ceylon and *D. heterocarpum* based on Wallich plant from Nepal. In 1839 Lindley figured a Ceylon collection calling it *D. aureum* var. *pallidum* with light colours. J.D. Hooker in 1853 considered these two taxa as conspecific and he chose the name *D. heterocarpum*. Thus *D. heterocarpum* is treated as valid name. The

further studies may show to recognize two separate species. By surveying many older drawings of these plants it becomes easy to characterize *D. aureum* by the petals being broader than dorsal sepal and epichile of lip broader, shorter and more obtuse than in *D. heterocarpum*, where the petals are less different in width from dorsal sepal.

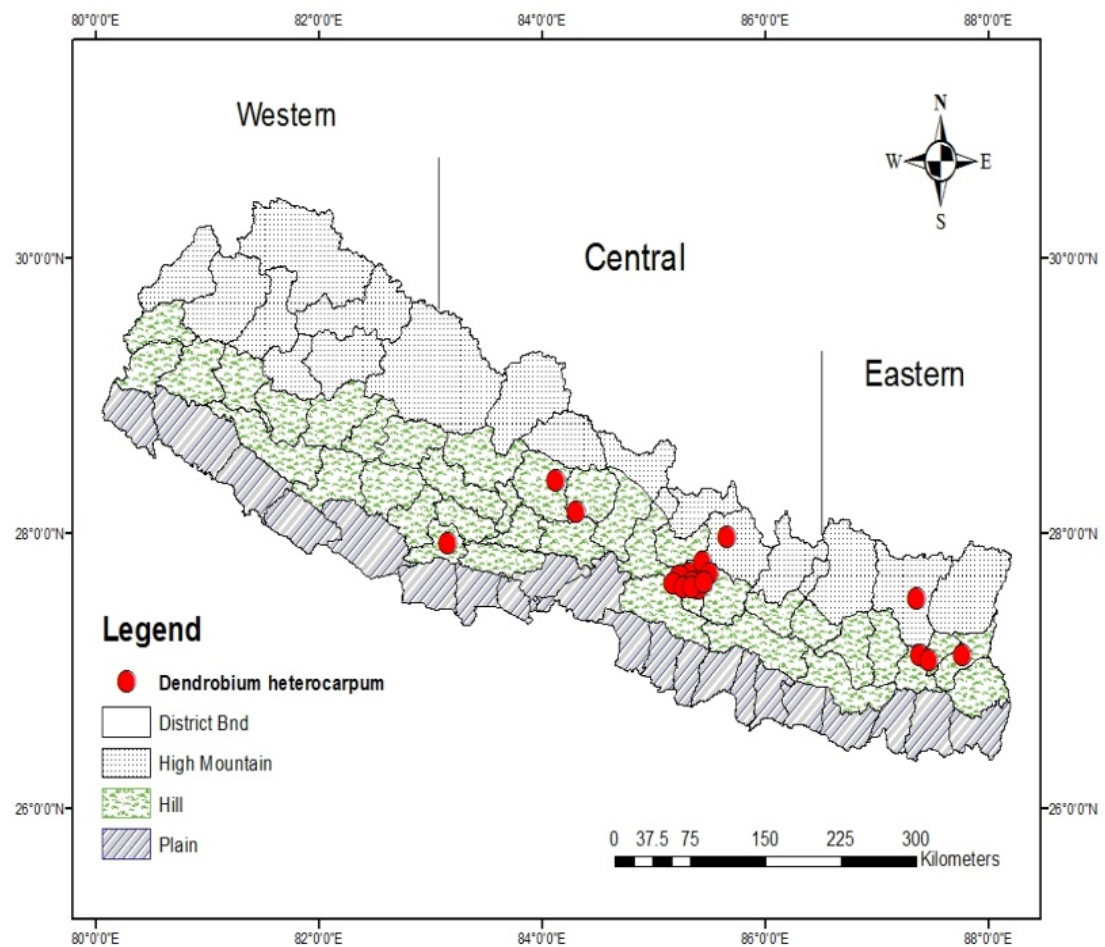


Fig. 28. Distribution map of *Dendrobium heterocarpum* Wall. ex Lindl. in Nepal.

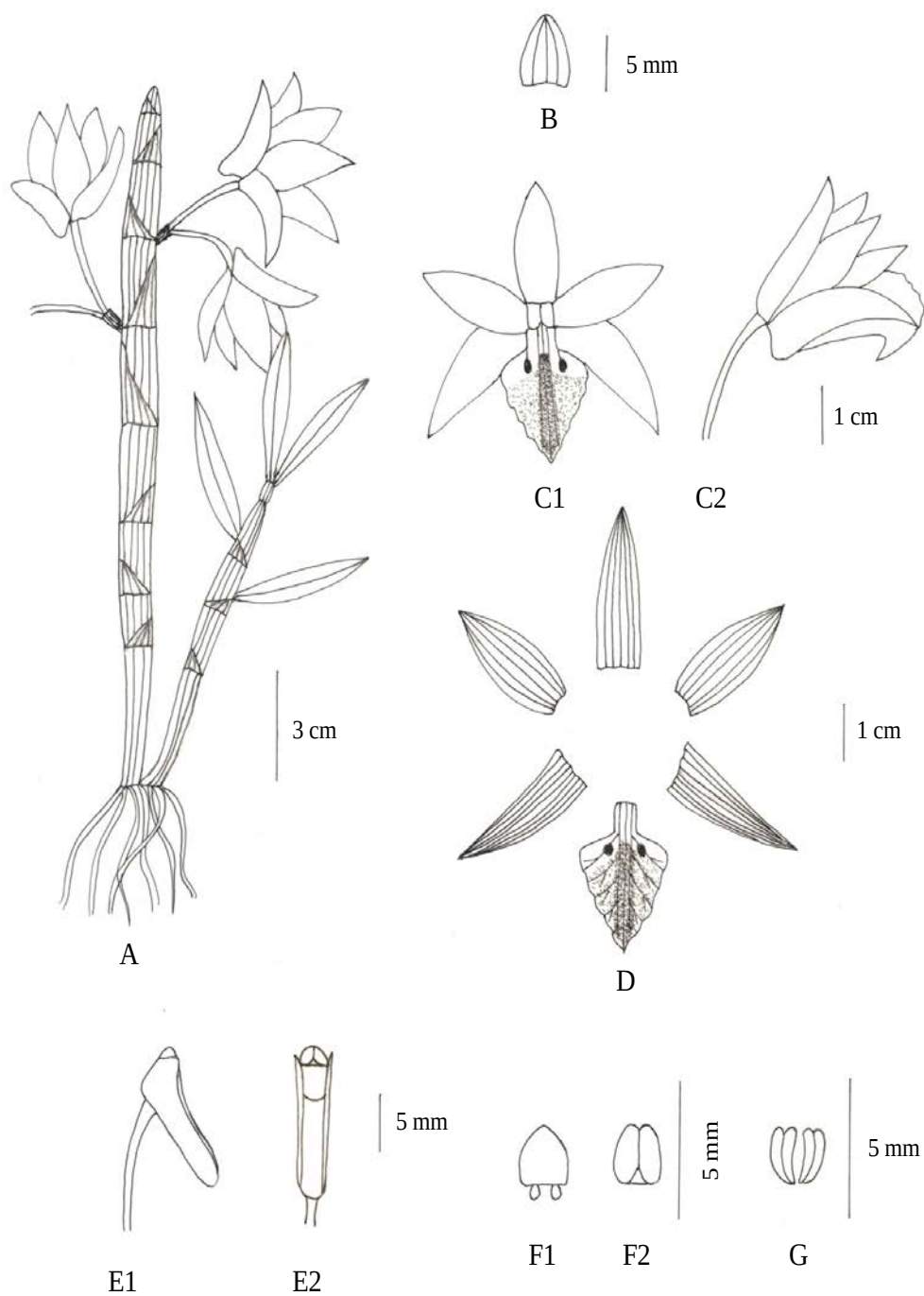


Fig. 29. *Dendrobium heterocarpum* Wall. ex Lindl.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia

Dendrobium moniliforme (Linnaeus) Swartz, Nova Acta Regiae Soc. Sci. Upsal., ser. 2. 6: 85 (1799).

Type: China, Wilson, # 4621 (Syntype: P). Appendix II O.

Herb, epiphytic, 15–25 cm high. **Stem** erect, cylindrical, slender, flexuous, 0.8–1.0 cm thick, unbranched with nodes, internode 1.5–3.0 cm long, covered with thread-like leafy sheaths. **Leaves** exstipulate, sessile, distichous, lanceolate, membranous, entire margin, apex obtuse, obliquely bifid, 3.5–8.0 cm x 0.5–1.3 cm. **Inflorescence** raceme axillary, flowering on leafless stems, 1–3 flowered, borne at nodes from short sheathed peduncle, rachis weakly zigzag, erect, 9.0 mm long, peduncle 3.0 mm long, sheath of peduncle ovate, acute, hyaline, 3 mm x 2.5 mm. **Flowers** bracteate, pedicellate, pedicel with ovary, 1.2 cm long, 1–3 flowers from short sheathed peduncle, white with yellowish green spot, fragrant, 2–2.5 cm across. **Bract** ovate, acute, dry, membranous, 3-veined, 0.6 cm x 0.3 cm. **Sepals** unequal, dorsal sepal lanceolate, acute, 5-veined, 1.5 cm x 0.5 cm, lateral sepals broadly lanceolate, subfalcate, acute, 5-veined, 1.6 cm x 0.6 cm, mentum broad, short, rounded. **Petals** as long as sepals, ovate-lanceolate, more acute, entire, 5-veined, 1.6 cm x 0.7 cm. **Lip** as long as sepal, oblong-lanceolate, white with yellowish green central spot near the base of mid-lobe, 3-lobed, side lobes rounded, short, incurved near the middle, apex rounded, margin entire, slightly wavy, glabrous, mid-lobe ovate-elliptic, apex abruptly acute, 3-veined, margin entire, disc with an elongated callus extended 5 mm from base, glabrous, 1.5 cm x 0.9 cm. **Column** short, 4 mm long, column foot broad, deeply excavated, 7 mm long. **Anther** suborbicular, papillose, anther cap conic, 2.0 mm x 1.5 mm. **Pollinia** 4 in 2 pairs, oblong, 1.1 mm x 1.2 mm (Fig. 31).

Habitat: On tree trunk of *Schima wallichii*.

Status: Endangered due to deforestation.

Flowering: April–May.

Distribution: Nepal (CE. 1700–2500 m), Bhutan, India and North Myanmar (Fig. 30).

Etymology: Derived from Latin word “moniliforme” meaning shaped like necklace in reference to the flower arrangement.

Specimens Examined: Appendix III 15.

Notes: *D. moniliforme* is the type species of genus *Dendrobium* Sw. The specimen available in KATH herbarium is labeled as *D. candidum*. *D. candidum* is the accepted

name but in turn seems to be a synonym of *D. moniliforme* (Kaempfer) Sw., the type species of genus. Wood (2006) studied literature with many images of both taxa and growing plants, no difference were found between them. These two specimens lie in their separate taxonomic histories. *D. candidum* was found in Khasia Hills, northeast India and described by Gibson (Duke of Devon's collector) in the 19th century. *D. moniliforme* was found in Japan and illustrated by Kaempfer in 1712. *D. candidum* was subsequently described by Linneaus (1753) and Swartz (1799a).

D. moniliforme in the plate in Botanical Magazine, t. 5482 (1864) was based on a Japanese plant and originally titled *D. japonicum* Lindl. Later this name was determined correctly to be a synonym. It seems that Lindley was not familiar with Kaempfer (1712) and did not have material of *D. moniliforme*. He did not compare *D. japonicum* with Wallich material and described it as *D. candidum*.

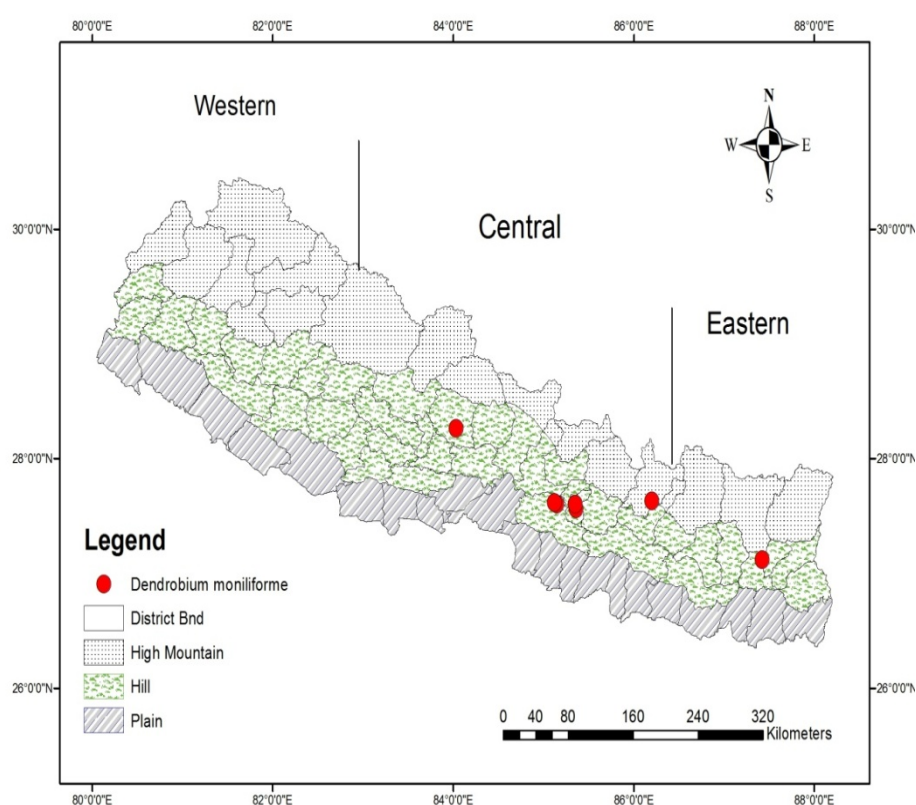


Fig. 30. Distribution map of *Dendrobium moniliforme* (Linn.) Swartz in Nepal Himalaya.

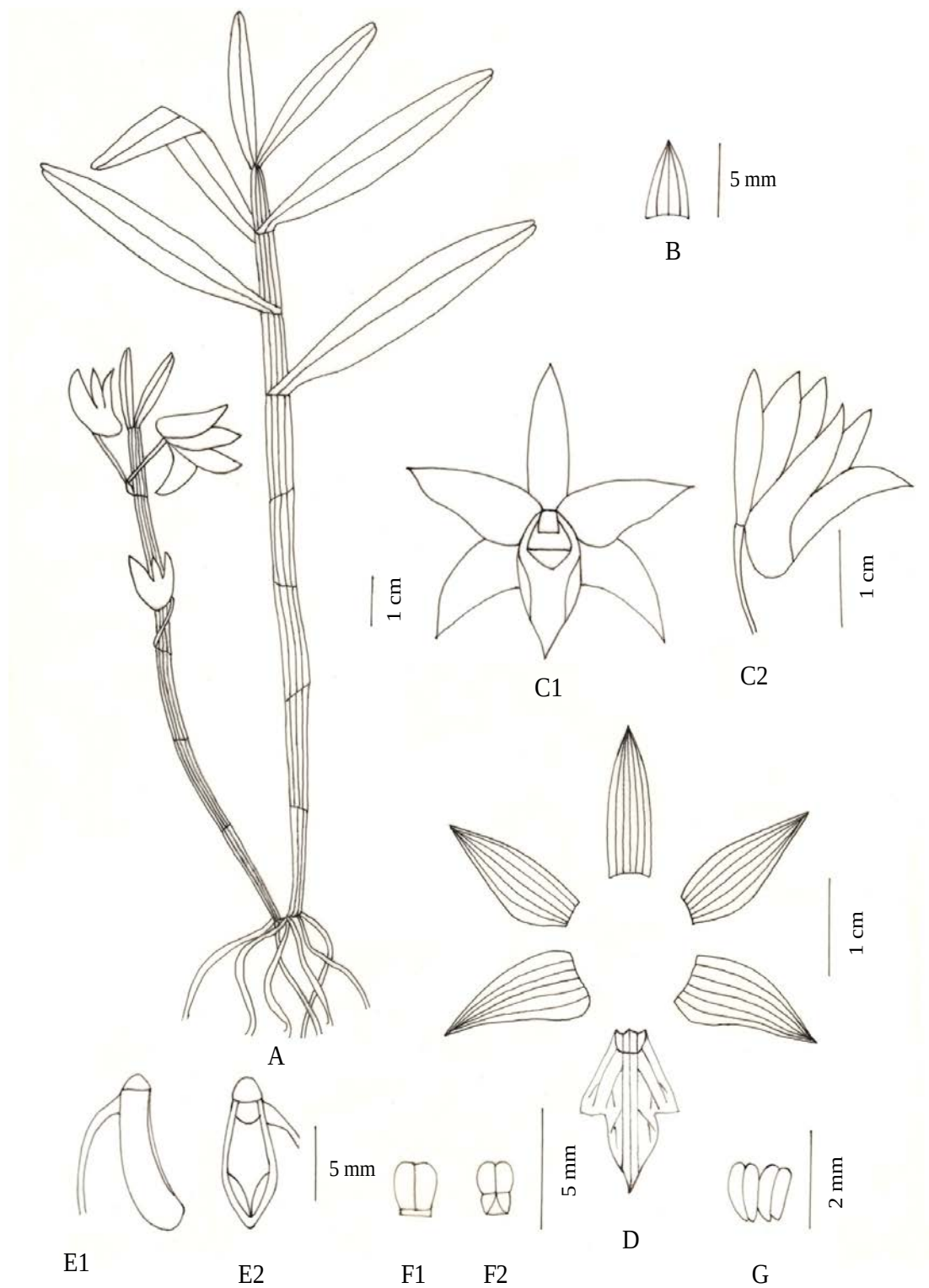


Fig. 31. *Dendrobium moniliforme* (Linn.) Swartz; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia.

Dendrobium moschatum (Buch.-Ham.) Swartz in Schrader, Neu. J. Bot. 1: 94 (1805).

Type: Myanmar, Buchanan, # s.n. (*Epidendrum moschatum* Buch.-Ham., Syntype: BM). Appendix II P.

Herb, epiphytic, 78-150 cm high. **Stem** erect to pendulous, stout, unbranched, ribbed, terete with many nodes, internodes slightly swollen at middle than at base and apex, internodes of about 3.0-4.5 cm long, older stem reddish brown covered with tubular leaf sheaths, apical half bearing leaves. **Leaves** sessile, exstipulate, ovate-lanceolate or oblong, distichous, coriaceous, smooth, acuminate, slightly notched at the apex, papery sheaths at the base of stem, deciduous, no leaves on old stem, 7.5-14.5 cm x 1.5-5.5 cm. **Inflorescence** lateral raceme, pendulous, rachis 16-26 cm long, arises near the apex of leafy or leafless stem, 8-12 flowered, peduncle 3.5-5.0 cm, stout at base and covered with many imbricate basal sheaths, sheaths 3-5, tubular, 1-1.5 cm long. **Flowers** bracteate, borne on leafy or leafless stem, pale yellow, showy, deeply musk perfumed, 6.5-7.0 cm in diameter, pedicel with ovary 5 cm long. **Bract** lanceolate, leathery, apex obtuse, 5-veined, 1.5 cm x 0.7 cm. **Sepals** dorsal sepal oblong, apex obtuse, 7-veined, 3.2 cm x 1.6 cm, lateral sepals oblong, apex acute slightly, 7-veined, 3.2 cm x 1.6 cm, mentum short, wide, stout, conic and yellow. **Petals** broadly ovate, apex obtuse, larger than sepals, 7-veined, 3.5 cm x 1.8 cm. **Lip** subglobular or calceolate, pale yellow with purplish brown blotches on either side, pubescent adaxially, glabrous abaxially, apex rounded, margin cucullate, involute and fimbriate, shorter than sepals, 7-veined, 3.0 cm x 1.7 cm. **Column** short, 4 mm x 3 mm, foot widening at lower side with nectary, 6 mm long. **Anther** with erose lip, 4 mm x 3 mm. **Pollinia** 4 in 2 pairs, oblong, 2.0 mm X 1.6 mm (Fig. 33).

Habitat: On tree trunks of *Schima wallichii*.

Distribution: Nepal (CE. 200-1200m), India, Bhutan, Bangladesh, Myanmar, Laos, China, Thailand (Fig.32).

Status: Threatened due to deforestation.

Flowering: May-July.

Etymology: Derived from Latin word “moschatum” meaning plants having musky smelling flowers.

Specimens Examined: Appendix III 16.

Notes: *D. moschatum* (Buch.-Ham.) Sw. is the type species and *Epidendrum moschatum* Buch.-Ham. is basionym of section *Holochrysa* Lindl. *D. moschatum* is the only species remaining in the Lindley's original *Holochrysa*. Seidenfaden (1985) treated the section *Holochrysa* under the section *Dendrobium*. Wood (2006) separated the section *Holochrysa* whereas Schuitman & Adams (2014) treated the section *Holochrysa* under section *Dendrobium*. Section *Holochrysa* is revived as it seems close to section *Dendrobium*.

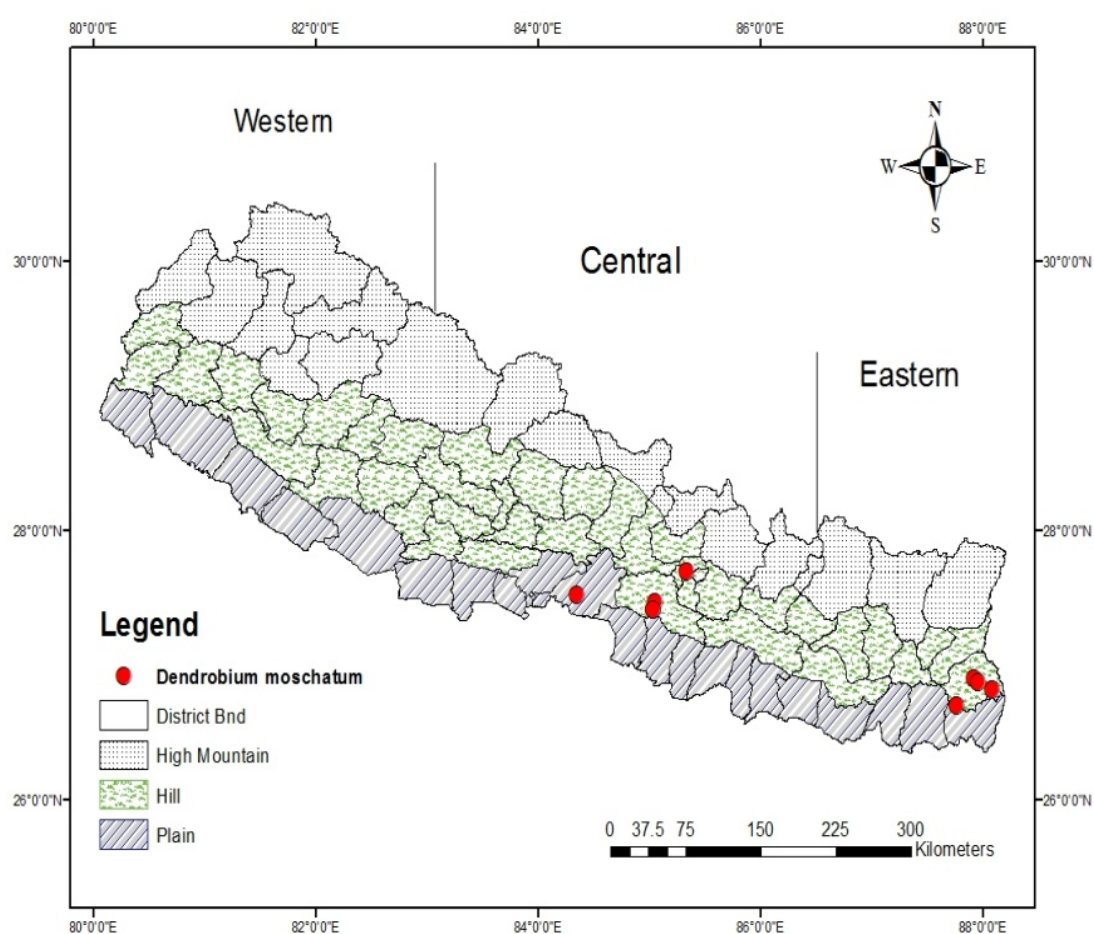


Fig. 32. Distribution map of *Dendrobium moschatum* (Buch-Ham.) Swartz in Nepal.

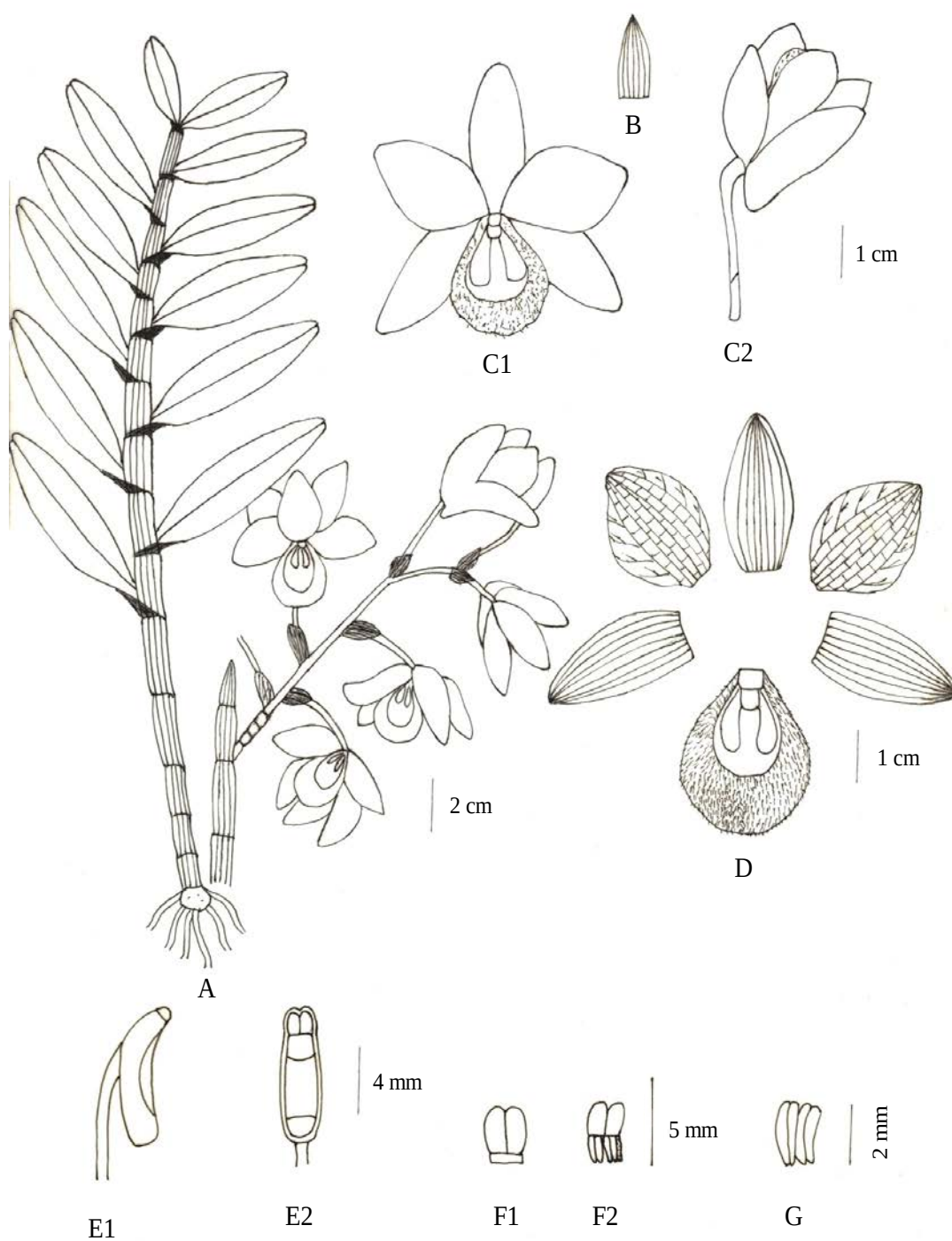


Fig. 33. *Dendrobium moschatum* (Buch.-Ham.) Swartz; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia.

Dendrobium nobile Lindl., Gen. Sp. Orchid. Pl.: 79 (1830); Hooker f., Fl. Brit. Ind. 5: 740 (1890).

Type: India, Hooker, # s.n. (*Dendrobium lindleyanum* Griff., Syntype: M).

Appendix IIQ.

Herb, epiphytic, 25-40 cm high. **Stem** erect, stout, unbranched, slightly compressed, narrowed at base, many nodes, internodes swollen at middle than at base and towards the apex, internodes of about 2.0-2.5 cm long, older stem yellow covered with tubular leaf sheaths, apical half bearing leaves. **Leaves** sessile, exstipulate, oblong, distichous, coriaceous, smooth, obtuse, obliquely notched, 8.0-13 cm x 1.5-2.5 cm. **Inflorescence** lateral raceme, arising from nodes, solitary or 2-4 flowered, erect, peduncle short, 0.5-1.5 cm long. **Flowers** bracteate, borne on leafy or leafless stem, waxy, white at base gradually becoming mauve above, fragrant, 6.0-7.0 cm in diameter, pedicel with ovary 3.5-4.0 cm long. **Bract** ovate-oblong, apex obtuse, 5-veined, scarious, 0.5-0.9 cm x 0.4-0.6 cm. **Sepals** dorsal sepal oblong-lanceolate, apex obtuse, 7-veined, 3.1 cm x 0.9 cm, lateral sepals oblong-lanceolate, apex acute, 7-veined, base oblique, margin incurved slightly, 3.2 cm x 0.8 cm, mentum short, and conical. **Petals** broadly elliptic, apex obtuse, larger than sepals, 7-veined, margin slightly incurved, 3.5 cm x 2.0 cm. **Lip** simple, ovate-oblong, apex obtuse, shortly clawed, upper half cucullate, lower half incurved, densely pubescent on both surfaces, margin entire, slightly ciliate, large purple blotch at adaxial sides, 3.5 cm x 2.2 cm. **Column** short, green, 5.0 mm x 2.0 mm, broad near stigma, foot green, slightly bilobed at apex and excavated, 4.0 mm long. **Anther** conic with truncate lip, purple, 4.0 mm x 2.0 mm. **Pollinia** 4 in 2 pairs, oblong, lemon yellow, 2.0 mm x 1.5 mm (Fig. 35).

Habitat: On tree trunks of *Schima wallichii*.

Distribution: Nepal (CE. 400-1500 m), India, Bhutan, Myanmar, Laos, China, Thailand, Vietnam (Fig. 34).

Status: Threatened due to deforestation.

Flowering: April-May.

Etymology: Derived from Latin word “nobile” referring to noble *Dendrobium*.

Specimens Examined: Appendix III 17.

Notes: *D. nobile* was established by Lindley in 1830. *D. nobile* Lindl. is the type species of section *Planifolia* Rchb.f. (1861), section *Eudendrobium* subsect. *Nobilia*

Pfitzer (1889), section *Nobilia* (Pfitzer) Kranzl. (1910), section *Nobilia* subsection *Integrilobia* Kranzl. (1910), section *Eugenanthe* Schltr. (1912), subgenus *Eudendrobium* Kranzl. (1920) and subgenus *Eugenanthe* Royen (1970). Schuitman & Adams (2014) treated all sections, subsection and subgenus under section *Dendrobium*.

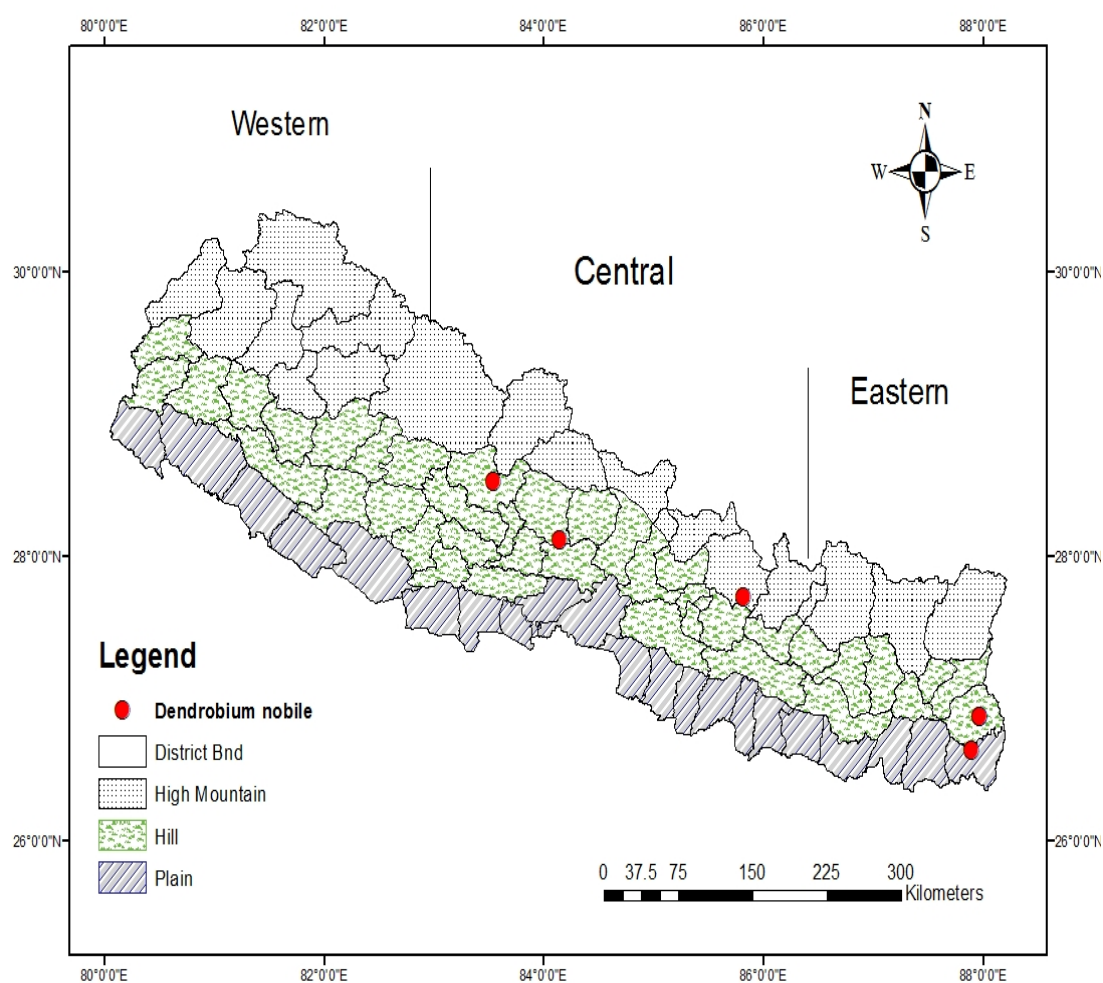


Fig. 34. Distribution map of *Dendrobium nobile* Lindl. in Nepal Himalaya.

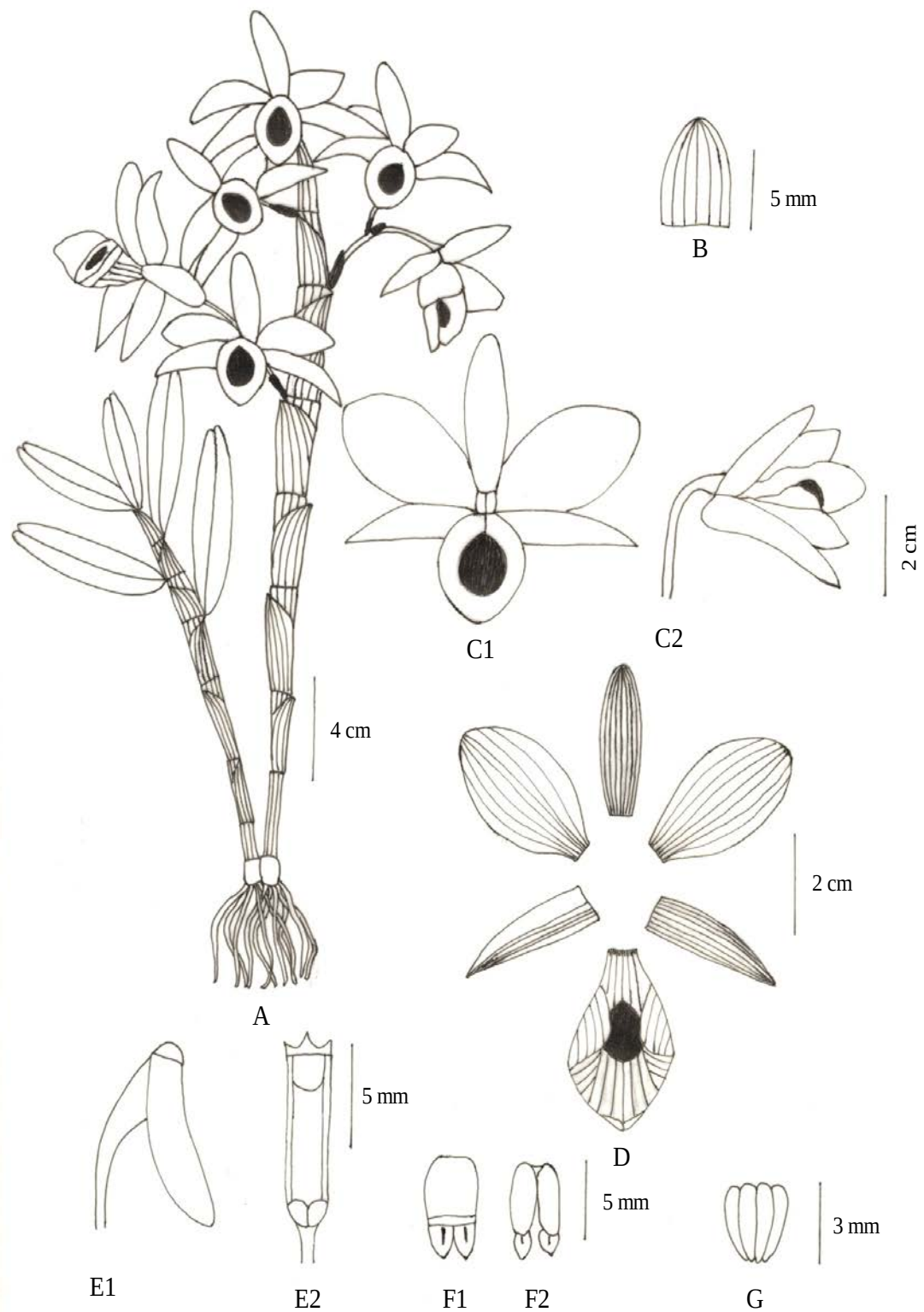


Fig. 35. *Dendrobium nobile* Lindl.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia.

Dendrobium polyanthum Wall. ex Lindl., Gen. Sp. Orchid. Pl.: 81 (1830).

Type: Myanmar, Wallich, # 2009 (Syntype: K). Appendix II R.

Herb, epiphytic, 10-25 cm tall. **Stem** pendulous, cylindrical, unbranched with many nodes, fleshy, covered with white thin striated sheaths, internodes slightly swollen at middle than at base and apex, internode 1.5-2.0 cm long. **Leaves** distichous, deciduous, withered while flowering, broadly oblong, membranous, apex obtuse, unequally bifid, 7.0-10.0 cm x 2.0-3.0 cm, leaf sheath papery. **Inflorescence** lateral raceme, borne on old leafless stem, 2-3 flowered, pendulous, peduncle penetrating 2 boat-shaped sheaths, 2 mm long, basal sheaths 3 or 4, 3.0 mm long, membranous. **Flowers** bracteate, spreading, pendulous, pink-purple, fragrant 6.0 cm across, pedicel with ovary yellowish green, 2.0-2.5 cm long. **Bract** ovate, apex obtuse, off-white, membranous, 1-veined, 8.0 mm x 5.0 mm. **Sepals** dorsal sepal lanceolate, apex subacute, 5-nerved, 2.2 cm x 0.6 cm, lateral sepals lanceolate, apex subacute, base oblique, 5-nerved, 2.3 cm x 0.5 cm, mentum small and rounded. **Petals** oblong, apex obtuse, pink-purple, 5-veined, 2.2 cm x 0.4 cm. **Lip** simple, broadly obovate, convolute towards base, apex rounded, margin denticulate, both surfaces densely pubescent, apical portion pinkish yellow, basal portion white, lip surfaces with purple veins, claw short, callus at base, 3 ridges running from base to apex, 2.5 cm x 2.0 cm. **Column** white, 2 horn like projections at the apex, 4 mm long, foot 5 mm long, conical, narrowed at base. **Anther** conical, purple, densely papillary hairs, front margin emarginated, 4.0 mm x 3.0 mm. **Pollinia** 4 in 2 pairs, ellipsoid, 2.2 mm x 2.5 mm (Fig. 37).

Habitat: Ontree trunks of *Syzygium cumini*.

Distribution: Nepal (WC. 400-1400 m), China, North East India, Laos, Myanmar, Thailand and Vietnam (Fig. 36).

Status: Threatened due to deforestation.

Flowering: March-April.

Etymology: Derived from Latin word “polyanthum” meaning many flowered referring to plant having many flowers.

Specimens Examined: Appendix III 18.

Notes: *D. polyanthum* was established by Lindley in 1830. *D. cretaceum* Lindl. (1847) and *D. primulinum* Lindl. (1858) are the synonyms of *D. polyanthum* Lindl.

There are discussions about valid names of all three Lindley's species going back more than a century. There were questions about white *D. cretaceum* whether it is the same species. Wood (2006) studied the type specimens at Kew and found no significant difference in plant or flower. *D. primulinum* referring to fragrance is the name that has been used in general. Giving the specimens priority over the descriptions it was agreed that the name *D. polyanthum* is correct.

The voucher specimen housed at KATH herbarium is labeled as *D. primulinum* Lindl.

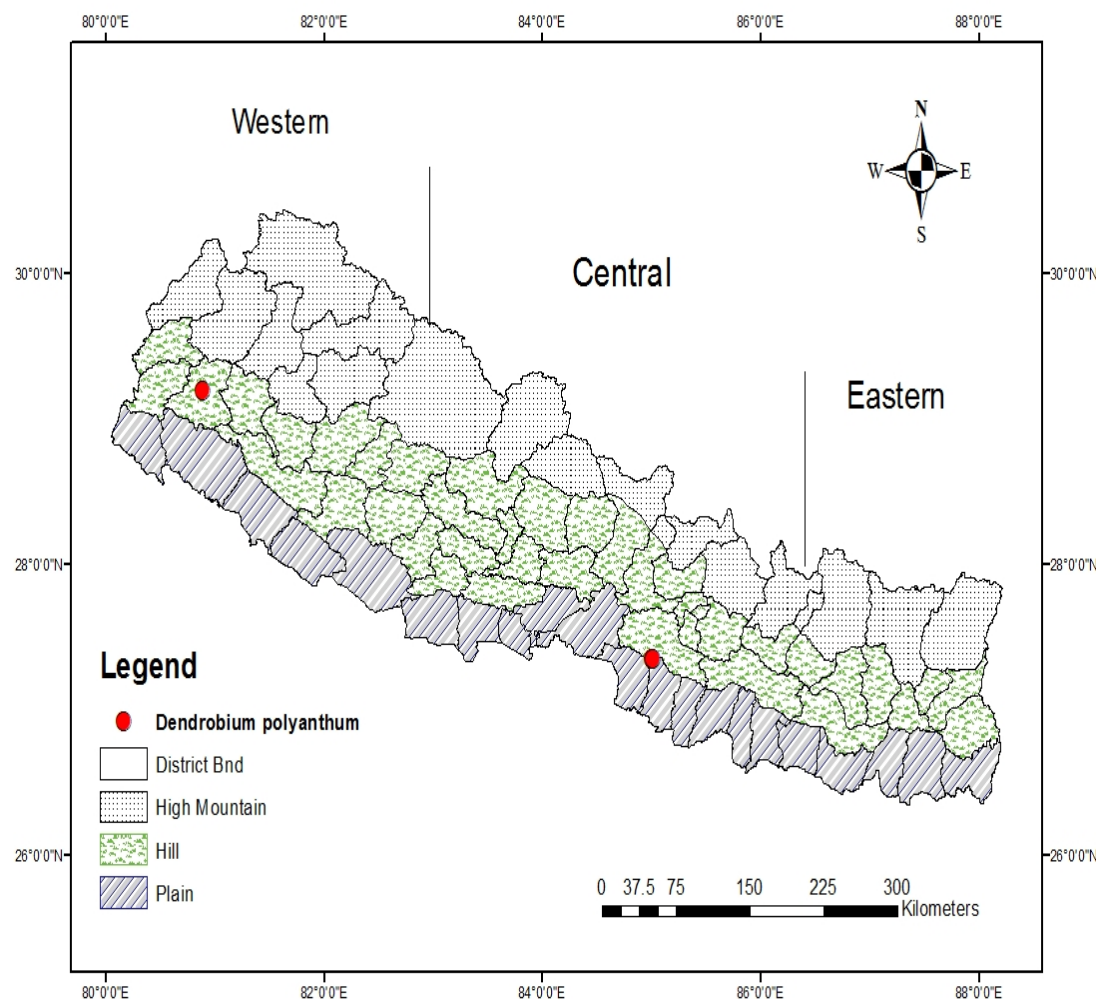


Fig. 36. Distribution map of *Dendrobium polyanthum* Wall. ex Lindl. in Nepal Himalaya.

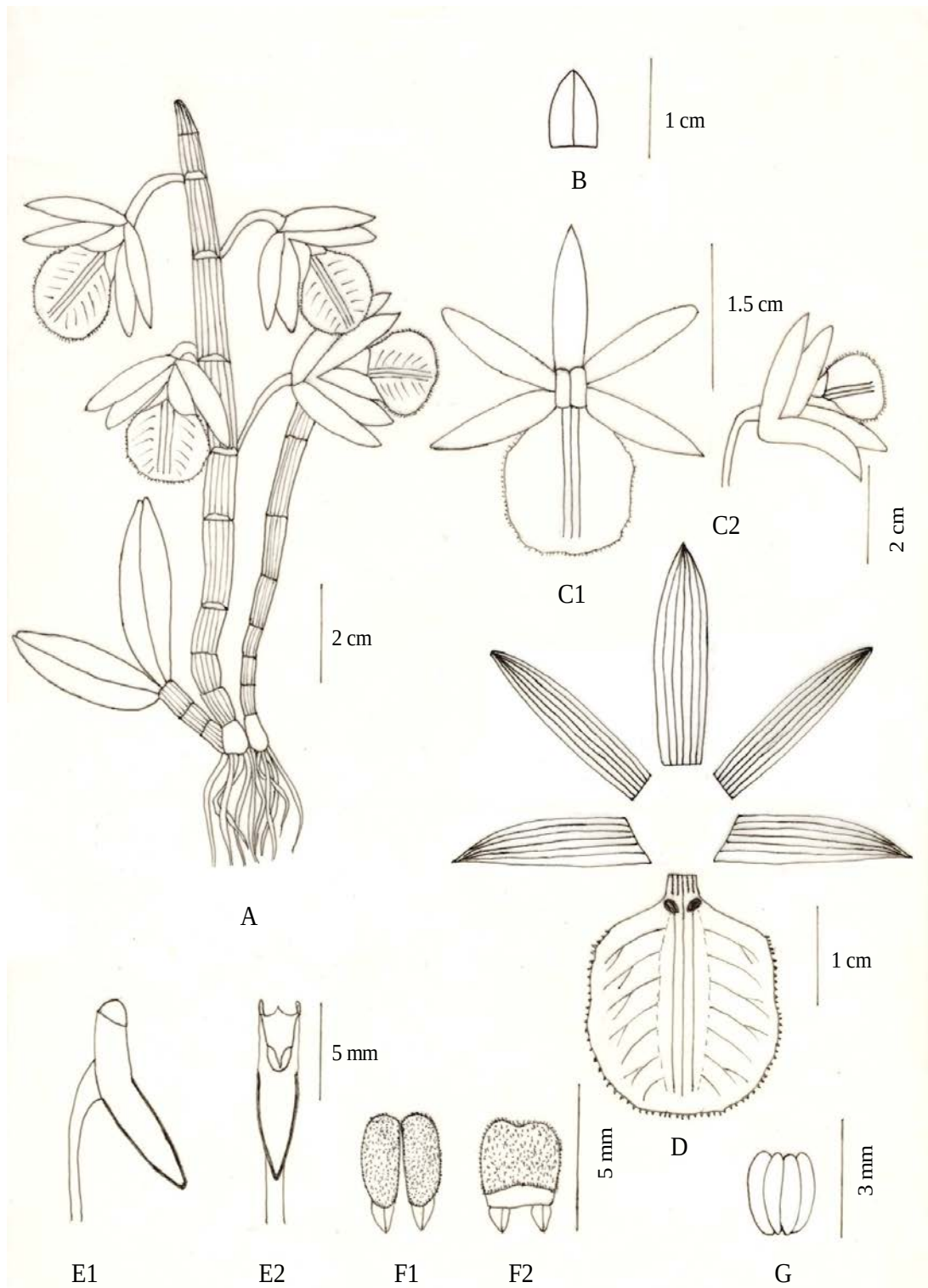


Fig. 37. *Dendrobium polyanthum* Wall. ex Lindl.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Ventral view F2: Dorsal view; G: Pollinia.

Dendrobium transparens Wall. ex Lindl., Gen. Sp. Orch. Pl. (Lindl.) 1: 79 (1830).

Type: Nepal, Wallich, # 2008A (Isotype: E). Appendix II S.

Herb, epiphytic, 24-40 cm tall. **Stem** erect, slender, terete, 0.7- 1.2 cm thick, swollen at nodes, internodes covered with leaf sheaths, internodes swollen at middle than at base and apex, internode 2.0-2.5 cm long, sheath fibrous at old, 4-6 leaved. **Leaves** distichous, deciduous, withered while flowering, linear-lanceolate, recurved, apex acute and oblique, membranous, 5.0-10.5 cm x 1.5-2.0 cm. **Inflorescence** axillary raceme, borne on old leafless stem, 2-3 flowers at nodes, erect, peduncle attenuate, 0.1 cm long, sheathed. **Flowers** bracteate, borne in pair on leafless stem, short-lived, fragrant, pedicel pink, 3.5 cm long, white with pink flooded, 3.4 cm across. **Bract** lanceolate, acute, scarious, much shorter than stalked ovary, 5-veined, 1.1 cm x 0.7 cm. **Sepals** dorsal sepal lanceolate, obtuse, 5-veined, 3.2 cm x 0.5 cm, lateral sepals lanceolate, acuminate, 5-veined, 3.3 cm x 0.5 cm, mentum short, conical, blunt, 1.3 cm x 0.3 cm. **Petals** oblong, white flushed with pink, obtuse, 5-veined, 3.3 cm x 1.3 cm. **Lip** clawed at base, broadly elliptic-obovate, white with purple patch at middle, convolute at apex, minutely emarginate, margin fimbriate, 3-lobed, side lobes broad, erose, convolute, mid-lobe suborbicular, undulate, apex acute, upper surface pubescent, disc hairy with 3 distinct central veins running from base to apex, 3.6 cm x 1.8 cm. **Column** short, erose behind anther, 2 horn like projections at the apex, white with purple patch at lower end, 0.4 cm long, foot narrowed, 1.0 cm long. **Anther** conical, truncate, 2.0 x 1.8 mm. **Pollinia** 4 in 2 pairs, oblong, narrow, 1.0 mm x 0.8 mm (Fig. 39).

Habitat: Ontree trunks of *Castanopsis indica*.

Distribution: Nepal (WCE. 700-2100 m), North East India, Bhutan, Bangladesh and Myanmar (Fig. 38).

Status: Threatened due to deforestation.

Flowering: May-June.

Etymology: Derived from Latin word “transperens” referring to plant having translucent flowers.

Specimens Examined: Appendix III 19.

Notes: *D. transparens* was established by Lindley in 1830. *D. transparens* Lindl. is the type species of section *Eudendrobium* subsection *Transparentia* Rchb.f. (1853).

Schuitman & Adams (2014) treated section *Eudendrobium* under section *Dendrobium*.

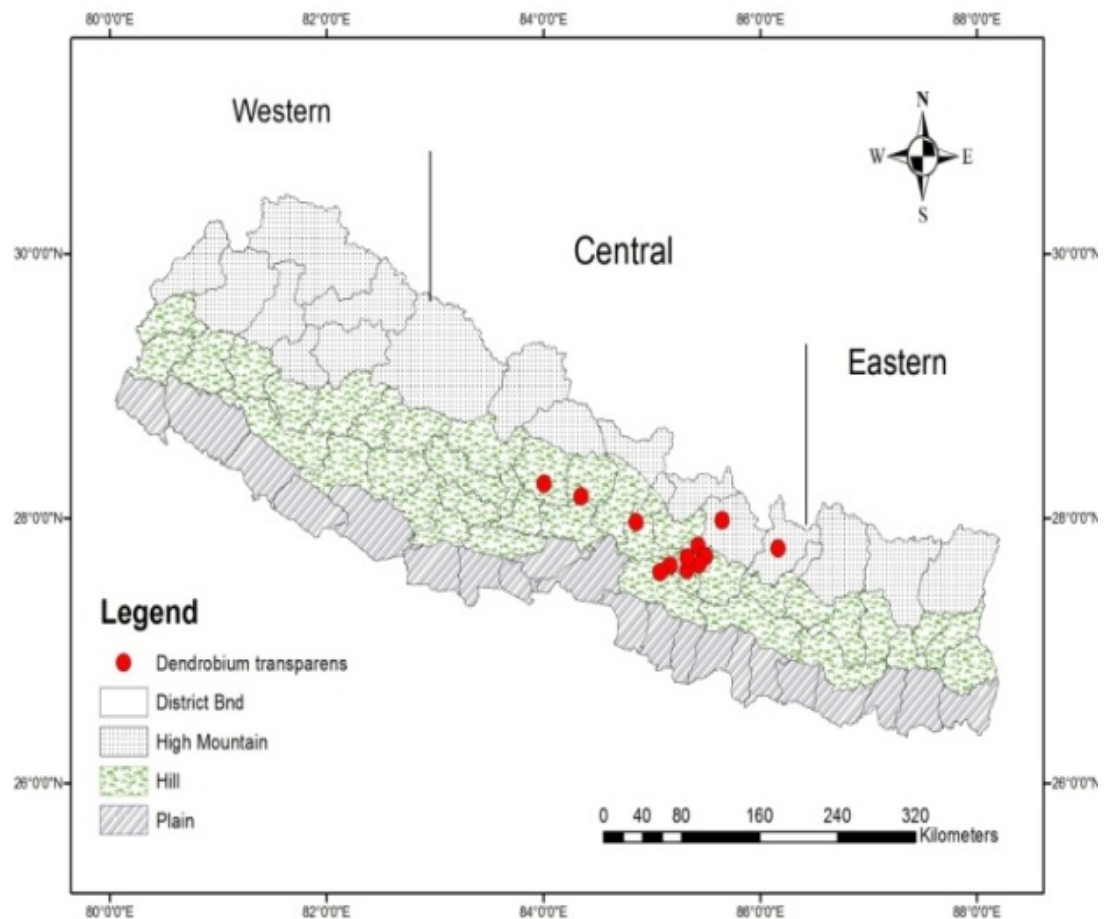


Fig. 38. Distribution map of *Dendrobium transparens* Wall. ex Lindl. in Nepal Himalaya.

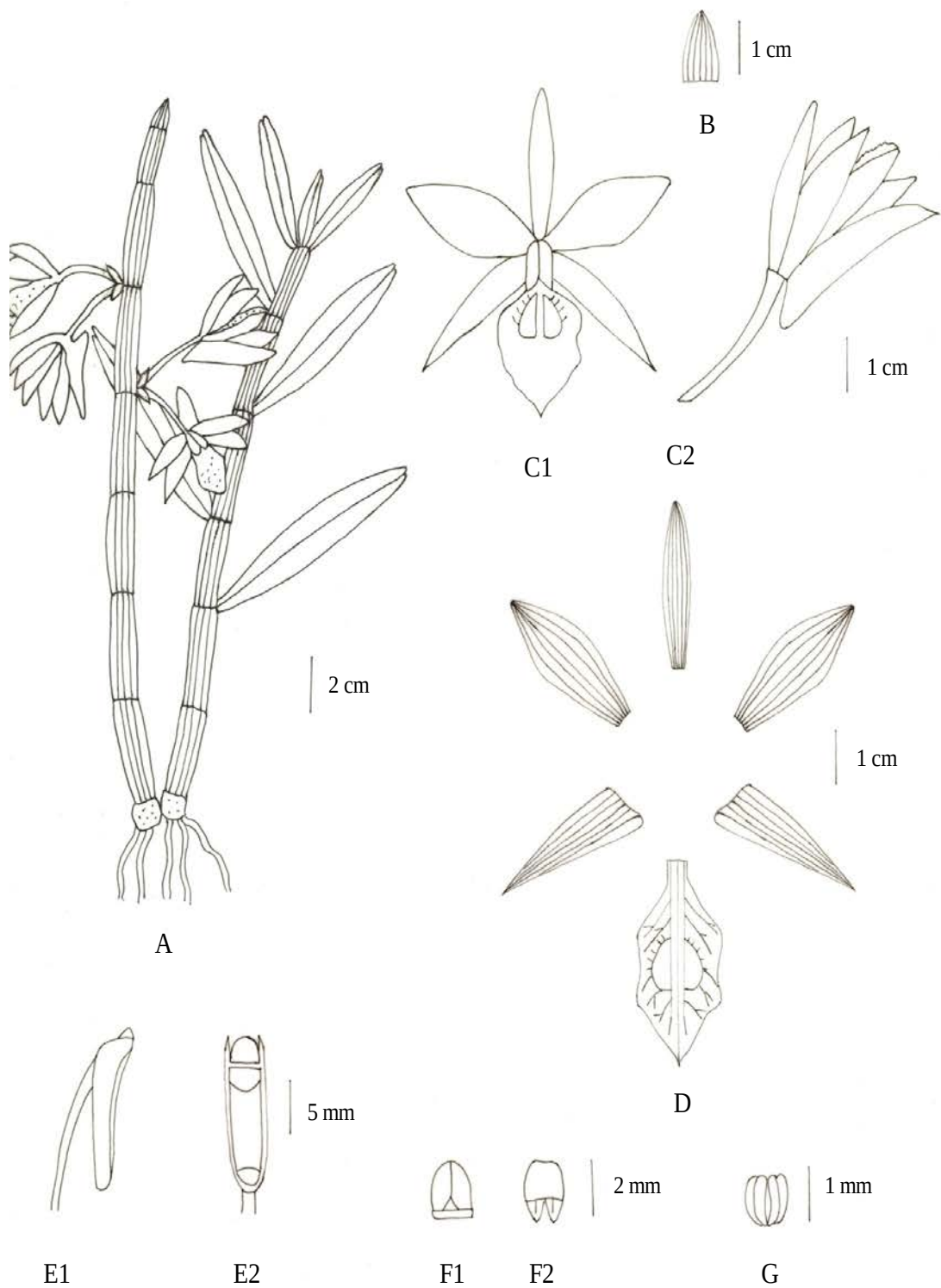


Fig. 39. *Dendrobium transparens* Wall. ex Lindl.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia.

Section IV. *Formosae* (Benth. & Hook.f.) Hook.f., Fl. Brit. Ind. 5: 710 (1890).

Type: *Dendrobium formosum* Roxb. ex Lindl. 1830.

Sectional Characters:

Stems cane-like, clustered with several nodes with few to many leaves mainly at apex, not branching. Leaves long-lived, attached to a tubular sheaths, leaf sheaths densely covered with short, blackish hairs on new shoots, in some species also on leaves, glabrous in a few species of uncertain position. Inflorescence terminal, lateral or axillary, one to few flowered. Flower large, showy, long lasting, generally more than a month, usually white with orange or red markings on the lip, straight to curved mentum forming a spur. Lip trilobed, adnate to column foot, fleshy with longitudinal ridges.

Distribution: About 50 species are distributed in India, Nepal, Bhutan, Bangladesh, Burma, Thailand, China, Laos, Cambodia, Vietnam, Peninsular Malaysia, Sumatra, Borneo, Sulawesi and the Philippines, with centres of diversity in continental southeast Asia and Borneo. In Nepal Himalaya, 2 species *D. formosum* Roxb. ex Lindl. and *D. longicornu* Wall. ex Lindl. are present.

Notes:

Lindley (1859) first recognized species with hairy stems and placed them under subsection *Nigrohirsutae* of his section *Eudendrobium*. Kranzlin (1910) proposed a subgenus *Nigrohirsuta* which is continued by Brieger at sectional level. Schlechter (1912) included the *Nigrohirsutae* in his section *Oxygenianthe* with somewhat broad circumscription. Hooker (1890) defined section *Formosae* which was ascribed on the basis of beautiful flowers. Hooker's section *Formosae* takes priority over *Nigrohirsutae* and *Oxygenianthe*.

Key to species:

- Stems tapering towards tip, young stem clothed in fine black hairs, inflorescence lateral or terminal, 1-5 flowered, flower 8.0-10.0 cm across, lip white with yellow marks, side lobes small, disc with two yellow tuberculate central ridges-----
----- ***D. formosum***
- Stems fractiflex, short coarse deciduous black hairs on stem and slightly on leaves, inflorescence axillary, 1-3 flowered, flower 3.5 cm across, lip white with orange yellow streaks, disc with a broad central ridge from base to apex-----
----- ***D. longicornu***

Dendrobium formosum Roxb. ex Lindl. in N. Wallich, Pl. Asiat. Rarior. 1: 34, t. 39 (1830).

Type: Nepal, Wallich# s.n. (Holotype: BM). Appendix II T.

Herb, epiphytic, 18-21 cm high. **Stem** stout, erect, terete, young stem clothed in fine black hairs, sheathed, tapering towards tip, 2.7-3.5 cm thick, noded, internodes swollen at middle than at base and apex, internode 1.8-2.0 cm long. **Leaves** oblong-elliptical, distichous, sessile, coriaceous, clustered at the apex and taper to an unequally notched apex, obtuse, tubular leaf sheath below, texture smooth, margin crenulate, 5.5-8.0 cm x 2.0-2.8 cm. **Inflorescence** terminal or lateral, borne at nodes near the apex of leafy stem, raceme with 1-5 flowers, erect, peduncle sheathed, 4-4.5 cm long, sheaths funnel shaped, 0.4 cm. **Flower** bracteate, white with attractive yellow inner lip, showy, fragrant, 8-10 cm across, pedicel with ovary 5.5 cm long. **Bract** ovate, much shorter than the ovary, subacute, sheathing, 5-veined, 5.0 mm x 2.0 mm. **Sepals** subequal, dorsal sepal erect, elliptic-oblong, slightly concave, subacute, 7-veined, 4.2 cm x 1.2 cm, lateral sepals oblong-lanceolate, subfalcate, acute, keeled, spreading, 7-veined, 4.0 cm x 1.6 cm, mentum conical, half as long as dorsal sepal, 2 cm long. **Petals** obovate or suborbicular, truncate, cuspidate, margin undulate, larger than sepals, 7-veined, 5.0 cm x 3.3 cm. **Lip** broadly ovate or obcuneate, 3-lobed, white with yellow marks, 6.0 cm x 3.5 cm, side lobes small, rounded, entire, obtuse, mid-lobe dilated, orbicular, retuse, apiculate, minutely mucronate at apex, margin undulate, disc with two yellow tuberculate central ridges. **Column** broad, edge not winged, 0.8 cm long, foot 1.7 cm long, contracted at apex. **Anther** quadrate, 5.5 mm x 4.5 mm. **Pollinia** 4 in 2 pairs, oblong, 2.5 mm x 1.0 mm (Fig. 41).

Habitat: On tree trunks of *Shorea robusta*.

Distribution: Nepal (CE. 500-1000 m), Indonesia, Myanmar, Sri Lanka and Thailand (Fig. 40).

Status: Endangered.

Flowering: June.

Etymology: Derived from Latin word “formosum” referring to the beautiful flower of the plant.

Specimens Examined: Appendix III 20.

Notes: *D. formosum* was described by Lindley in 1830. It is the largest flowered species of *Dendrobium*. This species is of high ornamental values because of beautiful flowers. *D. formosum* and Bornean *D. spectatissimum* have largest flowers in subtribe Dendrobiinae

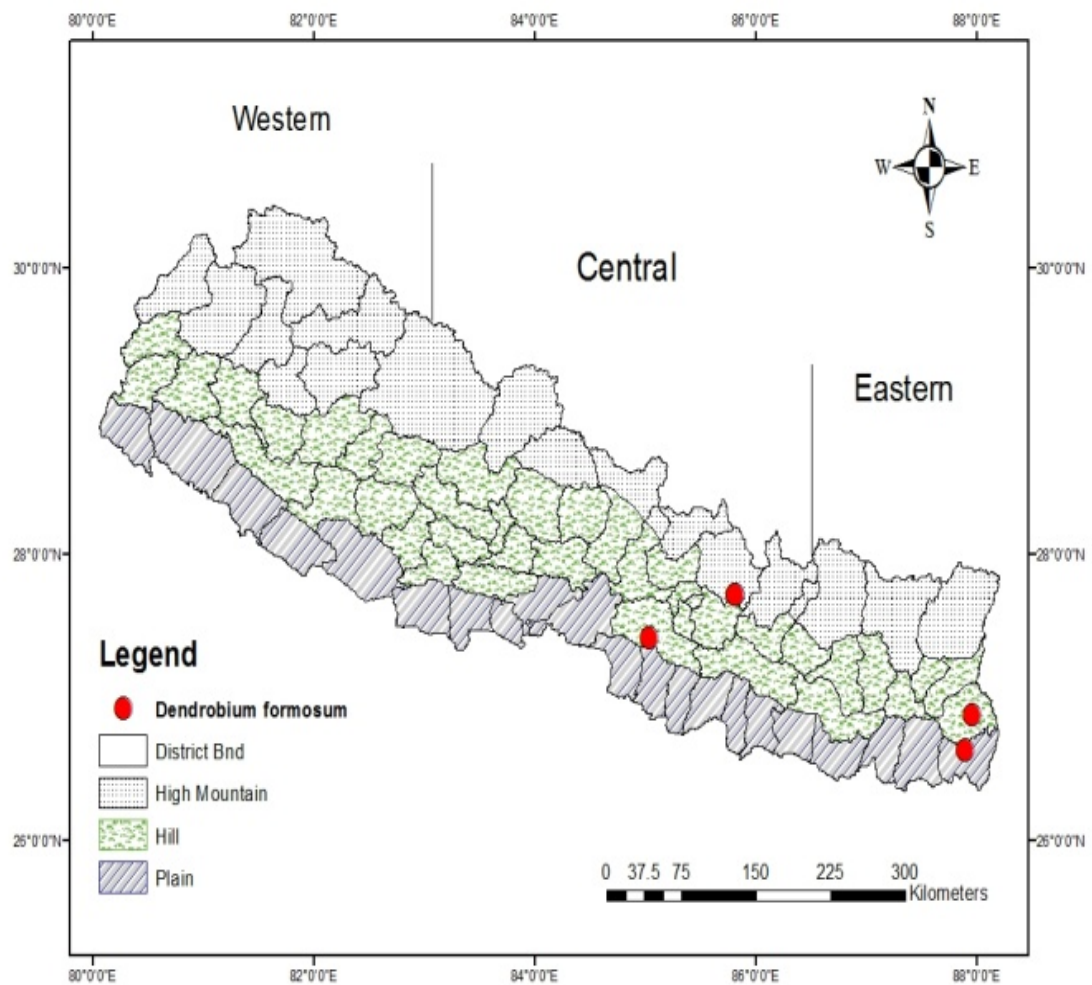


Fig. 40. Distribution map of *Dendrobium formosum* Roxb. ex Lindl. in Nepal Himalaya.

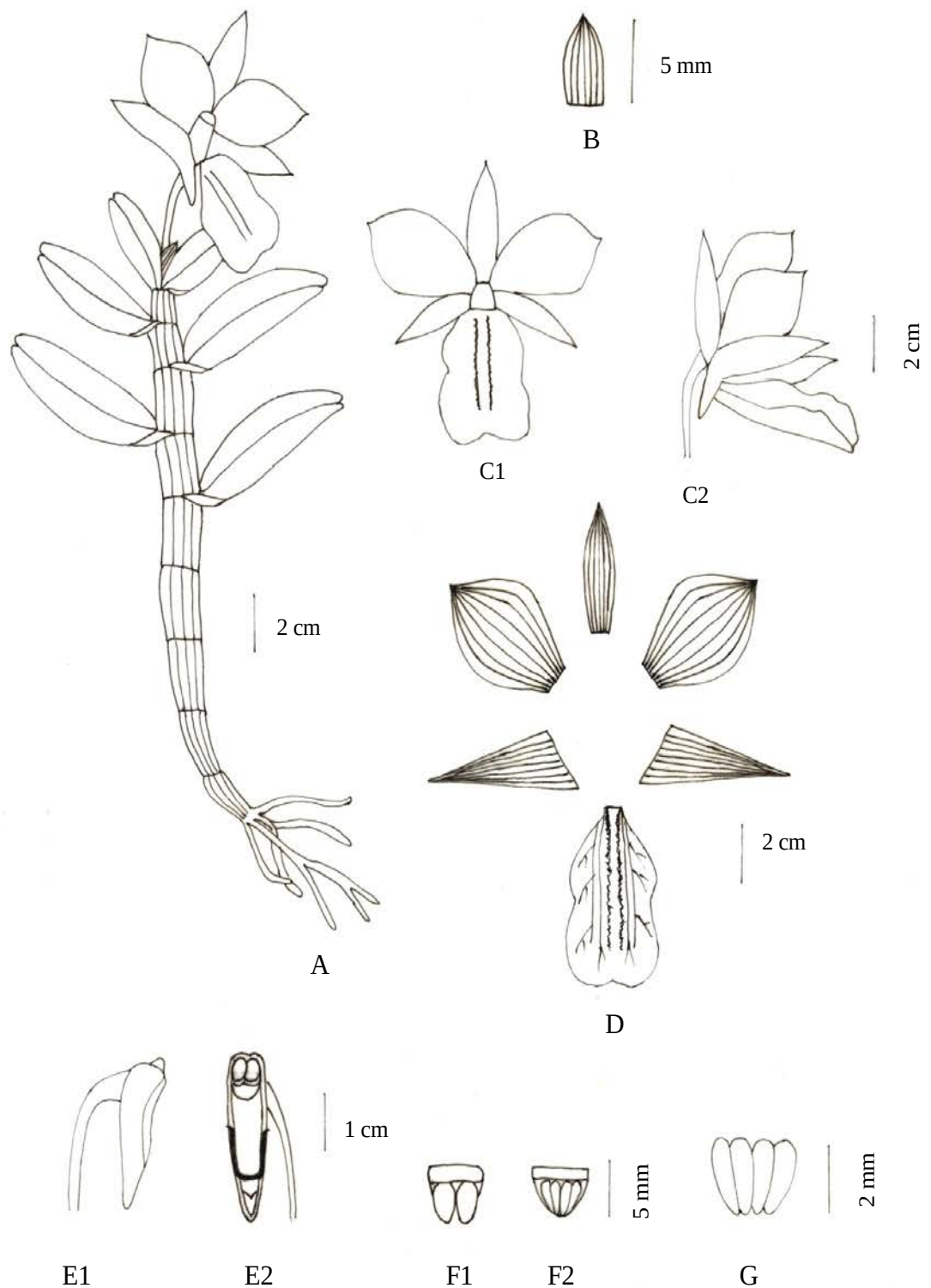


Fig. 41. *Dendrobium formosum* Roxb. ex Lindl.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia.

Dendrobium longicornu Lindl., Edward's Bot. Reg. **16**: t 1315 (1830).

Type: Nepal, Wallich, # 1997 (Syntype: K). Appendix II U.

Herb, epiphytic, 13-36 cm high. **Stem** erect, weakly zigzag, tufted, minutely sulcate covered by short coarse deciduous black hairs, 1.5-1.8 cm thick, unbranched with many nodes, sheathed, internodes swollen at middle than at base and apex, internode 2.5-3.0 cm long. **Leaves** linear-lanceolate, distichous, coriaceous, slightly hairy on both surfaces, obliquely acute, apex obliquely bifid, 4.0-6.0 cm x 0.7-1.6 cm. **Inflorescence** terminal or axillary raceme, borne on leafy stem, raceme with 1-3 flowered, erect, peduncle short, 5 mm long, sheathed, sheaths overlapping, membranous, 2.0 x 1.5 mm. **Flowers** bracteate, lateral or terminal, waxy, longlasting, white, lip with orange yellow, pendulous, facing downward, pedicel with ovary 2.5 cm, fragrant, 3.5 cm across. **Bract** ovate-lanceolate, acute, concave, hairy abaxially, 5-veined, 1.5 cm x 0.5 cm. **Sepals** dorsal sepal ovate-lanceolate, acuminate, keeled, 7-veined, 2.5 cm x 0.7 cm, lateral sepals adnate to form a long spur-like mentum, lanceolate, acuminate, keeled, recurved, 7-veined, 5.5 cm x 1.0 cm, mentum funnel shaped, straight (spur-like). **Petals** linear-lanceolate, acute, 3-veined, 2.5 cm x 0.5 cm. **Lip** white streaked orange yellow, 3-lobed, rhombic, broadly triangular when spread out, a broad ridge running along its centre from the base to the apex, side lobes rounded, more or less truncate, margin slightly wavy, boldly nerved with broad erose apices, mid-lobe small, sub-orbicular, fimbriate, disc with a broad central ridge from base to mid-lobe ending into 4 branches, 5.1 cm x 2.3 cm. **Column** with 2 stelidia at apex, short, 4mm long, foot broad at base and tapering towards apex, attenuate, 2.8-3.2 cm long. **Anther** with truncate lip, fringed, 3.3 mm x 2.3mm. **Pollinia** 4 in 2 pairs, oblong-elliptic, 2.0 mm x 1.4 mm (Fig. 43).

Habitat: On tree trunk of *Quercus semicarpifolia*.

Distribution: Nepal (CE. 1300-2900 m), India, Bhutan, China and Myanmar, Vietnam (Fig. 42).

Status: Endangered.

Flowering: September - November.

Etymology: Derived from Latin word "longicornu" means long horn referring the plant having long horned flower.

Specimens Examined: Appendix III 21.

Notes: The literature study about protologue of *D. longicornu* Lindl. revealed that the actual protologue is Bot. Reg. 16: t. 1315, 1830 and not Gen. and Sp. Orchid. Pl. 80: 1830 as mentioned and followed in recent literatures (Pearce and Cribb, 2002 and Wood, 2006). *D. longicornu* is closely related to *D. wattii* (Hook.f.) Rchb.f. and *D. infundibulum* Lindl. Schelpe considered *D. wattii* to be conspecific with *D. infundibulum*. These species along with *D. cariniferum* Rchb.f. are closely allied. To resolve the taxonomy, further work is required.

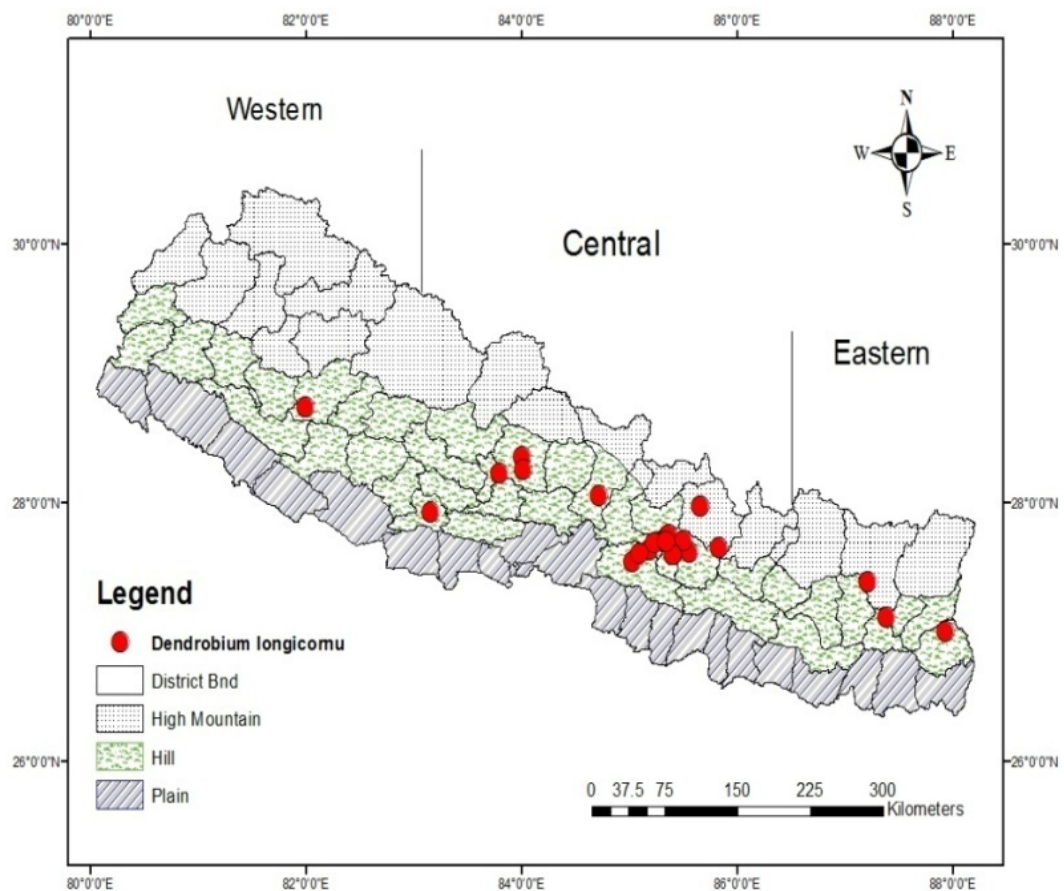


Fig. 42. Distribution map of *Dendrobium longicornu* Lindl. in Nepal Himalaya.

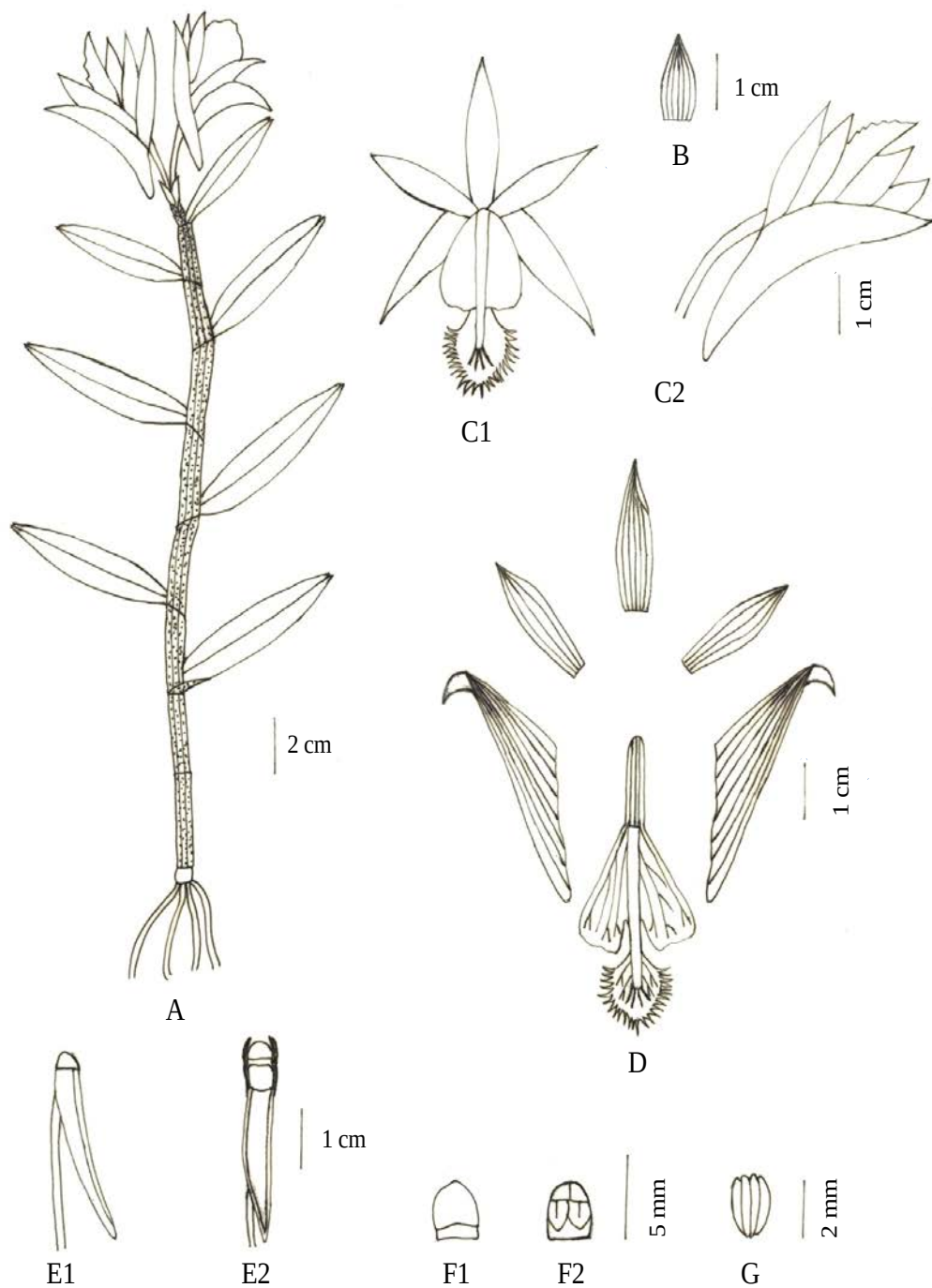


Fig. 43. *Dendrobium longicornu* Lindl.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia.

Section V. *Sarcopodium* Benth. & Hook. f., Gen. Pl., 3, 499 (1883).

Type: *Dendrobium amplum* Lindl. in N. Wallich, Pl. Asiat. Rar. 1: 25 (1830).

Sectional Characters:

Root glabrous or verrucose. Rhizome creeping or climbing with well-spaced, ovoid, ellipsoidal or oblong pseudobulbs. Pseudobulb of one internode, springing singly from a stout creeping rhizome, one to two fleshy distal leaves. Leaves coriaceous, without tubular sheaths at base, opposite, from the apex of pseudobulb, persistent. Flower solitary from between the leaves, large, stellate, mentum not spurlike, rounded. Lip trilobed, attached to apex of column foot with few calli or interrupted ridges basally.

Distribution: About 38 species are distributed in Nepal, India, Bhutan, Burma, Thailand, China, Laos, Vietman, Taiwan, Peninsular Malaysia, Borneo, Sumatra, Java and the Philippines. In Nepal Himalaya, 3 species *D. amplum* Lindl., *D. fuscescens* Griff. and *D. rotundatum* (Lindl.) Hook. f. are present.

Notes: In 1883, Bentham and Hooker established section *Sarcopodium* of genus *Dendrobium* which was accepted and followed nowadays. The type species of section *Sarcopodium* is *Dendrobium amplum* Lindl.

Lindley (1850) proposed the name *Sarcopodium* for a group of plants. Among group of plants, *Epigeneium amplum* the only survivor becomes the type and other species have been reclassified. Hooker (1890) did not accept *Sarcopodium* as a genus separate from *Dendrobium*. Kranzlin (1910) also accepted Lindley (1850) concept. Schlechter (1912) reclassified *Sarcopodium* which then included only a few Himalayan and Phillipine species, as a section in *Dendrobium*. In 1932 Gagnepain established a new genus *Epigeneium* in which he placed four taxa. The type species was *Dendrobium fargesii*. Tang & Wang (1951) transferred these four taxa to *Sarcopodium*. Hawkes (1965) unacquainted of Tang & Wang's paper found that *Sarcopodium* Lindl. was a later homonym and replaced it with a new name *Katherinea* for Lindley's *Sarcopodium*. Summerhayes (1957) accepted Tang & Wang's findings and found that Gagnepain' generic epithet must have priority over *Katherinea*. *D. fargesii* takes place as type species of genus. Garay and G. Romero's (1999) sections of *Epigeneium* as section *Katherinea* and section *Racemosus* were treated as synonyms of section *Sarcopodium* of genus *Dendrobium* by Schuitman & Adams (2014).

Key to species:

- 1a. Flower 7.5 cm across, midlobe of lip subrhomboid, disc with 3 parallel mesial ridges ----- ***D. amplum***
- 1b. Flower 3.4-5.0 cm across, midlobe of lip suborbicular to subreniform, disc with 3 crenulate lamellae, a triangular thickened keel ----- 2
- 2a. Flowers 5.0 cm across, midlobe of lip suborbicular, disc with 3 crenulate lamellae between side lobes ----- ***D. fuscescens***
- 2b. Flowers 3.4 cm across, midlobe of lip subreniform, disc with a triangular thickened keel ----- ***D. rotundatum***

Dendrobium amplum Lindl. in N. Wallich, Pl. Asiat. Rar. 1: 25 (1830).

Type: Nepal, Wallich, # 2001 (*Dendrobium angulatum* Lindl., Syntype: K).

Appendix IIV.

Epigeneium amplum (Lindl.) Summerh., Kew Bull. 12: 260 (1957).

Herb, epiphytic, 60.0-64.0 cm high. **Rhizome** stout, creeping, branched, 0.6-0.8 cm thick, covered with sheaths, noded, internodes 3.0-5.5 cm long. **Pseudobulb** borne apart on rhizome at distances of 8.0-11.0 cm, ellipsoidal or oblong, 3.0-5.5 cm x 2.0-2.2 cm, half covered by large scarious sheaths, 2.0-4.0 cm long. **Leaves** two from one point, oblong or oblong-elliptic, 9.0-18.0 cm x 2.2-5.0 cm, glabrous, acute, coriaceous, notched at apex, petiole 2.0 cm, many veined. **Inflorescence** terminal raceme with a solitary flower arises in between leaves, shorter than leaves, erect, peduncle 2.0 cm long, enclosed in two sheaths, sheath brown, papery, 4.0 cm x 1.0 cm. **Flowers** bracteate, yellowish brown, lip deep purple with bronze edges, profusely spotted and blotched with dark brown, 7.5 cm across, pedicel with ovary 5.0 cm long. **Bract** ovate-oblong at the base of ovary, large, scarious, acute, 5-veined, 1.7 cm x 0.5 cm. **Sepals** unequal, dorsal sepal lanceolate, apex acuminate, 10-veined, 4.7 cm x 0.7 cm, lateral sepals lanceolate with broad bases, falcate, apex acuminate, 10-veined, 4.6 cm x 0.7 cm, mentum short, conic. **Petals** linear-lanceolate, apex acute, wide spreading, 5-veined, 4.8 cm x 0.3 cm. **Lip** pandurate in outline, 3-lobed, side lobes short, rounded, brown spotted, obtuse, margin entire, mid-lobe sub-rhomboid, mucronate, recurved, dark purple with bronze edges, crenulate with 3 parallel mesial ridges and strong branching nerves extending to apex, space between side lobes (disc) with three lamellae, the outer two having an erect tooth at their bases, the middle one

is shorter and toothless, 2.7 cm x 1.7 cm. **Column** straight with purple spots, sides thickened, involute at the anterior end, 1.5 cm long, foot at right angle to column, 1.4 cm long. **Anther** oblong, yellow, emarginate at apex, 3.0 mm x 2.5 mm. **Pollinia** 4 in 2 pairs, oblong, waxy, 2.4 mm x 2.0 mm (Fig. 45).

Habitat: Ontree trunks of *Schima wallichii*.

Distribution: Nepal (CE. 1300-2100 m), Bhutan, China, North East India, Myanmar, Thailand and Vietnam (Fig. 44).

Status: Threatened due to deforestation.

Flowering: September - November.

Etymology: Derived from Latin word “amplum” meaning large and spacious referring to plant having large and spacious flowers.

Specimens Examined: Appendix III 22.

Notes: *Epigeneium amplum* was coined by Summerhayes (1957). The genus *Epigeneium* was condensed into *Dendrobium* on the basis of molecular analysis (Schuitman & Adams, 2014) and the name *E. amplum* was changed into *D. amplum*.

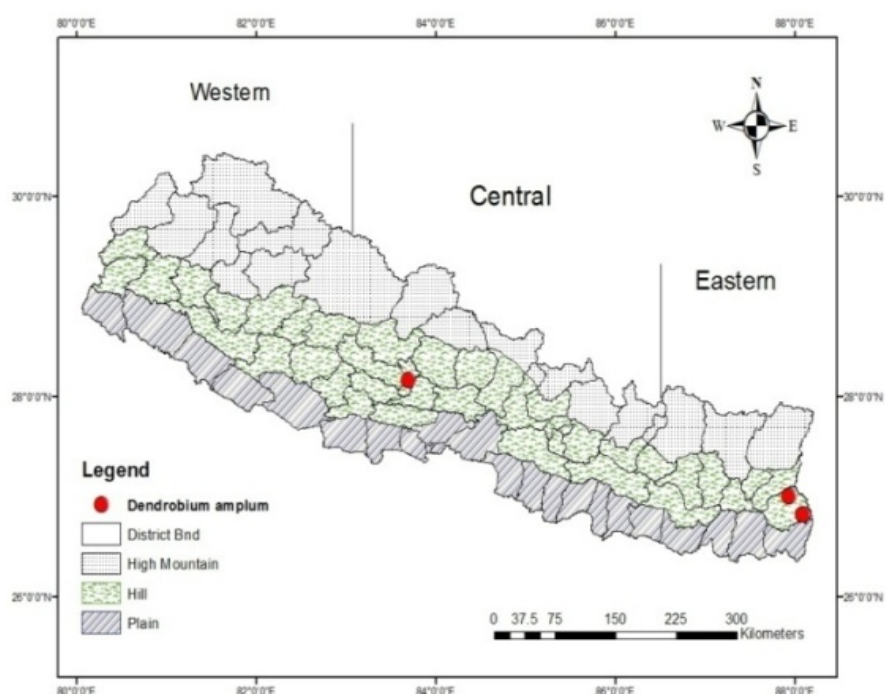


Fig. 44. Distribution map of *Dendrobium amplum* Lindl. in Nepal Himalaya.

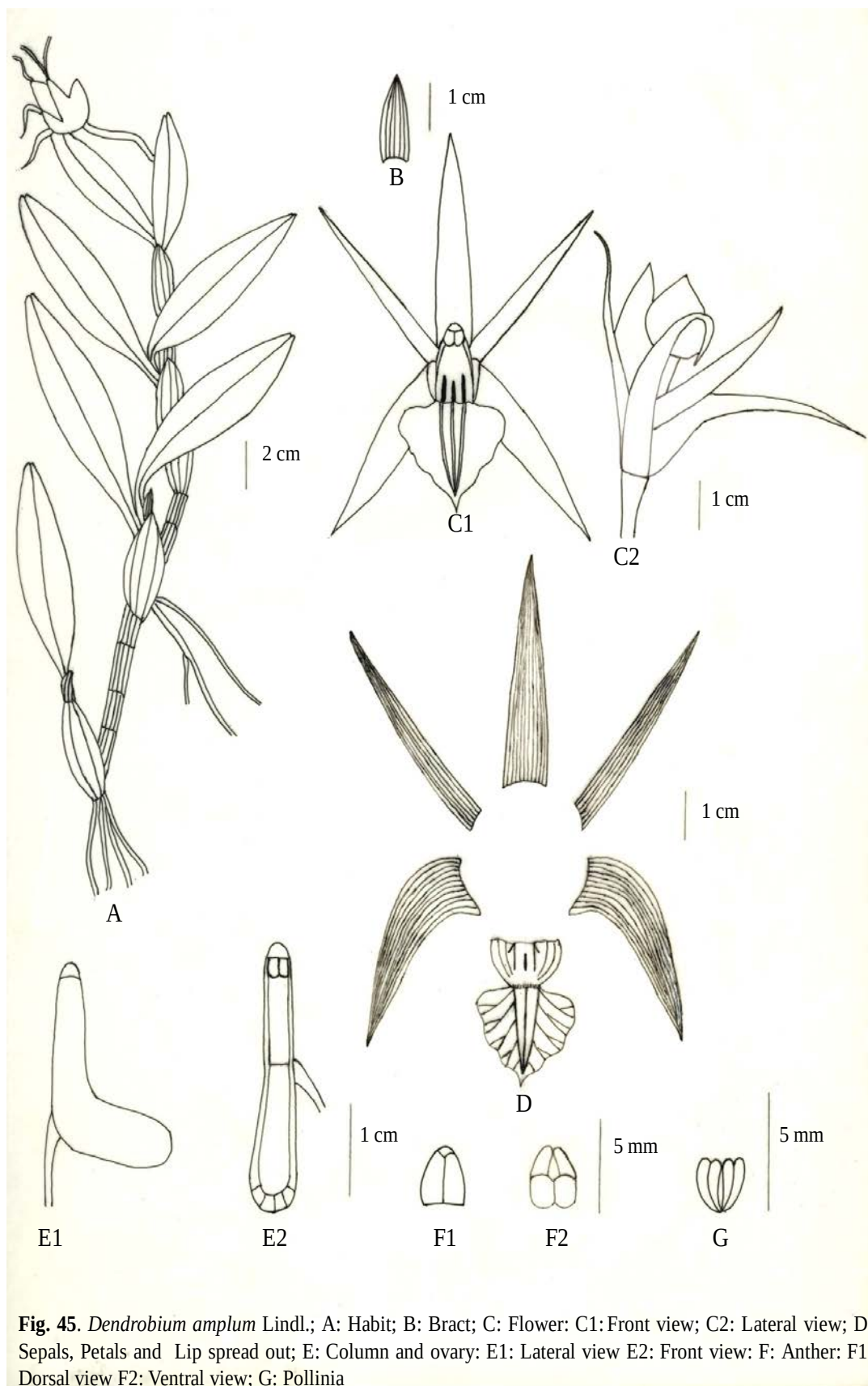


Fig. 45. *Dendrobium amplum* Lindl.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia

Dendrobium fuscescens Griff., Not. Pl. Asiat. 3: 308 (1851).

Type: India, Griffith, # 1123 (Holotype: K, K000883989). Appendix II W.

Epigeneium fuscescens (Griff.) Summerh., Kew Bull. 12: 262 (1957).

Herb, epiphytic or lithophytic, 42-46 cm high. **Rhizome** creeping, pendant, branched, woody, 0.2-0.4 cm thick, covered with overlapping sheaths, noded, 3.0-4.0 cm long. **Pseudobulb** borne apart on rhizome at distances of 5.0-8.0 cm, cylindric-ovoid, 3.0-4.0 cm x 0.8-1.2 cm, 3-4 scarious, close sheaths present at base of pseudobulb, 3.0-4.0 cm long. **Leaves** two from one point, elliptic-lanceolate, 7.5-9.0 cm x 1.7-2.0 cm, glabrous, coriaceous, obtuse, notched at apex, sessile. **Inflorescence** terminal raceme with a solitary flower arises in between leaves, shorter than leaves, peduncle short, 3.0-4.0 mm long, enclosed in sheaths. **Flowers** bracteate, purplish-brown, 4.5-5.0 cm across, pedicel with ovary 2.5-3.0 cm long. **Bract** ovate-lanceolate, scarious, acute, 5-veined, 1.0 cm x 0.5 cm. **Sepals** subequal, dorsal sepal ovate-lanceolate, apex acuminate, 10-veined, 2.8 cm x 0.8 cm, lateral sepals ovate-lanceolate with broad bases, slightly falcate, apex acuminate, 10-veined, 2.8 cm x 1.0 cm, mentum saccate. **Petals** linear-lanceolate, apex acute, spreading, 5-veined, 2.7 cm x 0.3 cm. **Lip** ovate-oblong in outline, 3-lobed, side lobes oblong, obtuse, margin undulate, mid-lobe sub-orbicular, apex emarginated to minutely mucronate, margin undulate, disc with 3 crenulate lamellae between side lobes, middle lamella shorter, 1.8 cm x 1.6 cm. **Column** wingless, 0.7 mm long, foot long, blunt, curved, 0.9 mm long. **Anther** and **Pollinia** not seen (Fig. 47).

Habitat: Ontree trunks of *Castonopsis* sp.

Distribution: Nepal (E. 600-1800 m), Bhutan, China, North East India (Fig. 46).

Status: Threatened due to deforestation.

Flowering: March - April.

Etymology: Derived from Latin word “fuscus” meaning (swarthy brown) and “escens” meaning (like) referring to flower colour.

Specimens Examined: Appendix III 23.

Notes: Like *D. amplum*, *D. fuscescens* is also accepted name for *E. fuscescens*. *D. fuscescens* was established by Griffith (1851) whereas *E. fuscescens* was established by Summerhayes (1957). This specimen could not be collected from field sites. So this specimen was described from voucher specimen deposited at KATH.

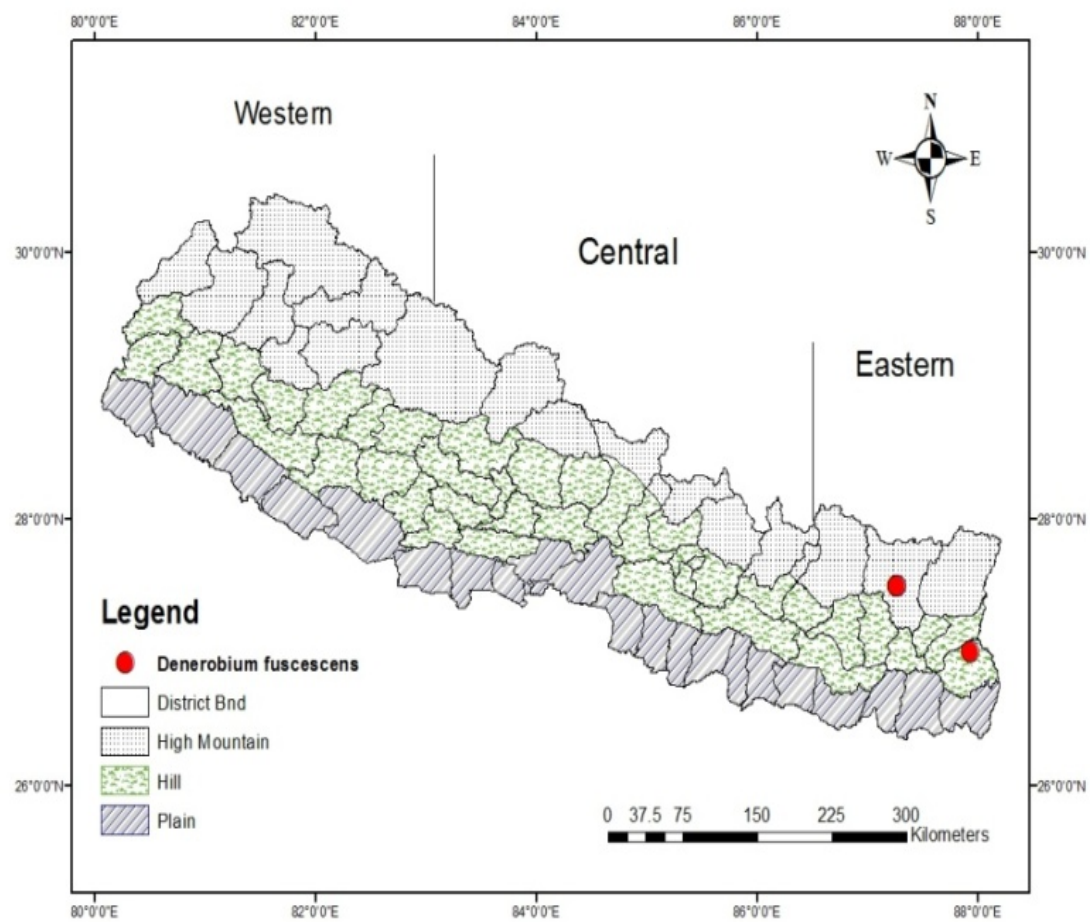


Fig. 46. Distribution map of *Dendrobium fuscescens* Griff. in Nepal Himalaya.

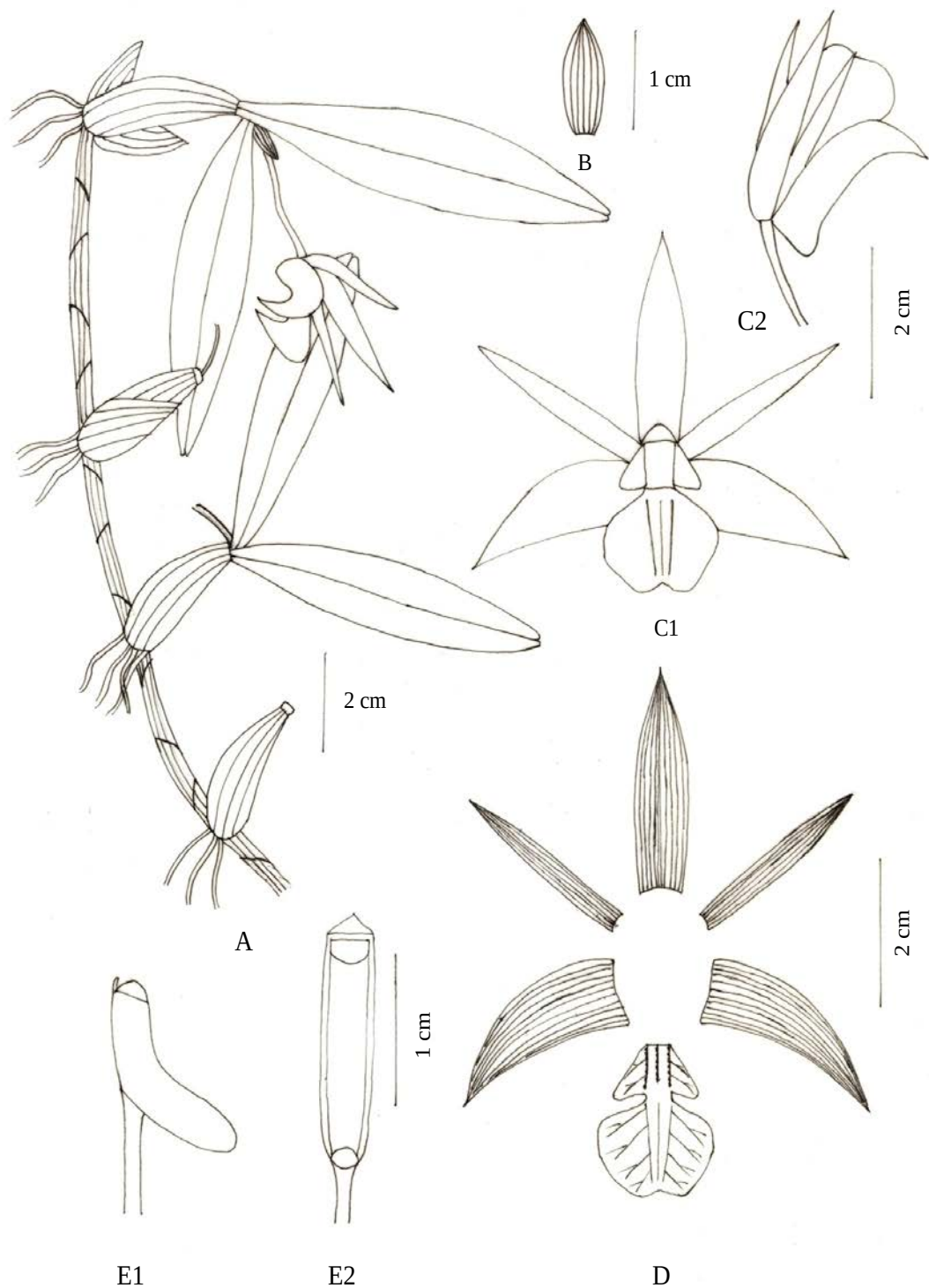


Fig. 47. *Dendrobium fuscescens* Griff.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view.

Dendrobium rotundatum (Lindl.) Hook.f., Fl. Brit. India 5: 712 (1890).

Type: India, Hooker, # s.n. (*Sarcopodium rotundatum* Lindl., Syntype: K).

Appendix IIX.

Epigeneium rotundatum (Lindl.) Summerh., Kew Bull. 12: 264 (1957).

Herb, epiphytic, 40-48 cm high. **Rhizome** creeping, pendant, woody, branched, 4-5 mm thick, covered with brown papery tubular sheaths, noded, 2.5-5.0 cm long. **Pseudobulb** borne apart on rhizome at distances of 2.5-11.5 cm, narrowly ovoid, curved, 2.5-5 x 1.5-2.0 cm, covered by 3 scarious basal sheaths, 1.5-3 x 0.5-1.5 cm, 2 leaved at apex. **Leaves** two from one point, elliptic-oblong, 4.0-13.5 x 1.2-2.8 cm, glabrous, sessile, retuse, coriaceous, many veined. **Inflorescence** terminal raceme with a solitary flower arises in between leaves, erect, peduncle ca. 5.0 mm long, enclosed in large scarious sheaths, 1.5-2.5 x 0.5-0.7 cm. **Flowers** bracteate, pale yellowish brown, lip yellow with brown spots, 3.4 cm across, pedicel with ovary 2.5 cm long. **Bract** ovate, thin, membranous, small, acute, 5-veined, 1.0 cm x 0.6 cm. **Sepals** unequal, dorsal sepal ovate-lanceolate, apex acute, 7-veined, 3.0 cm x 1.0 cm, lateral sepals little broader than dorsal sepal, subfalcate, ovate, apex acute, 7-veined, adnate to column foot, 2.8 cm x 1.3 cm, mentum rounded. **Petals** oblong-lanceolate, apex acuminate, 7-veined, 3.0 cm x 0.8 cm. **Lip** trilobed, obovate-oblong in outline, obtuse, slightly undulate, mid-lobe sub-reniform to obscurely bilobed, with a triangular thickened keel adaxially, apex emarginate, margin thin, undulate, brownish yellow, disc with 3 crenulate lamellae between side lobes, the middle one being much shorter, 1.9 cm x 1.2 cm. **Column** curved, 1.1 cm x 0.5 cm, foot at right angle to column, slightly winged, 0.9 cm x 0.6 cm. **Anther** oblong, creamy yellow, 2.2 mm x 1.9 mm. **Pollinia** 4 in 2 pairs, oblong, 1.8 mm x 1.7 mm (Fig. 49).

Habitat: On tree trunks of *Rhododendron arboreum*.

Distribution: Nepal (E. 1300-2500 m), Bhutan, China, North East India and Myanmar (Fig. 48).

Status: Threatened due to deforestation.

Flowering: March-May.

Etymology: Derived from Latin word “rotundatum” meaning rounded off referring to plant having rounded side lobes of lip.

Specimens Examined: Appendix III 24.

Notes: *D. rotundatum* is accepted name of *E. rotundatum*. *D. rotundatum* was established by Hooker (1851) whereas *E. rotundatum* was established by Summerhayes.

No voucher specimen was deposited at KATH and TUCH. This species has been reported by Banerji and Thapa from East Nepal (1970). In the present study this specimen was collected from Maipokhari, Ilam, East Nepal.

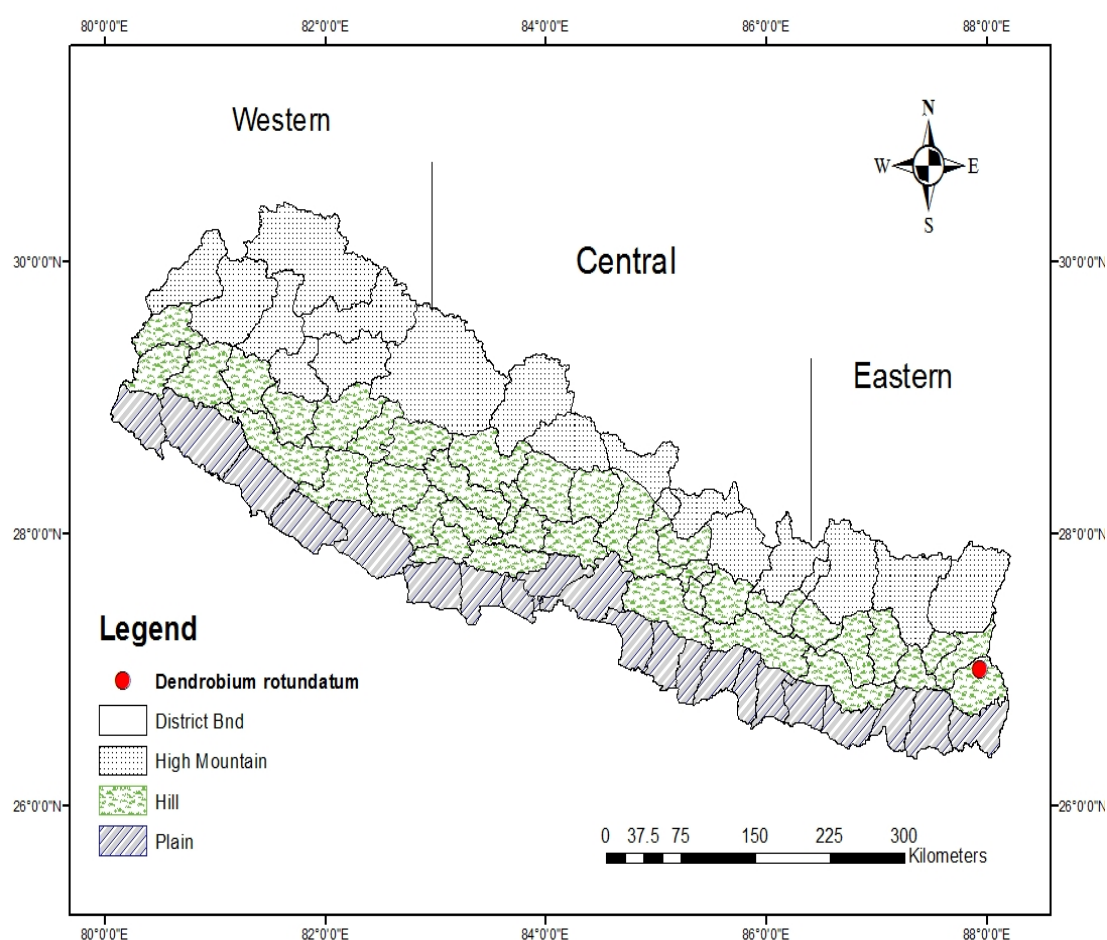


Fig. 48. Distribution map of *Dendrobium rotundatum* (Lindl.) Hook.f. in Nepal.

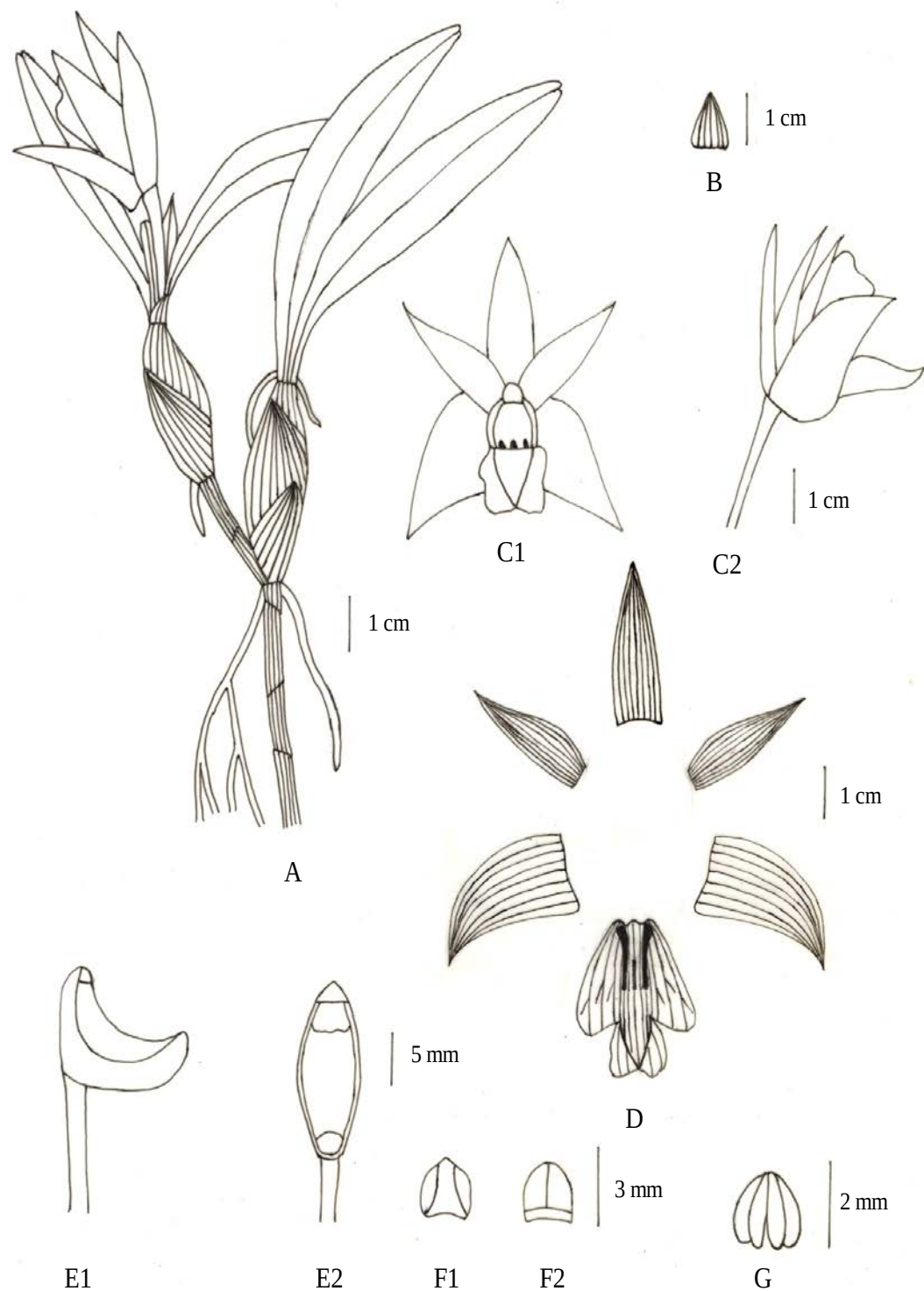


Fig. 49. *Dendrobium rotundatum* (Lindl.) Hook.f.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Ventral view F2: Dorsal view; G: Pollinia.

Section VI. *Stachyobium* Lindl., Edward's Bot. Reg., 30, 55 (1844).

Type: *Dendrobium denudans* D. Don, Prodr. Fl. Nepal: 34 (1825).

Sectional Characters:

Most species small. Stem with pseudobulbs, clustered, fusiform, fleshy, not branching, leafy throughout or with leaves in apical part. Leaves membranous, with tubular sheaths at base, deciduous or persistent. Inflorescence apical or lateral from leafy shoots of current growing season, erect or pendulous, elongate with rachis, few-many flowered. Flower usually small, whitish with green or purplish markings on lip, mentum conical. Lip simple or trilobed, hinged with column-foot, lamellate keel basally or with a flattened rod-shaped callus often lobed at apex, midlobe with undulate margins, sometimes with numerous, clavate appendages.

Distribution: About 44 species are distributed in Sri Lanka, India, Nepal, Bhutan, Burma, China, Thailand, Laos, Cambodia, Vietnam, Pennisular Malaysia, Java and the Lesser Sunda Islands. 5 species of *Dendrobium* viz. *D. darjeelingense* Pradhan, *D. denudans* D. Don, *D. eriiflorum* Griff., *D. porphyrochilum* Lindl. and *D. monticola* P.F.Hunt & Summerh. were reported from Nepal Himalaya.

Notes: Lindley (1844) established the section *Stachyobium* with the species having flowers growing in racemes, including some 32 taxa in his unfinished division of *Dendrobium*. This section is close to the first section *Eudendrobium*. In his more complete system (1851) he maintained this arrangement with same no. of taxa. In the key he defines the section such: "Folia horisontalia. Flores laxe racemosi, mento brevi, petalis conformibus". Later in 1859, he added a further series of taxa.

Bentham & Hooker f. (1883) proposed 6 subsections. Pfitzer (1889) did not mention the sections. Hooker f. (1890) placed 22 Indian taxa under this section. Kranzlin (1910) included Hooker's section *Breviflores* in the section. Brieger (1981) gives subgenus status to *Stachyobium* characterized by racemose inflorescences with several flowers and distinct long scape.

Key to species:

- 1a. Plants with elongate stems ----- 2
- 1b. Plants with cylindrical or elongate pseudobulbs ----- 4

- 2a. Plants 4-15 cm high, deciduous leaves, 8-many flowered, lip trilobed, disc with 3 ridges with triangular apex, margin of sidelobes lacerate ----- ***D. denudans***
- 2b. Plants 7-21 cm long, leaves deciduous or persistent, flowers more than ten, lip trilobed, margin of sidelobes entire or pectinate-serrate ----- 3
- 3a. Plants 20-21 cm long, leaves deciduous, flowers 16-20, lip with 3 keels from base to apex, side lobes margin entire ----- ***D. darjeelingense***
- 3b. Plants 7-12 cm high, leaves persistent, flowers many, lip with a mesial ridge from base to apex, side lobes margin pectinate-serrate ----- ***D. eriiflorum***
- 4a. Plants 2-5 cm high, pseudobulb cylindrical, flowers 7-12, lip simple with 3 obscure ridges of variable lengths from base to apex, margin entire -----
----- ***D. porphyrochilum***
- 4b. Plants 4-6 cm high, pseudobulb elongate, flowers 3-8, lip 3-lobed with irregular, orbicular and triangular apex, margin inciso-serrate ----- ***D. monticola***

Dendrobium darjeelingense Pradhan, Indian Orchids: Guide Identif. & Cult. 2: 336 (1979).

Type: Not seen. This species was described by Pradhan (1979) from Darjeeling, India. Holotype of this species was kept in his personal herbarium and it was destroyed few years back in a fire accident (Pers. commun). Protologue was seen. No synonyms are recorded for this specimen. Later this species was recorded from Nepal by White (1992) (www.eflora.org; Annotated Checklist of the flowering plants of Nepal). This species was again reported from Assam, India by Barbhuiya *et al.* (2012). This constitutes the second collection of species from India. The collection of Barbhuiya *et al.* is the only available material in any Indian Herbarium.

Herb, epiphytic, 20 cm high. **Stem** erect, fusiform or conical, 2.0 cm thick, covered with leaf sheaths from base to apex, unbranched, noded, internode 1.5-2.0 cm long. **Leaves** 10-12, linear-ovoid, distichous, membranous, apex acute, notched unequally, 6.0 cm x 1.2 cm. **Inflorescence** terminal or axillary raceme, erect, from nodes of leafless stem, 16-20 flowered, peduncle sheathed, 1.0-1.5 cm long, rachis 3.0-4.0 cm long. **Flowers** bracteate, small, fragrant, sepals and petals creamy with light greenish tinge, lip and lobes red lined, 1.0 cm across, pedicel with ovary red-purplish, 0.4 cm long. **Bract** small, triangular, acute, 3-veined, 4.0 mm x 1.0 mm. **Sepals** dorsal sepal lanceolate, apex acuminate, margin entire, 3-veined, 8.0 mm x 2.0 mm, lateral sepals

ovate-lanceolate, obliquely curved, apex acute, 5-veined, 8.0 mm x 2.5 mm, mentum short, spur-like. **Petals** oblong-lanceolate, apex acute, 3-veined, entire, 7.0 mm x 1.5 mm. **Lip** 3-lobed, oblong-ovate, 6.0 mm x 3.0 mm at middle, connate with column foot forming mentum, side lobes expanded with triangular front, apex acute, margin entire, midlobe obovate, margin crenulate slightly to undulate, apex acute, incurved, disc with 3 keels from base to apex. **Column** short and broad, 2.5 mm long, foot 4.5 mm long. **Anther** dome shaped, papillose, pilose at front margin, 0.8 mm x 0.7 mm. **Pollinia** 4 in 2 pairs, oblong, yellow, 0.5 mm x 0.2 mm (Fig. 51).

Habitat: On tree trunks of *Shorea robusta*.

Distribution: Nepal (C. 1500-2000 m), India (Darjeeling) (Fig. 50).

Status: Threatened due to deforestation and over exploitation for ornamental plants.

Flowering: October-November.

Etymology: Derived from word Darjeeling, from where type specimen was collected.

Specimens Examined: Appendix III 25.

Notes: This specimen could not be collected from the locality mentioned in voucher specimen (KATH) due to loss of host tree by forest firing in Lamidanda, Makawanpur and other field sites also. So this specimen was described from voucher specimen deposited at KATH.

D. darjeelingense was established by Pradhan (1979). This species is related to *D. eriiflorum* but differing in erect scapes, small flowers, lack of serrations on the lateral lobes and presence of three keeled disc.

This specimen recorded from here varies in habit and stem size than the plant mentioned in protologue. The flowering plant is leafless and stem size is 20.0 cm high while the flowering plant is with leaf and stem size upto 7.5 cm in protologue. There is variation in no. of flowers also. In protologue the plant is with 4-6 flowers per rachis whereas the plant present here is with 16-20 flowers. These variations may be due to different geographical conditions and climatic changes. Flowering period is October to November.

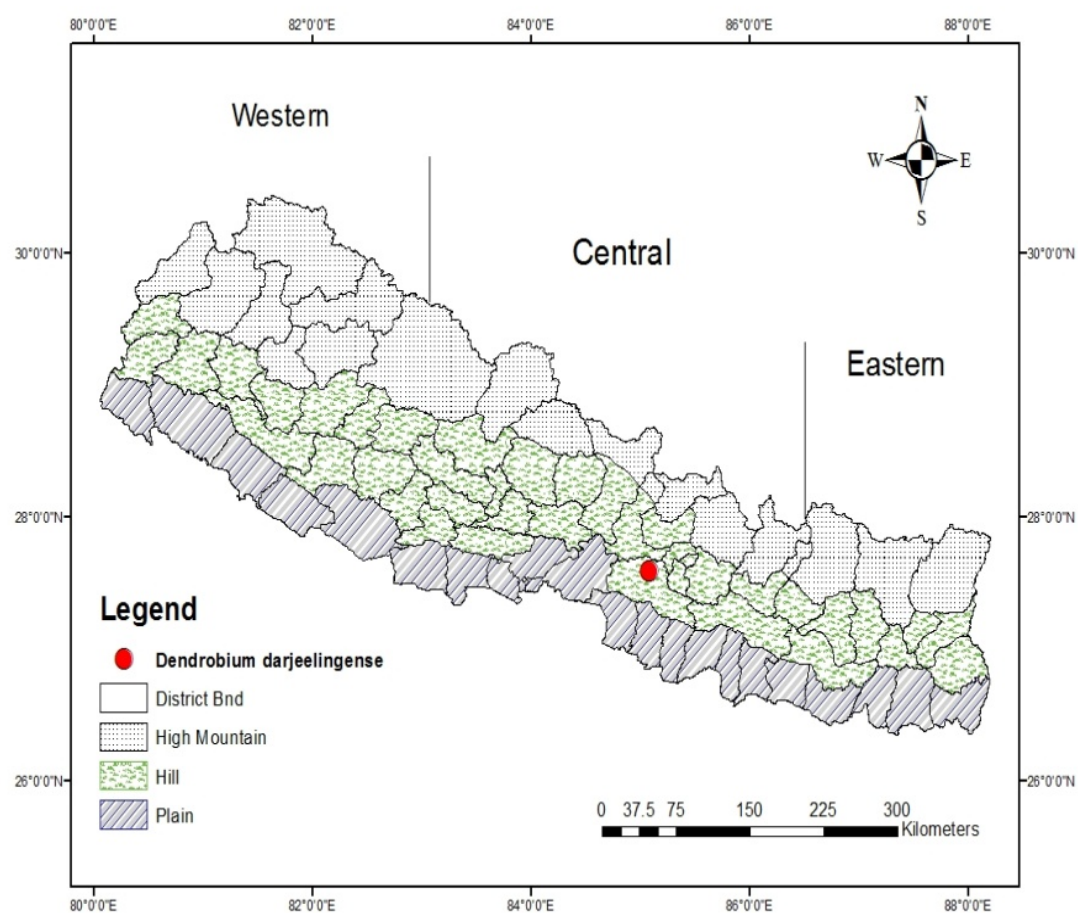


Fig. 50. Distribution map of *Dendrobium darjeelingense* Pradhan in Nepal Himalaya.

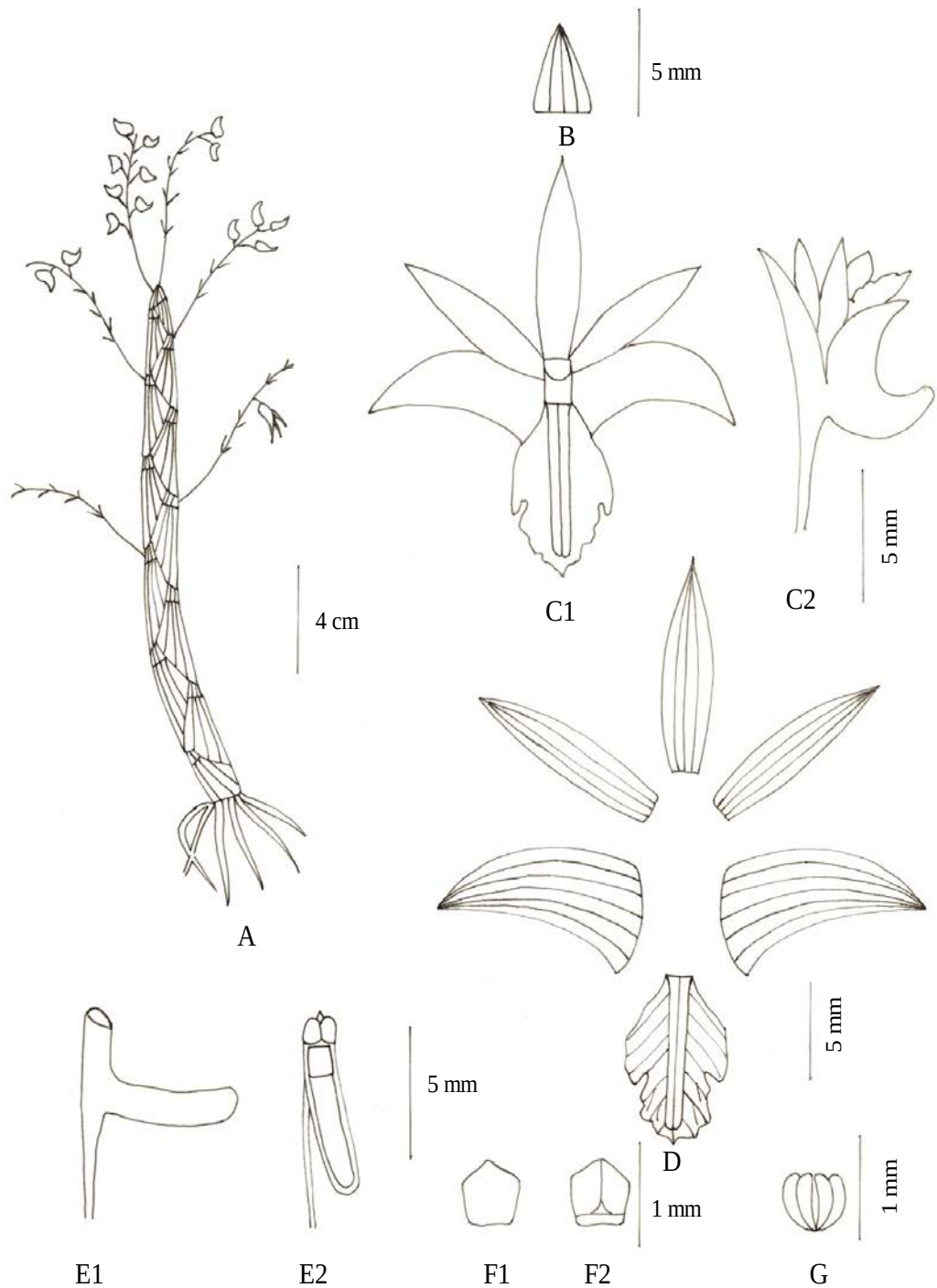


Fig. 51. *Dendrobium darjeelingense* Pradhan; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia.

Dendrobium denudans D. Don, Prodr. Fl. Nepal: 34 (1825); Hooker f., Fl. Brit. Ind. 5: 715 (1890).

Type: Nepal, Wallich, # 2014 (Isotype: GH). Appendix II Y.

Herb, epiphytic, 4-15 cm high. **Stem** suberect, terete, 2.0-2.5 cm thick, covered by leaf sheaths, sheaths tubular, ovate, noded, internode 1.0-2.0 cm long, new growth stem translucent yellowish green and darkening with age to dull gray brown, many leaved, leaves sometimes early deciduous. **Leaves** linear-oblong, distichous, sessile, acute to subacute, obliquely emarginate, jointed from base to apex, deciduous, membranous, 6.0-10.0 cm x 1.0-1.5 cm. **Inflorescence** axillary raceme, leaf-opposed, 8-many flowered, pendulous, rachis 5.0-7.0 cm long, peduncle sheathed, 2.5-3.0 cm long, sheath membranous, 3.0 x 1.0 mm. **Flower** bracteates, lunate in bud, 1.0-2.0 cm across, creamy to pale green, lip with radiating red-purple lines, pedicel and ovary slender, 6.0-9.0 mm long. **Bract** lanceolate, acute, minute, membranous, 1-veined, 3.0 mm x 1.5 mm. **Sepals** subequal, dorsal sepal linear-lanceolate, acuminate, 3-veined, 1.2 cm x 0.25 cm, lateral sepals lanceolate-triangular, falcate, acuminate, 5-veined 1.2 cm x 0.4 cm, mentum broadly conical, deep purple, 2mm long. **Petals** linear-lanceolate, acuminate, 3-veined, 1.3 cm x 0.12 cm. **Lip** 3-lobed, obovate, decurved from base, a band of radiating red-purple lines round its crisped or serrate edges, 1.1 cm x 0.5 cm, sub-quadrate at base (when spread out), side lobes long, narrow, apex acute, margins lacerate, mid-lobe strongly recurved, obovate, apex acute, margins serrate-crisped, disc with an obscurely 3-ridges with a triangular apex ending at mid-lobe. **Column** short, 3 mm long, foot angled to column, curved, concave, hispid, reddish purple, 6 mm long. **Anther** suborbicular, grooved on the upper surface, 1.5 mm x 1.3 mm. **Pollinia** 4 in 2 pairs, oblong, 1.1 mm x 1.0 mm (Fig. 53).

Habitat: On tree trunks of *Schima wallichii*.

Distribution: Nepal (WCE. 1000-2200 m), Bhutan and India (Fig. 52).

Status: Threatened due to deforestation and over exploitation for medicinal value.

Flowering: August-September.

Etymology: Derived from Latin word “denudans” referring plants with stripped stem.

Specimens Examined: Appendix III 26.

Notes: David Don (1825) introduced *D. denudans* from Wallich collection without much description about lip characters in his “Prodromous Flora of Nepal”. The plant

is distinguished by multiple arching, brush-like inflorescences composed of pendant half opened flowers. Flower creamy to pale green, lip with radiating red purple lines.

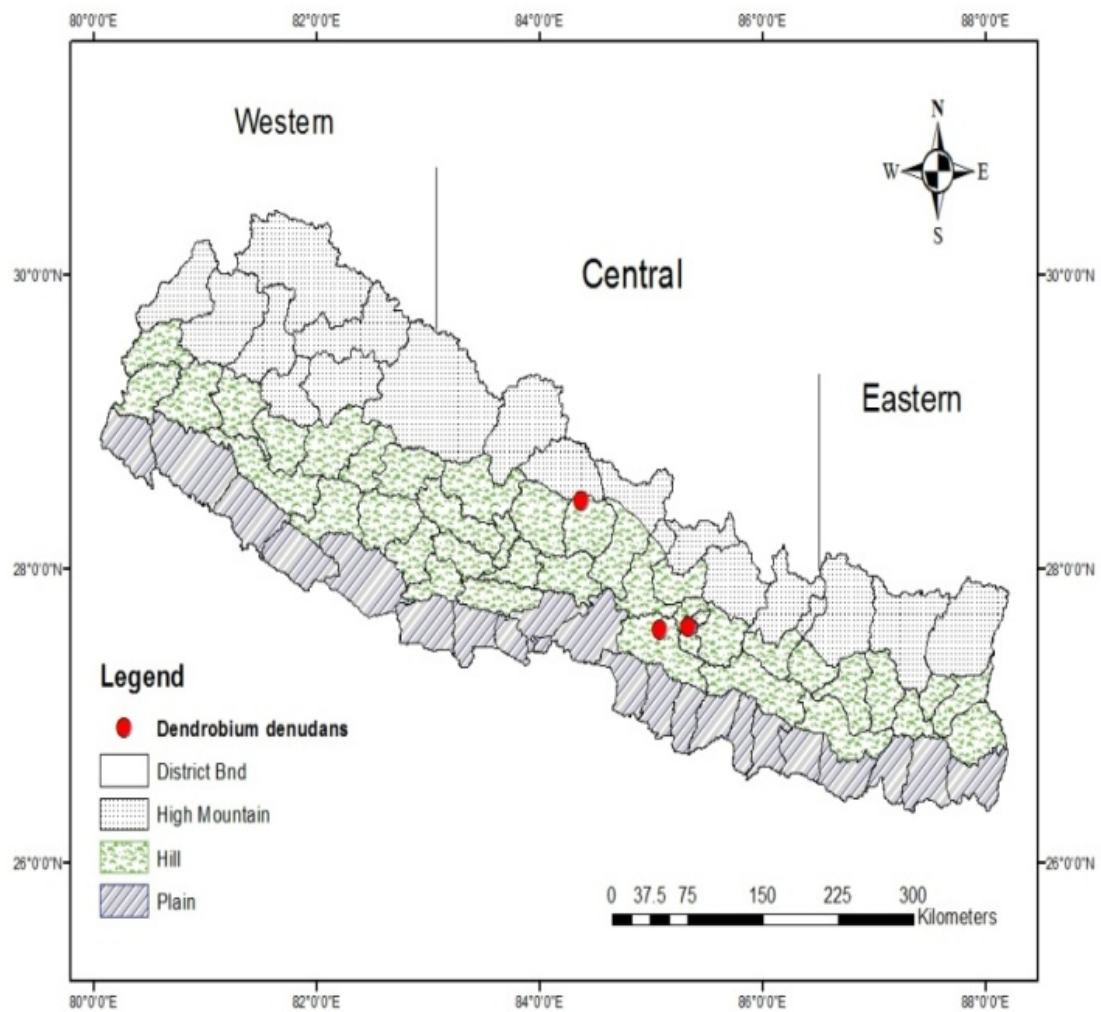


Fig. 52. Distribution map of *Dendrobium denudans* D. Don in Nepal Himalaya.

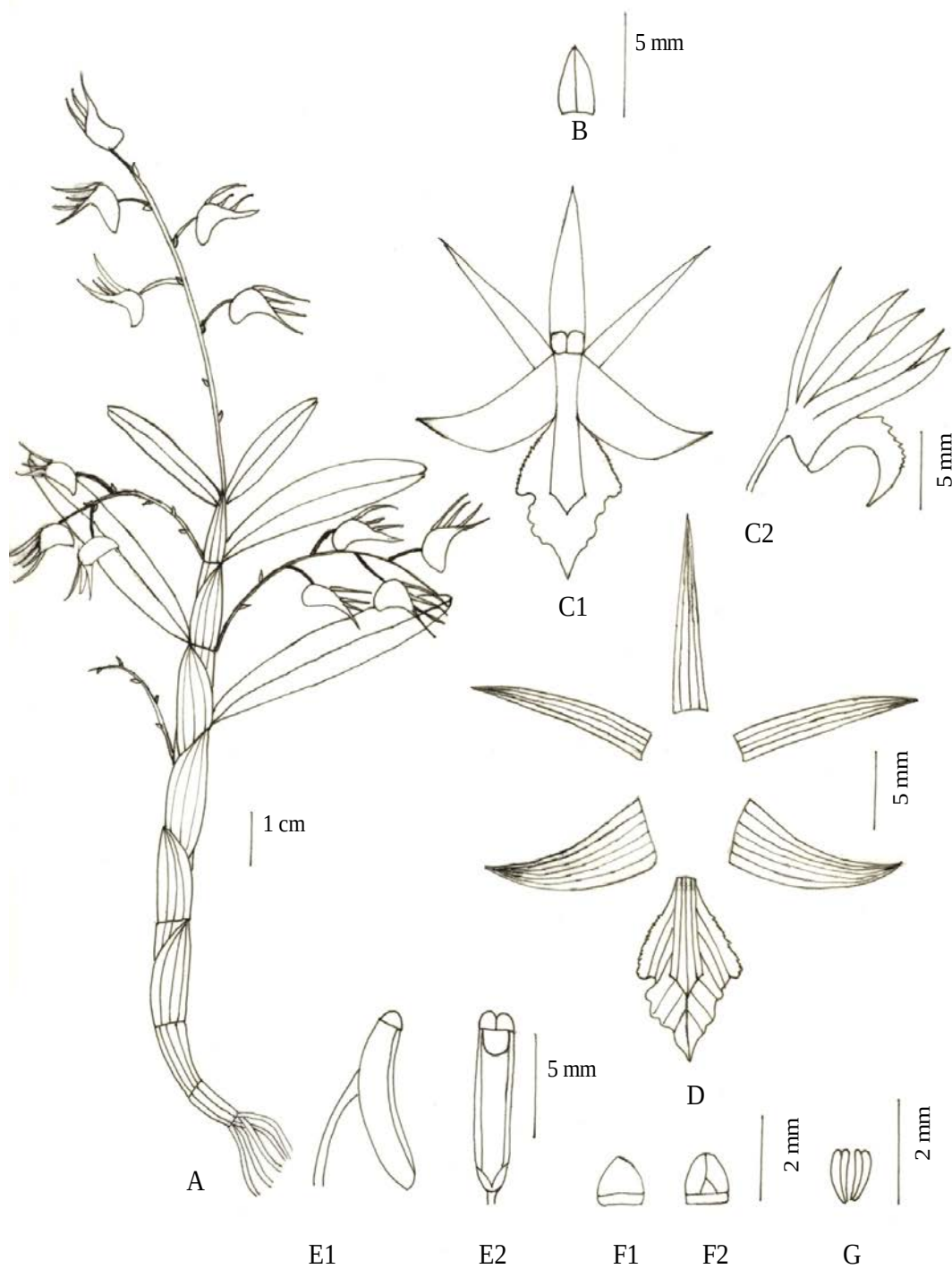


Fig. 53. *Dendrobium denudans* D. Don; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia.

Dendrobium eriiflorum Griff., Icon. Pl. Asiat. t. 307 (1851); Hooker f., Fl. Brit. Ind. 5: 715 (1890).

Type: India, Griffith, # 131 (Syntype: K). Appendix II Z.

Herb, epiphytic or lithophytic, 7-12 cm high. **Stem** erect, many leaved, tapering from base to apex, 1.4-1.6 cm thick, thick at base, noded, internodes 1.6-2.0 cm long, covered with sheaths, sheaths brown membranous, broadly ovate, many veined, 2.0 cm x 0.8 cm. **Leaves** linear-lanceolate, distichous, sub-sessile, apex blunt, oblique, emarginate, obtuse, membranous, 4.0-6.8 cm x 0.3-0.6 cm. **Inflorescence** terminal or axillary raceme, many flowered, leaf opposed, noded, slightly longer than leaf, rachis 3.0-10.0 cm long, erect to arching with flowers, peduncle slender, 2.5-3.0 cm long, sheathed, sheaths two, membranous, 3.0 mm x 0.8 mm. **Flower** bracteate, minute, many flowered, light greenish-white, 1.5 cm across, lunate or boat shaped in bud, pedicel with ovary slender, 7.0 mm long, white with attractive yellow inner lip, showy, fragrant. **Bract** ovate-lanceolate, minute, acuminate, membranous, 1-veined, 4.0 mm x 1.5 mm. **Sepals** sub-similar, dorsal sepal lanceolate, acuminate, 5-veined, 1.2 cm x 0.25 cm, lateral sepals larger, lanceolate, falcate, broad at base, acuminate, 5-veined, 1.2 cm x 0.3 cm, mentum broadly conical, incurved, 4 mm long. **Petals** linear-lanceolate, acute, lying parallel above column, 3-veined, 1.1 cm x 0.18 cm. **Lip** 3-lobed, shorter than sepals, sessile, oblong-ovate (when spread), concave, curved from narrow bases, light greenish-white spotted with dull purple, 8.0 mm x 7.0 mm, side lobes elongate, narrow, pectinate-serrate, mid-lobe shorter than side lobes, orbicular, recurved, acute, margin undulate, disc with a mesial ridge running from base to apex of mid-lobe. **Column** long, slightly spotted with dull purple, nectary, 2.5 mm long, foot at right angles, foot 6 mm long. **Anther** ovate with pectinate lip, white, 1.5 mm x 1.0 mm. **Pollinia** 4 in 2 pairs, oblong-lanceolate, 1.1 mm x 1.0 mm (Fig. 55).

Habitat: On the branches of *Berberis* sp.

Distribution: Nepal (CE. 1500-2100 m), Bhutan, India, Malaysia, Myanmar and Thailand (Fig. 54).

Status: Endangered due to deforestation and over exploitation for medicinal values.

Flowering: September-October.

Etymology: Derived from Greek word “eriiflorum” referring Eria-like flower meaning the plant having Eria-like flowers.

Specimens Examined: Appendix III 27.

Notes: *D. eriiflorum* was established by Griffith in 1851. In the protologue, the epithet is spelled as ‘*eriaeflorum*’ but the Plant list (April, 2013) mentions the specific epithet as ‘*eriiflorum*’ instead of ‘*eriaeflorum*’. Hence in the present study, ‘*eriiflorum*’ is treated as epithet. The plant is characterized by multiple arching inflorescences with light greenish white flowers, lip light greenish white spotted with deep purple. The plant is similar to *D. denudans* but more compact habits, looser racemes and shorter flower segments.

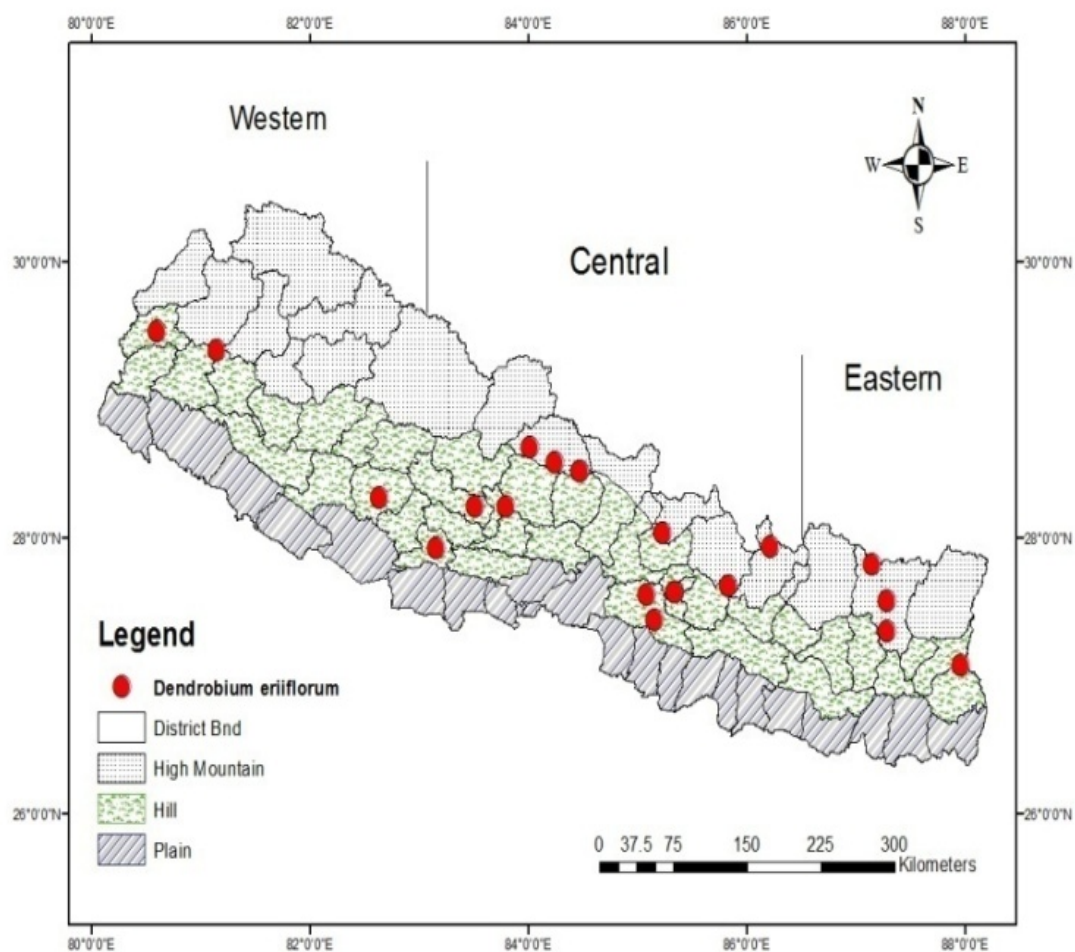


Fig. 54. Distribution map of *Dendrobium eriiflorum* Griff. in Nepal Himalaya.

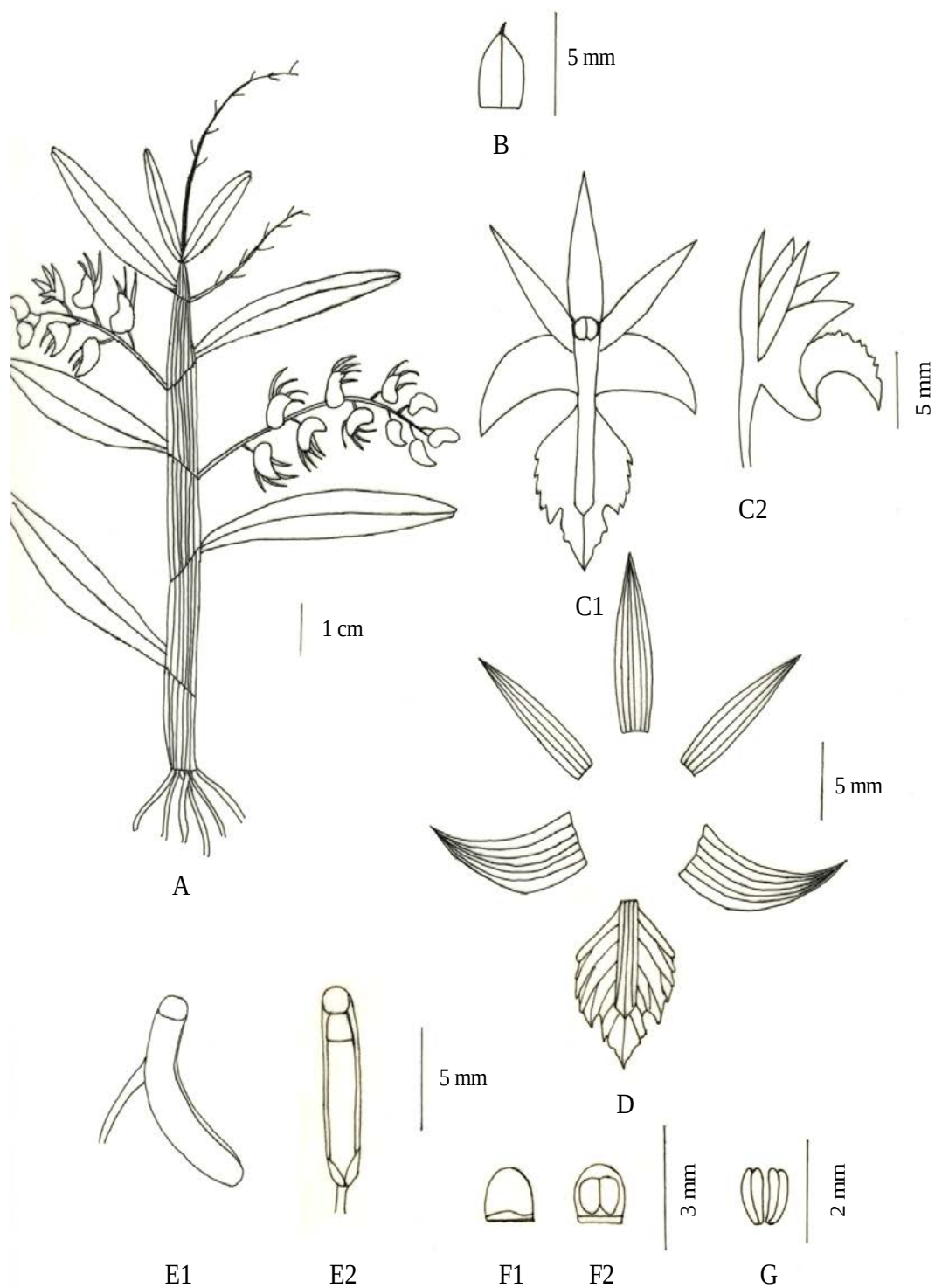


Fig. 55. *Dendrobium eriiflorum* Griff.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view; G: Pollinia.

Dendrobium monticola P. F. Hunt & Summerh., Taxon 10: 110 (1961).

Type: India, Royle, # s.n. (*Dendrobium alpestre* Royle, Syntype: K). Appendix II I.

Herb, epiphytic or lithophytic, small, 4.0-6.0 cm high. **Pseudobulb** erect, elongate, tapering towards apex, enclosed in loosely arranged leaf sheaths, caespitose herbs with many nodes, internodes of about 1.0-1.5 cm long. **Leaves** 3-4, at apex of pseudobulb, sessile, exstipulate, linear lanceolate, thinly leathery, apex obtuse, slightly curved and bilobed, base enlarged to bulky-shaped sheaths, leaf sheaths loosely arranged around the stem, leaf sheath membranous, basal sheath larger, gradually smaller towards apex, 2.5-3.0 cm x 0.4-0.6 cm. **Inflorescence** 1-4, terminal raceme or arising from upper part of leafy stem of current year, rachis 2.5 cm long, 3-8 flowers, erect, peduncle short, 1.5 cm, covered with sheaths. **Flowers** bracteate, white, purplish red stripes in side lobes of lip, disc white with purplish red stripes, column foot with purplish red stripes, 1.5 cm across, pedicel with ovary 6 mm long. **Bract** narrowly ovate, membranous, apex acute, 1-veined, 3.5 mm x 2.0 mm. **Sepals** dorsal sepal lanceolate, apex acuminate, 3-veined, 1.0 cm x 0.2 cm, lateral sepals falcate, lanceolate, apex acute, base broad, contracted above middle part, 5-veined at base, 3-veined at apex, 9.0 mm x 3.5 mm., mentum short, conic. **Petals** linear-lanceolate, apex acuminate, petals shorter than sepal, 3-veined, 8.0 mm x 1.5 mm. **Lip** 3-lobed, subelliptic, shortly clawed, attached to foot of column, middle part with wavy edge, side lobes erect, rounded, margin deeply irregularly inciso-serrate, apex acuminate, mid lobe ovate triangular, apex acute, recurved, undulate, disc with 3 lamellate ridged projections in central part, ridges thick, fleshy and slightly curved, extending from base of lip to base of mid lobe, apex slightly enlarged, disc with irregular orbicular triangular apex, 8.0 mm x 4.5 mm. **Column** 3 mm long, middle part thick 1 mm wide, foot 5 mm long, densely fine papillae present in margin. **Anther** subglobose, dentate margin in front side, 0.8 mm x 1.0 mm. **Pollinia** not seen (Fig. 57).

Habitat: On tree trunks of *Schima wallichii*.

Distribution: Nepal (C. 1700 – 2200 m), India, Laos, China, Thailand, Vietnam (Fig. 56).

Status: Threatened due to deforestation.

Flowering: July - August.

Etymology: Derived from Latin word “monti” meaning mountain and “cola” meaning dweller referring plant a mountain dweller, growing in mountains.

Specimens Examined: Appendix III 28.

Notes: *D. monticola* was established by P.F. Hunt & Summerh. (1961). From Wallich collection in Nepal, D. Don (1825) proposed 2 taxa viz. *D. denudans* and *D. pusillum*, both of which come under section *Stachyobium*. Unfortunately most of Don’s type specimens were considered lost. Lindley (1830) accepted the name *D. denudans* in his ‘Gen. & Sp. Orch. Pl.’ and that epithet is still considered valid today. Don’s *D. pusillum* is listed as synonym of his *D. pygmaeum* but Hooker f. (1890) expressed that *D. pusillum* is conspecific with *D. alpestre* described by Royle (1839). *D. pusillum* D. Don have priority over *D. alpestre* Royle but the epithet cannot be used on account of earlier *D. pusillum* Kenth 1815 (now *Pleurothallis pusilla* (Kenth) Lindl.) and the name *D. alpestre* was used for a long time. In 1961, P.F.Hunt & Summerh. proposed the new name *D. monticola*.

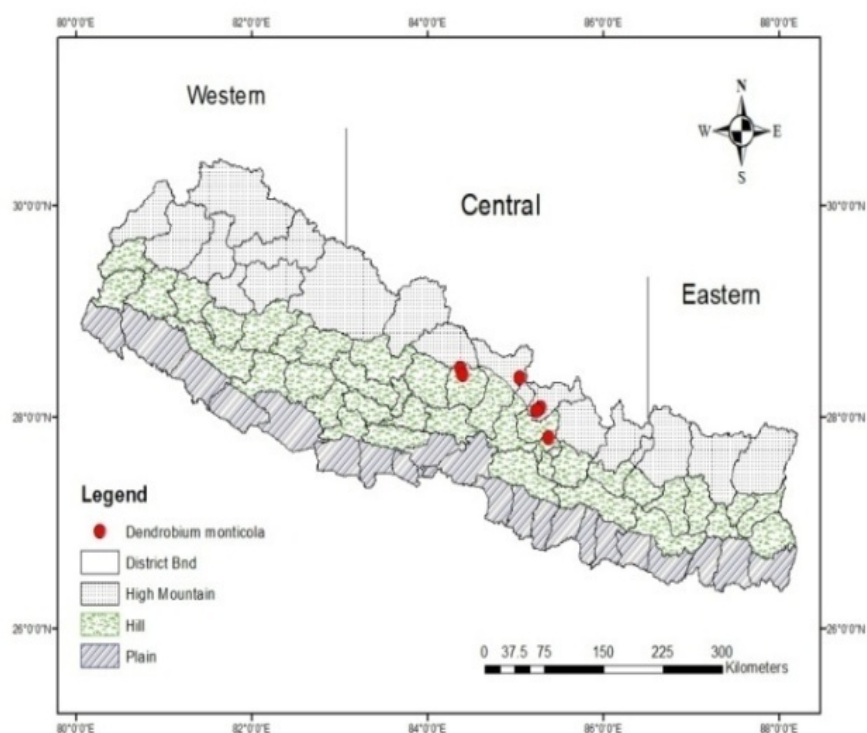


Fig. 56. Distribution map of *Dendrobium monticola* P.F. Hunt & Summerh. in Nepal.

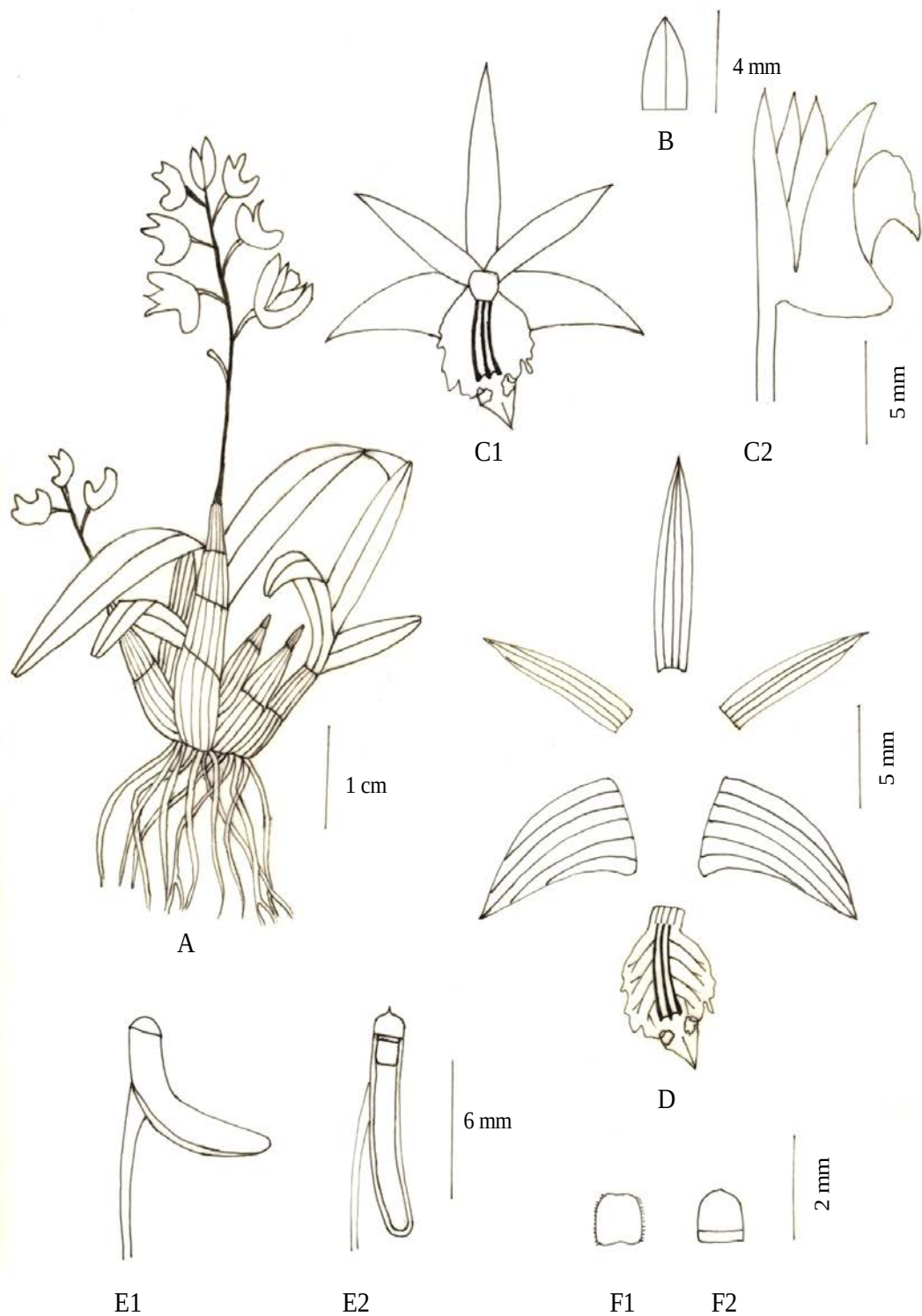


Fig. 57. *Dendrobium monticola* P.F. Hunt & Summerh.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view; F: Anther: F1: Dorsal view F2: Ventral view.

Dendrobium porphyrochilum Lindl., J. Proc. Linn. Soc. Bot. 3: 18 (1859).

Type: India, Hooker, # s.n. (Isotype: P). Appendix II II.

Herb, epiphytic, 2.0-5.0 cm tall. **Pseudobulb** erect, slender, cylindrical, narrowed towards apex, covered by membranous striped sheaths, internode 0.5 cm. **Leaves** 1-3, at apex of pseudobulb, linear-oblong, tapering to sharp apex in some leaves, obtuse with obliquely notched in some leaves, membranous, 2.5–5.0 cm x 0.5–0.8 cm. **Inflorescence** terminal raceme, pendant, solitary, 7-12 flowered, peduncle slender, sheathed at base, 3.0 cm long, rachis zigzag, 4.0-5.0 cm long, sheath 1, 3.0 mm long. **Flowers** bracteate, fragrant, pedicel with ovary 0.7 mm long, creamy or yellowish green, 0.8-1.0 cm across. **Bract** lanceolate, acuminate, glabrous, 1-veined, shorter than pedicel and ovary, 2.0-4.0 mm x 1.0-1.2 mm. **Sepals** dorsal sepal lanceolate, obtuse, 3-nerved, 6.0 mm x 1.5 mm, lateral sepals lanceolate, subfalcate, slightly broader than dorsal sepal, obtuse, 3-nerved, 8.0 mm x 2.0 mm, mentum small, obliquely rounded. **Petals** oblong-lanceolate, acute, shorter than sepal, pale yellow green with red veins, 3-veined, 5.0 mm x 1.0 mm. **Lip** simple, elliptic, purplish brown with yellowish green margin, subacute, decurved from base, margin entire, weakly undulate, 3 obscure ridges of variable lengths from slightly depressed base to apex, 4.0 mm x 2.5 mm. **Column** short, white tinged with purple, 1.0 mm x 0.6 mm, foot concave, 1.4 mm long. **Anther** suborbicular with upturned lip, 0.8 mm x 1.0 mm. **Pollinia** not seen (Fig. 59).

Habitat: On tree trunks of *Rhododendron arboreum*.

Distribution: Nepal (CE. 1800-2500 m), North East India, Bhutan, China, Myanmar, Vietnam, Thailand (Fig. 58).

Status: Threatened due to deforestation.

Flowering: July-August.

Etymology: Derived from Greek word “porphyro” (purple) and “cheilos” (lip) referring to plant having purple lip.

Specimens Examined: Appendix III 29.

Notes: *D. porphyrochilum* was established by Lindley in 1859. King and Pantling (1895) declared their *D. caespitosum* conspecific.

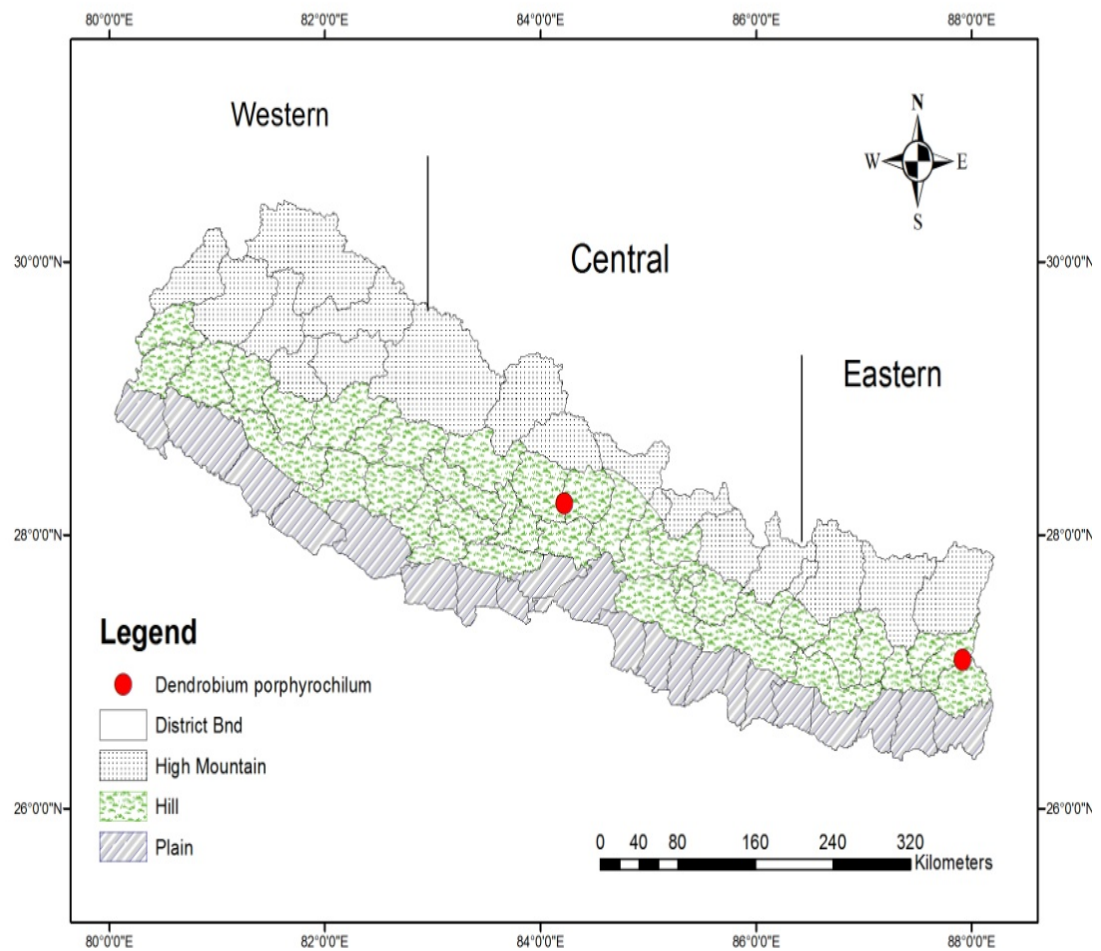


Fig. 58. Distribution map of *Dendrobium porphyrochilum* Lindl. in Nepal Himalaya

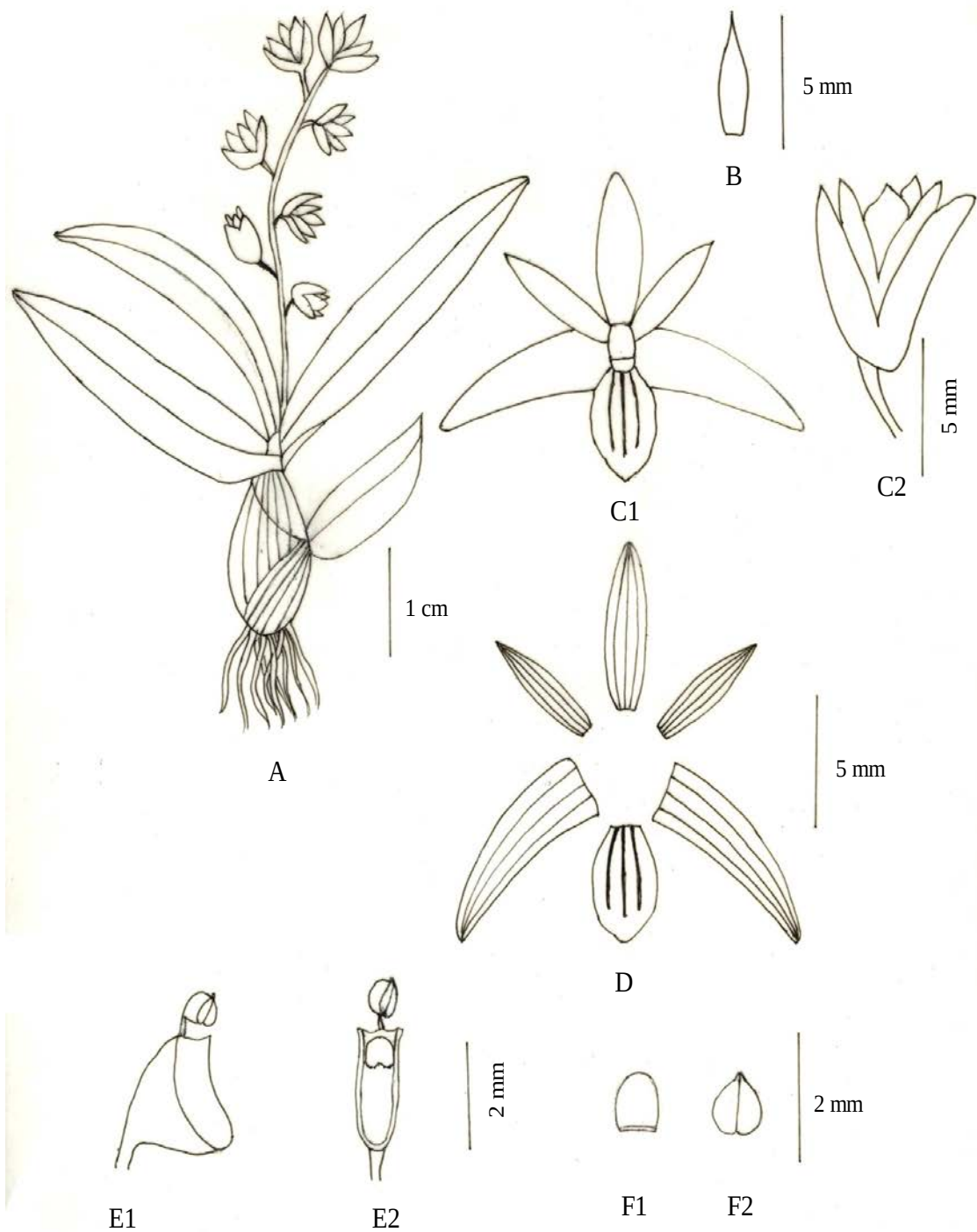


Fig. 59. *Dendrobium porphyrochilum* Lindl.; A: Habit; B: Bract; C: Flower: C1: Front view; C2: Lateral view; D: Sepals, Petals and Lip spread out; E: Column and ovary: E1: Lateral view E2: Front view: F: Anther: F1: Dorsal view F2: Ventral view.

4.1.2. Discussion

Dendrobium belonging to subtribe Dendrobiinae is represented by 1500 species, ranges from Sri Lanka, throughout tropical Asia and pacific region, north to Japan, east to Tahiti and south to New Zealand (Schuiteman and Adams, 2014). The exploration of orchid of Nepal begins in 1802 with the collections by Buchanan-Hamilton. Based on the plant collections of Buchanon-Hamilton, Wallich (1820-1821), D. Don published “Prodromous Florae Nepalensis”. Since then Hooker (1823), Don (1825), Lindley (1830), Tuyama (1966-1975) and many Nepalese scientists had enlisted *Dendrobium* species from Nepal Himalaya from time to time. Rajbhandari and Rai (2017) enlisted 26 species of *Dendrobium* and 2 species of *Epigeneium* from Nepal Himalaya based on herbarium specimens deposited at different herbaria like KATH, TUCH, K, E, BM and TI. In the present work, 29 species of *Dendrobium* from Nepal Himalaya were studied based on enlisting of *Dendrobium* species by Rajbhandari and Rai (2017). Here one species *Dendrobium rotundatum* was added to that listing as it was collected during field visits. Among 29 species of *Dendrobium*, 3 species viz. *D. chryseum*, *D. darjeelingense* and *D. plicatile* were described from literatures and herbarium specimens because of inability to acquire the specimens. The present study revealed the vast range of diversity of the vegetative and floral characters of the various species. Based on gross morphological characters, identification keys to sections and species were provided.

In *Dendrobium* the nature of stem or pseudobulb, shape and size of flower, shape of mentum, type of lip, ornamentation on disc are the most important diagnostic characters for elucidating different species of *Dendrobium*. The genus *Dendrobium* was categorized into 6 sections viz. Section I. *Aporum*, Section II. *Crinifera*, Section III. *Dendrobium*, Section IV. *Formosae*, Section V. *Sarcopodium* and Section VI. *Stachyobium*.

Section I. *Aporum* is characterized by laterally compressed cane-like stem, leaves overlapping, equitant, lip with expanded midlobe and saccate shaped mentum. This section includes only one species *Dendrobium anceps* from Nepal Himalaya.

Section II. *Crinifera* is characterized by elongate rhizome, pseudobulb with one leaf at apex, ephemeral flower and lip attached to the apex of column. This section includes *Dendrobium fugax* and *Dendrobium plicate* from Nepal Himalaya. *D. fugax* and *D.*

plicatile were morphologically similar but they differed in size of leaf, number and colour of flower and shape of sepal and petal. Dressler (1993) placed these two species under genus *Flickingeria*. But Schuiteman and Adams (2014) rearranged the sections and included genus *Flickingeria* A. D. Hawkes into genus *Dendrobium* based on molecular studies. *Dendrobium fugax* was found related to *Dendrobium denneanum* as they had coriaceous leaf, glabrous stem and acute floral bract apex. So the inclusion of *Flickingeria* into genus *Dendrobium* was acceptable.

Section III. *Dendrobium* is characterized by cane-like, elongate, fusiform to clavate stem, deciduous or persistent, flowers small to large, in lateral pairs, fascicled or many flowered and highly coloured. This section includes 16 species of *Dendrobium* from Nepal Himalaya. Among 16 species of *Dendrobium*, *D. moschatum*, *D. chrysanthum*, *D. fimbriatum*, *D. gibsonii* were similar in size of leaf and phyllotaxy of leaf and inflorescence but *D. moschatum* differed from other species in floral bract, dorsal and lateral sepals. Among *D. chrysanthum*, *D. fimbriatum*, *D. gibsonii*, *D. chrysanthum* differed from other species in leaf texture, rachis, lip margin and ornamentation on disc. *D. fimbriatum* and *D. gibsonii* differed in habit, inflorescence and lip apex. *D. denneanum* and *D. densiflorum* were similar in habit and floral character but they differed in leaf phyllotaxy, inflorescence orientation and lip margin. *D. crepidatum*, *D. aphyllum* and *D. nobile* were similar in habit, stem habit, leaf position, dorsal sepal shape and type of lip but they could be differentiated from one another by height of plant, leaf texture, apex of dorsal and lateral sepal, lip margin and ornamentation on disc. *D. bicameratum* differed from *D. crepidatum*, *D. aphyllum* and *D. nobile* in leaf texture, inflorescence orientation, apex and margin of lip. *D. chryseum* and *D. nobile* had similar habit, vegetative characters and floral characters but *D. chryseum* differed from *D. nobile* in having pendulous stem, large leaf, absent of rachis and apex and margin of lip. *D. polyanthum* resembled with *D. amoenum* and *D. transparens* in stem surface, texture and size of leaf, shape of dorsal and lateral sepal but it differed from them in having lateral inflorescence, large flower and simple lip. *D. amoenum* differed from *D. transparens* in habit, lip apex and orientation on disc. *D. heterocarpum* and *D. moniliforme* were similar in habit and floral characters but they could be differentiated from one another by leaf texture, floral bract apex and type of lip.

Section IV. *Formosae* is characterized by cane-like stem, long-lived leaf, leaf sheaths densely covered with short blackish hairs, in some species on leaves and trilobed lip. This section includes *Dendrobium formosum* and *Dendrobium longicornu* from Nepal Himalaya. *D. formosum* and *D. longicornu* are similar in habit, vegetative and floral characters but they differed in plant height, inflorescence type, flower size, lip apex and margin.

Section V. *Sarcopodium* is characterized by pseudobulb with one node from stout creeping rhizome, leaves two, flower solitary in between leaves and trilobed lip attached to apex of column foot. This section includes *Dendrobium amplum*, *Dendrobium fuscescens* and *Dendrobium rotundatum*. *D. amplum* resembled with *D. fuscescens* and *D. rotundatum* in habit, rhizome, position of leaf, inflorescence orientation and lip type and apex but it differed from them in having ellipsoid pseudo bulb, large leaf and flower, lateral sepal shape and entire lip margin. *D. fuscescens* differed from *D. rotundatum* in habit, shape of pseudobulb, floral bract shape, lateral sepal shape, lip apex and margin, ornamentation on disc.

Section VI. *Stachyobium* is characterized by small plants, stem with or without pseudobulb, pseudobulbs clustered, leafy throughout or at apical part, small flower and lip simple or trilobed hinged with column foot. This section includes *Dendrobium darjeelingense*, *Dendrobium denudans*, *Dendrobium eriiflorum*, *Dendrobium monticola* and *Dendrobium porphyrochilum*. *D. darjeelingense* and *D. denudans* are similar in habit, vegetative characters and floral characters but they differed in plant height, inflorescence orientation, apex and margin of lip and ornamentation on disc. *D. porphyrochilum* resembled with *D. eriiflorum* and *D. monticola* in stem habit, leaf phyllotaxy and number of floral bract veins but it differed from them in having epiphytic habit, cylindrical pseudobulb, simple lip with subacute apex and entire margin. *D. monticola* resembled with *D. eriiflorum* in habit, leaf phyllotaxy, lip type, size, apex and margin but it differed from *D. eriiflorum* in having elongate pseudobulb, coriaceous leaf, erect and terminal inflorescence and lamellae on disc.

In all species of *Dendrobium* studied, *D. formosum* was found differed from all other species in having terminal or lateral inflorescence, subacute floral bract apex and cuspidate petal apex.

The species like *D. eriiflorum*, *D. fimbriatum* and *D. longicornu* were reported from West to Central to East Nepal; *D. bicameratum* and *D. polyanthum* were reported from West to Central Nepal; *D. chryseum*, *D. crepidatum*, *D. darjeelingense*, *D. denneanum*, *D. denudans*, *D. fugax*, *D. gibsonii*, *D. monticola* and *D. transparens* were reported from Central Nepal; *D. amoenum*, *D. amplum*, *D. anceps*, *D. aphyllum*, *D. chrysanthum*, *D. densiflorum*, *D. formosum*, *D. heterocarpum*, *D. moniliforme*, *D. moschatum*, *D. nobile*, *D. porphyrochilum* and *D. rotundatum* were reported from Central to East Nepal; *D. fuscescens* and *D. plicatile* were reported from East Nepal. The Central to East Nepal was found to represent the largest number of *Dendrobium* species whereas the number of species was gradually decreasing towards West Nepal because of biogeographical and climatic factors. In Central and East Nepal there is presence of high relative humidity in the atmosphere which is the one of the important factors for heavy growth of orchids. By voucher specimen study, *D. fimbriatum* was reported from Central and East Nepal but it was also reported from West Nepal by field collection, thus redefining the range of distribution of *D. fimbriatum*. *D. longicornu* was reported from Central to East Nepal (Rajbhandari and Rai, 2017) but the voucher specimen revealed its presence in West Nepal, thus redefining the range of distribution. Previously *D. gibsonii* was reported from East Nepal but the voucher specimen revealed that it was Central Nepal and field collection also from Central Nepal, thus redefining the range of distribution.

The distribution of *Dendrobium* species along with region, altitudinal range, flowering time and host plants in Nepal Himalaya was given in Appendix IV.

4.2. Anatomy

4.2.1. Introduction

Anatomy is one of the classical sources of data used in plant taxonomy. Anatomical data are useful in solving the problems of relationships among plant species. Although morphological and floristic studies of Orchidaceae have been carried out extensively, anatomical investigations are yet inadequate on orchids from Nepal. Only a few anatomical characters have been explored by some of the scientists as a supplementary portion of the revision of respective genera (*Coelogyne*, *Dendrobium*, *Eria*, *Gastrochilus*, *Oberonia* and *Pholidota*) in Nepal. In subtribe Dendrobiinae, only certain species have been studied anatomically as a part of a broad investigation (Morris *et al.*, 1996). Kaushik (1983) explored the ecological and anatomical marvels of the Himalayan Orchids and discussed the impact of anatomy on the classification of the family and formulated the phylogenetic classification based on the morpho-anatomical characters. He also mentioned that anatomical characters can be used as taxonomical characters to distinguish different species. Mohana *et al.* (1991) studied vegetative anatomy of some members of subfamily Epidendroideae and observed the differences among the species with respect to stomatal features, presence or absence of trichomes, cellulose thickened mesophyll cells and fibrous bodies. Morris *et al.* (1996) studied the vegetative anatomy and systematic of subtribe Dendrobiinae. They found that the anatomy of plants reflects a high degree of morphological diversity and many of the anatomical characters appear to be homoplasous. They also recommended that a more detailed understanding of the phylogeny of subtribe Dendrobiinae will require the characters from morphology, micromorphology, anatomy and DNA studies. Carlsward *et al.* (1997) studied the comparative leaf anatomy and systematic in *Dendrobium*, Sections *Aporum* and *Rhizobium* and concluded that two sections of *Dendrobium* are hypothesized to be sister taxa because of synapomorphies in their foliar anatomy. The cladistic analysis performed with various anatomical characters of the leaf demonstrates that both groups are monophyletic. Anatomical characterization helps in the identification of plant taxa when morphological characters are similar. It also helps in understanding the physiological processes and phylogenetic relationships among plant species (Liu and Zhu, 2011).

4.2.2. Materials and Methods

The plant materials were collected from West, Central and East Nepal on the basis of those regions mentioned in the herbaria and also from the available literature. The vegetative organs such as leaves and stems and pseudobulbs were fixed in FAA (0.5 part formalin + 0.5 part glacial acetic acid + 9 part 70% ethanol) for 24 hours. These techniques involve killing and fixing the tissues in FAA and then storing in 70 % ethanol before sectioning. Anatomical studies were done on the preserved materials such as leaves, stems and by two methods: Free hand sections and Microtomy (Cutler, 1978).

Free hand sections Method

Free hand cross sections of the vegetative organs were made at standardized levels. The transverse sections of leaves, stems and pseudobulbs were cut with sharp blades. Fine sections of the materials were dehydrated with different alcohol series. Double staining was done by Safranin-fast green combination (Johansen, 1940 with some modifications). The sections were dehydrated with different alcohol series and double staining was done by dehydrating in 30% for 5 minute, 50% for 10 minute, alcoholic safranin for 30 minute, wash in 50% alcohol, 70% alcohol for 10 minute, 90% alcohol for 10 minute, fast green for 1 minute, wash in 90% alcohol, absolute alcohol for 5 minute and xylene for 2 minute. Then the sections were mounted in DPX, observed and investigated with the help of compound light microscopes (Olympus 646545). Microscopic photography was carried out of these slides. Observations were made with compound light microscope. Measurements were taken with the help of the standardized ocular micrometer scale.

Microtomy

Microtome sections were prepared using standard micro-technical methods for anatomy by using a rotary microtome (Yorco Spencer type) as described by Cutler (1978). For microtome sections, leaf, stem and pseudobulb parts of specimens were dehydrated in alcohol and xylene series, infiltrated and embedded in paraffin wax (melting point 60-62⁰c). The embedded materials in the block of wax were sectioned with a rotary microtome at a thickness of 15-30 µm. Double staining was done by Safranin-fast green combination (Johansen, 1940 with some modification) and the sections were mounted in DPX. Observations were made with compound light

microscope. Microscopic photography was carried out of these slides. Measurements were taken with the help of the standardized ocular micrometer scale.

4.2.3. Result

4.2.3.1. Anatomy of species

Section I. *Aporum*

Dendrobium anceps

Transverse Section of Leaf

Cuticle: Cuticle is the outermost layer and present on both sides. It is thick, smooth and intermittently domed. **Epidermis:** A single layer of thin-walled, polygonal and tangentially elongated cells with suberization are present on both adaxial and abaxial sides. The adaxial cells are larger than abaxial cells. The adaxial cells are 16.65 μm –36.63 μm (w) x 6.66 μm –13.32 μm (l). The abaxial cells are 16.65 μm –23.31 μm (w) x 6.66 μm –13.32 μm (l). **Hypodermis:** A single layer of thin-walled chlorenchymatous, rounded, small cells is present in the abaxial side only. **Fibre Bundles:** Fibre bundles are present in one series both on adaxial and abaxial sides subtending the hypodermis. Fibre bundle consists of heterogenous bundles and homogenous bundles. Heterogenous bundle is composed of both small, thick-walled fibres and large, thin-walled fibres and homogenous bundle is composed of thin or thick-walled fibres. Heterogenous bundles alternate with homogenous bundles. The cells are oval to polygonal in shape. Stegmata with rough-surfaced, spherical silica bodies are present along outer margin of fibre bundle facing towards epidermis (Plate 29B). **Mesophyll:** Mesophyll is homogenous. It consists of smaller assimilatory cells and larger water storage cells. The assimilatory cells are living, thin-walled and chlorenchymatous whereas the water storage cells are nonliving, thin-walled and rounded. Water storage cells with smooth or pleated walls are scattered throughout the mesophyll but more towards the middle of leaf and they varies in size from small to large from periphery toward the centre. It consists of eighteen layers of chlorenchymatous cells. The cells are oval to polygonal in shape. Intercellular spaces are small and numerous. Raphide bundles are present in mesophyll cells. **Vascular bundle:** Vascular bundles are arranged in two symmetrical rows within the mesophyll. A major large vascular bundle is present at only one pole of the leaf section. Vascular bundle is conjoint, collateral, closed and circular in shape. Large

vascular bundle at pole measures 139.06 μm (l) x 136.53 μm (w). Vascular bundle comprises xylem and phloem. Xylem is facing towards the midline, 6.66 μm – 9.99 μm (l) x 4.99 μm - 9.99 μm (w) and the phloem facing towards epidermis, 3.33 μm – 4.99 μm (l) x 2.66 μm - 3.33 μm (w). Vascular bundle is surrounded by thin-walled parenchymatous bundle sheath cells. C-shaped fibre cap is developed at phloem poles of large polar bundle, largest lateral bundles and poorly developed at smaller bundles. C-shaped fibre cap is poorly developed at xylem poles of large polar bundle, largest vascular bundles and absent at the xylem poles of smaller vascular bundles. Fibre cap is made up of sclerenchymatous cells, phloem cap is 2-layered, 26.64 μm (l) x 139.86 μm (w) and xylem cap is one-layered, 23.31 μm (l) x 119.88 μm (w) in midrib bundle. The larger and smaller vascular bundles are found alternating with each other (Plate 4 B, C) (Table 8). Stigmata with rough-surfaced spherical silica bodies are found associated with fibre cap of phloem (Plate 30 B).

Transverse Section of Stem

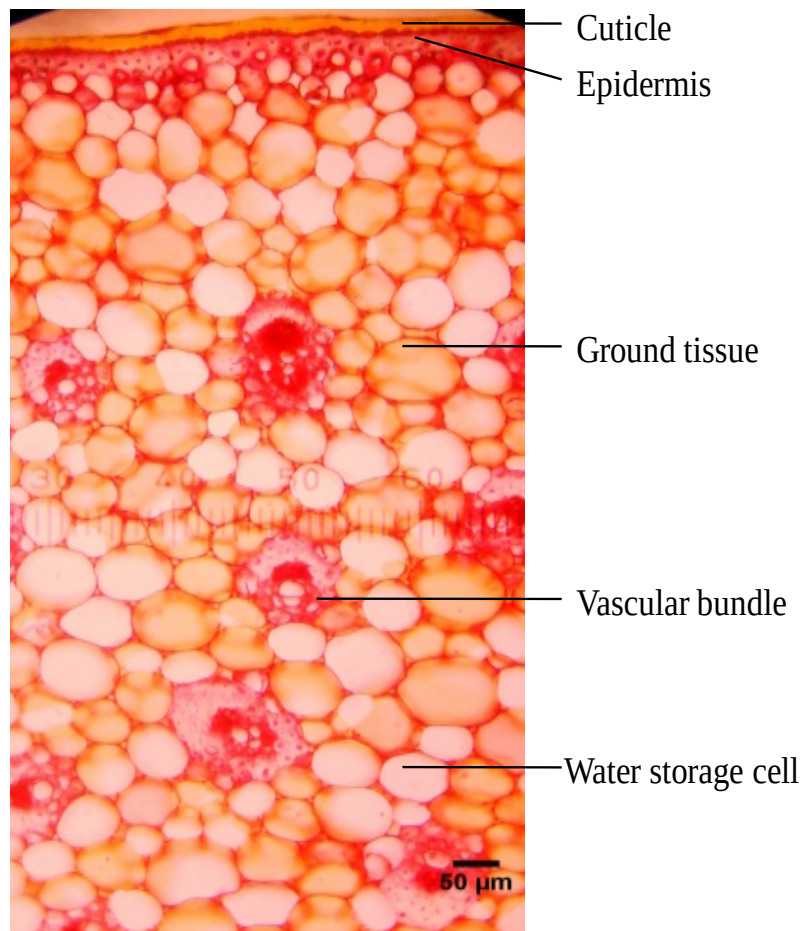
The surface layer of stem is irregular, intermittently undulating and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick. **Epidermis:** Epidermis is represented by a single layer of barrel-shaped parenchymatous cells. The cells are thin-walled. The epidermal cell varies from 9.99 μm – 16.65 μm (w) x 6.66 μm - 9.99 μm (l) in size. **Hypodermis:** Epidermis is followed by hypodermis. Hypodermis is made up of 2 layers of thick-walled polygonal parenchymatous cells. Outer hypodermal layer is made up of sclerified parenchymatous cells and inner layer of sclerenchymatous cells. Outer hypodermal cells are smaller than inner cells in size. Hypodermal cells are smaller than ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with unpleated outlines. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 64. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is oval-shaped in outline. The size of vascular bundle ranges from 116.55 μm - 199.80 μm (l) x 73.26 μm – 99.90 μm (w). The vascular bundle consists of xylem towards centre and phloem towards periphery. Xylem and phloem vary in

different sized vascular bundles scattered in ground tissue. Xylem cells are 13.32 μm – 16.65 μm (l) x 4.99 μm – 13.32 μm (b) and phloem cells 4.99 μm – 6.66 μm (l) x 3.33 μm – 6.66 μm (b) in small to large sized vascular bundles. Sclereid caps are present above phloem and xylem. Xylem cap cells are larger than phloem cap cells in size. Xylem caps are present in large vascular bundles, 16.65 μm – 26.64 μm (l) x 79.92 μm – 86.58 μm (w) and phloem cap 19.98 μm - 49.95 μm (l) x 73.26 μm – 99.90 μm (w). Sclerenchymatous bundle sheath cells are present surrounding xylem and phloem (Plate 4 A) (Table 9). Stegmata is indistinct.

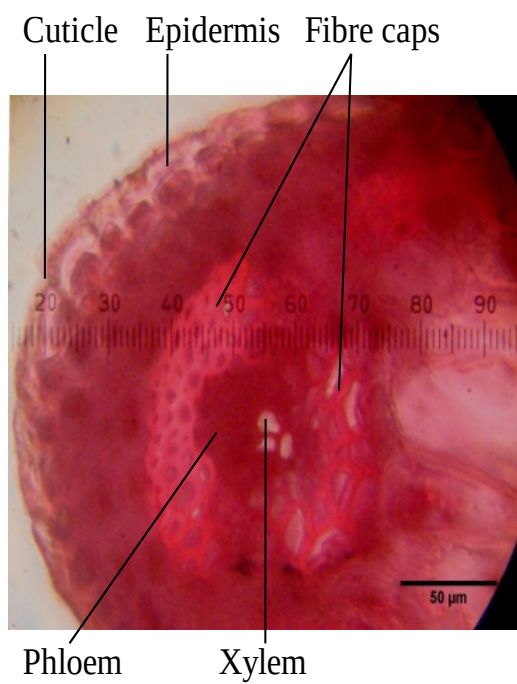
Plate 4. Anatomy of *Dendrobium anceps*

A. T.S. Stem showing cuticle, epidermis, ground tissue, vascular bundle, water-storage cell.

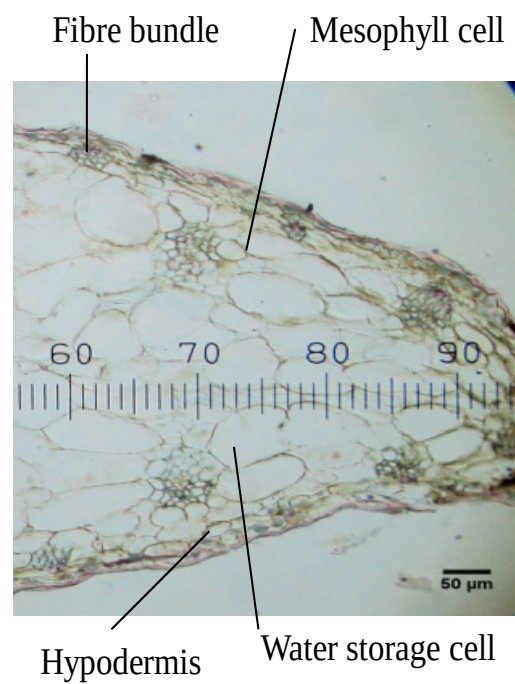
B, C. T.S. Leaf showing cuticle, epidermis, hypodermis, mesophyll cell, xylem, phloem, fibre cap, fibre bundle, water-storage cell.



A



B



C

Section II. *Crinifera*

Dendrobium fugax

Transverse Section of Leaf

Cuticle: Both sides of leaf have a surface covered with cuticle. It is thick, undulating, smooth in adaxial side and irregular in abaxial side, notched in adaxial side at midrib region. **Epidermis:** A single layer of thin-walled rectangular to square cells with rounded angles is present on both adaxial and abaxial surfaces. The adaxial cells are larger than those of abaxial cells. The adaxial cells measure 19.98 μm – 33.30 μm (w) x 9.99 μm – 16.65 μm (l). The abaxial cells measure 13.32 μm – 23.31 μm (w) x 9.99 μm – 16.65 μm (l). Cell lumina are occluded with safranin-staining materials in adaxial and abaxial sides. **Hypodermis:** Absent. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is homogenous. It consists of fifteen layers of chlorenchymatous cells. The cells are polygonal, oval to round. Intercellular spaces are small. Raphide bundles are present in mesophyll. Druses are abundant in mesophyll. **Vascular Bundle:** Vascular bundles are arranged in one row with a large midrib bundle in the centre. The smaller and larger bundles are found alternating each other. Vascular bundle lies at abaxial side of midrib region. Vascular bundle is conjoint, collateral, closed and flask-shaped in shape. Midrib vascular bundle measures 223.11 μm (l) x 166.50 μm (w). Vascular bundle is composed of xylem, phloem. Xylem lies towards adaxial side, 9.99 μm – 26.64 μm (l) x 9.99 μm – 16.65 μm (w) and phloem towards abaxial side, 4.99 μm – 9.99 μm (l) x 3.33 μm – 6.66 μm (w). Sclerenchymatous cells are well developed at phloem pole and xylem pole. Sclereid caps are found surrounding xylem and phloem completely. U-shaped fibre cap towards xylem pole and C-shaped sclereid caps towards phloem poles are present at midrib bundle. Xylem cap is 6-layered, 56.61 μm (l) x 166.50 μm (w) and phloem cap of 6-layered, 36.63 μm (l) x 199.80 μm (w). Parenchymatous bundle sheath cells are discontinuous surrounding xylem of midrib and continuous surrounding xylem and phloem of larger and smaller lateral bundles (Plate 5B) (Table 8). Stegmata with rough-surfaced spherical silica bodies is present along outer margin of phloem cap of midrib bundle, xylem and phloem caps of larger lateral bundles (Plate 30H).

Transverse Section of Pseudobulb

The surface layer of stem is irregular and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of

barrel-shaped parenchymatous cells. The cells are very thick-walled. The epidermal cell varies from 13.32 μm – 23.31 μm (w) x 9.99 μm – 16.65 μm (l) in size.

Hypodermis: Below the epidermis is hypodermis. Hypodermis is made up of 2 layers of irregular or polygonal shaped sclerenchymatous cells. Outer cells are smaller than inner cells. Hypodermal cells are smaller in size than the ground tissues.

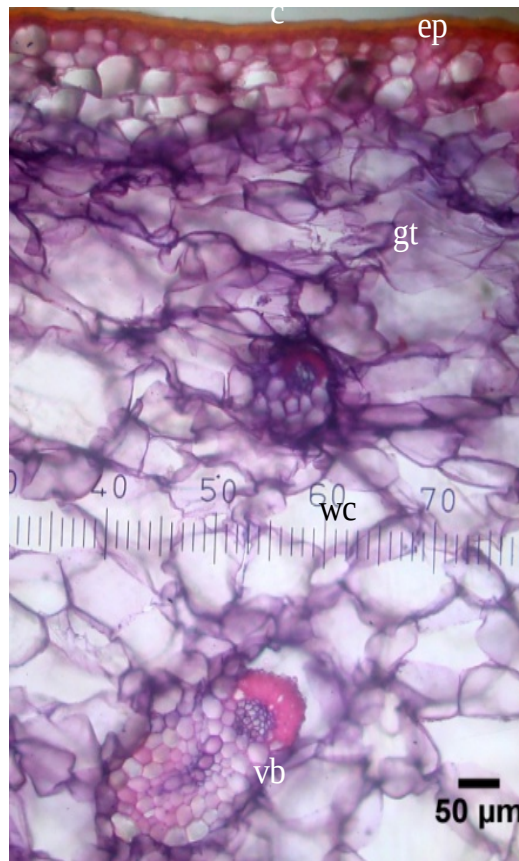
Ground Tissue: There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with pleated outlines. Starch grains are present in assimilatory cells.

Vascular Bundle: Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 71. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is elongate-shaped in outline. The size of vascular bundle ranges from 116.55 μm – 216.45 (l) x 86.58 μm – 166.50 μm (w). The vascular bundle consists of xylem and phloem. Xylem is facing towards centre, 13.32 μm – 19.98 μm (l) x 9.99 μm – 16.65 μm (w) and phloem towards periphery, 4.99 μm – 6.66 μm (l) x 3.33 μm – 6.66 μm (w). Sclereid cap is present towards the upper side surrounding phloem, 26.64 μm – 33.30 (l) x 79.92 – 99.90 μm (w). Sclerenchymatous bundle sheath cells are present surrounding xylem on lower side (Plate 5A) (Table 9). Lacuna is present in ground tissue adjacent to sclereid cap of phloem of vascular bundle. Stegmata all with rough-surfaced spherical silica bodies is present surrounding the outer margin of sclereid cap of phloem (Plate 30 S).

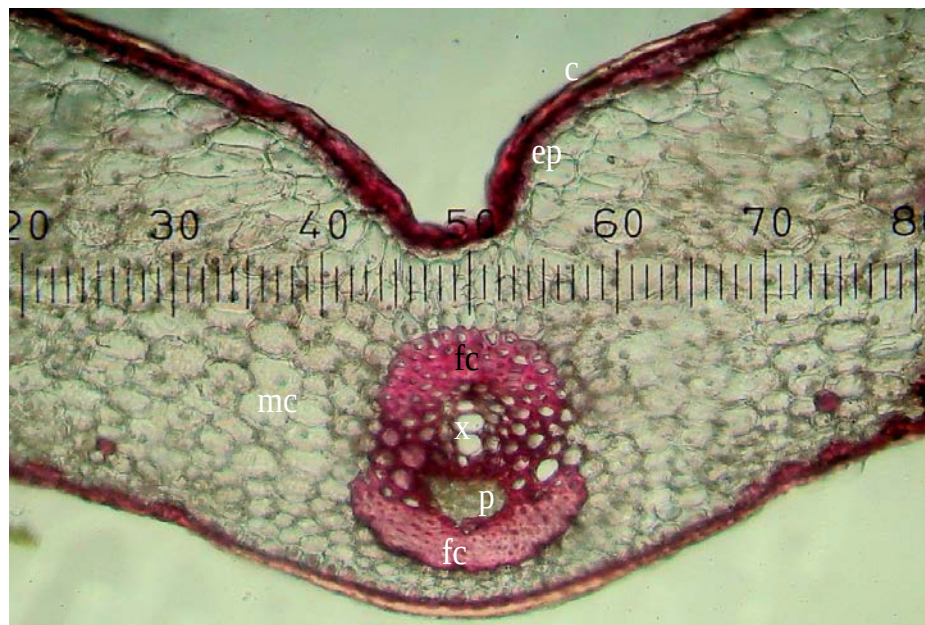
Plate 5. Anatomy of *Dendrobium fugax*

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc).



A



B

Section III. *Dendrobium*

Dendrobium amoenum

Transverse Section of Leaf

Cuticle: Cuticle is the outermost layer and present on both sides. It is thin and irregular. **Epidermis:** A single layer of rectangular to polygonal cells are present on both adaxial and abaxial surfaces. The adaxial cells are 19.98 μm – 69.93 μm (w) x 19.98 μm – 33.30 μm (l), the abaxial cells are 13.32 μm – 43.29 μm (w) x 9.99 μm – 23.31 μm (l). Epidermal cells in mid-rib region are smaller in size than other epidermal cells in adaxial and abaxial sides. **Hypodermis:** Absent. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is homogenous. It consists of seven layers of thin-walled chlorenchymatous cells. The cells are columnar, polygonal in shape and irregular in size. Small intercellular spaces are present in parenchymatous cells. Water-storage cells are usually lacking. Raphide bundles are present in mesophyll cells. **Vascular Bundle:** Vascular bundles are arranged in one row with a large midrib bundle in the centre, smaller and larger bundles throughout the lamina. The vascular bundle is conjoint, collateral, close and oval in shape. Each vascular bundle consists of xylem and phloem. Mid vascular bundle measures 193.14 μm (l) x 133.20 μm (w). Xylem is facing towards adaxial, 9.99 μm – 29.97 μm (l) x 6.66 μm – 26.64 μm (w) and phloem facing towards abaxial side, 4.99 μm – 6.66 μm (l) x 3.33 μm – 4.99 μm (w). C-shaped sclereid cap is present surrounding the phloem on the abaxial side and U-shaped sclereid cap is present on the adaxial side surrounding xylem in midrib bundle. Xylem cap is 4-layered, 83.25 μm (l) x 143.19 μm (w) and phloem cap is 3-layered, 33.30 μm (l) x 133.20 μm (w) (Plate 6B) (Table 8). Stigmata with rough-surfaced spherical silica bodies are present along the outer margin of sclereid caps of xylem and phloem (Plate 30 A).

Transverse Section of Stem

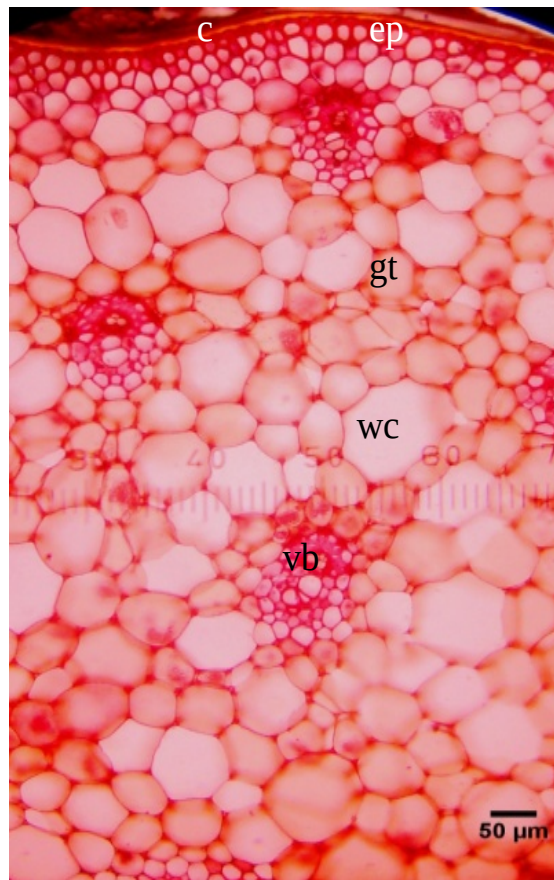
The surface layer of stem is irregular and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis consists of a single layer of rectangular to polygonal sclerified parenchymatous cells. The cells are thick walled. The epidermal cell varies from 9.99 μm – 19.98 μm (w) x 4.99 μm - 9.99 μm (l) in size. **Hypodermis:** Epidermis is followed by hypodermis. Two layers of polygonal shaped, thick-walled sclerenchymatous cells represent the hypodermis. Outer hypodermal

cells are smaller than inner cells. The hypodermal cells are smaller than the ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue consists of thin-walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, dead, scattered, water-storage cells with pleated outlines. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 76. Vascular bundle is oval in shape. Vascular bundle consists of xylem towards inner side and phloem towards outer side. The inner vascular bundle is larger than outer bundles. The size of vascular bundle ranges from 143.19 μm - 183.15 μm (l) x 93.24 μm - 113.22 μm (w). Xylem cells and phloem cells vary in different size of vascular bundles and scattered in ground tissue. Xylem cells are 9.99 μm – 29.97 μm (l) x 6.66 μm – 23.31 μm (w) and phloem cells 6.66 μm – 16.65 μm (l) x 4.99 μm – 9.99 μm (w) in small to large sized vascular bundles. Fibre cap is present above the phloem, 26.64 μm – 33.30 μm (l) x 83.25 μm – 96.57 μm (w). Sclerenchymatous bundle sheath cells are present around the vascular bundle (Plate 6A) (Table 9). Stegmata with rough-surfaced spherical silica bodies are present associated with phloem fibre cap (Plate 30 M).

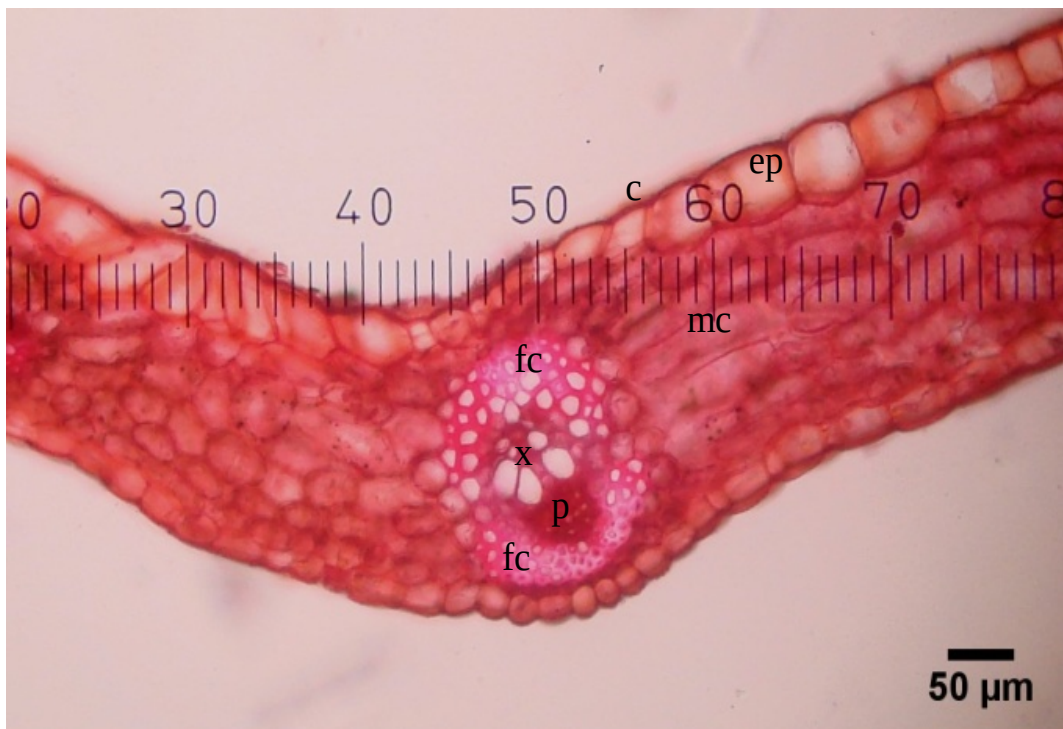
Plate 6. Anatomy of *Dendrobium amoenum*

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc), water-storage cell (wc).



A



B

Dendrobium aphyllum

Transverse Section of Leaf

Cuticle: Cuticle is the outermost layer and present on both sides. It is thin and smooth. **Epidermis:** Leaf is covered with cutinous layer on both sides. A single layer of thin walled rectangular, square to hexagonal shaped parenchymatous cells is present on both adaxial and abaxial surfaces. The adaxial cells are larger than those of abaxial cells. The adaxial cells are 46.62 μm – 76.59 μm (w) x 36.63 μm – 49.95 μm (l) and the abaxial cells 23.31 μm – 66.60 μm (w) x 13.32 μm – 29.97 μm (l). **Hypodermis:** Hypodermis is absent. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is homogenous. It consists of nine layers of oval, rounded to polygonal chlorenchymatous cells but they are vertically elongated in adaxial side of mid-rib region. Water-storage cells with pleated outlines are present. Intercellular spaces are absent. Starch grains are present in mesophyll cells. **Vascular Bundle:** Vascular bundles are arranged in one row in stagger manner with a large bundle in the midrib. The larger and smaller bundles are found alternating each other. Vascular bundle is small and lies towards the abaxial side. The vascular bundle is conjoint, collateral, closed, oval in shape and composed of xylem and phloem. Mid-rib vascular bundle measures 126.54 μm (l) x 106.56 μm (w). Xylem lies towards the adaxial side, 9.99 μm – 19.98 μm (l) x 6.66 μm – 16.65 μm (w) and phloem towards abaxial side, 4.99 μm – 6.66 μm (l) x 3.33 μm – 4.99 μm (w) in the vascular bundle. Xylem vessels have heavily lignified. Bundle sheath cell is absent. Fibre cap is made up of sclerenchymatous cells, well developed at both xylem and phloem poles of mid-rib bundle but better developed at xylem pole of small lateral bundles. C-shaped fibre cap is present at xylem and phloem poles. Xylem cap is 2-layered, 19.98 μm (l) x 86.58 μm (w) and phloem cap 3-layered, 19.98 μm (l) x 89.91 μm (w) (Plate 7B) (Table 8). Stigmata with rough-surfaced spherical silica bodies are present along phloem cap and found associated with phloem cells (Plate 30C).

Transverse Section of Stem

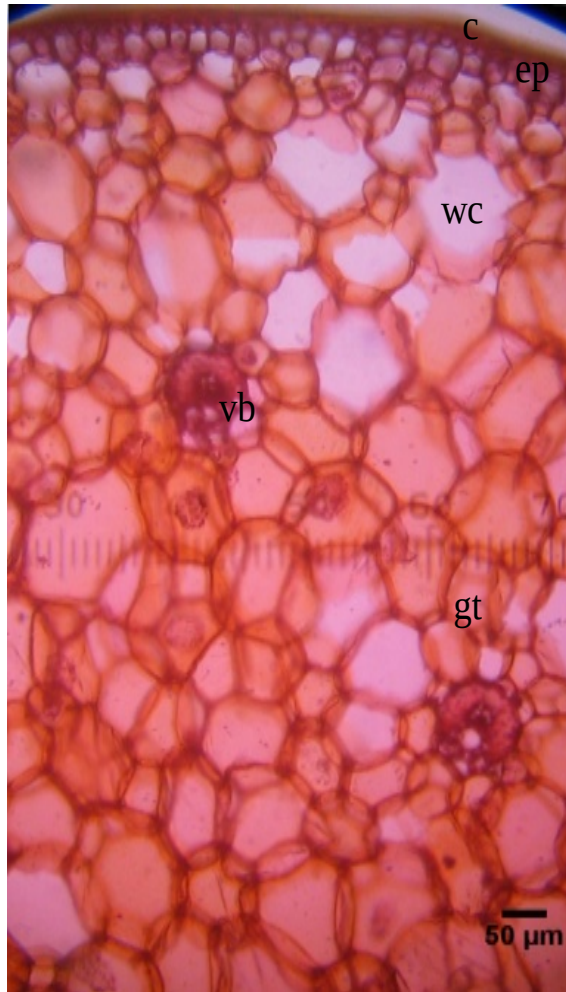
The surface layer of stem is irregular with ridges and furrows and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of barrel-shaped parenchymatous cells. The cells are thick-walled. The epidermal cell varies from 9.99 μm - 13.32 μm (w) x 16.65 μm - 26.64 μm (l) in

size. **Hypodermis:** Epidermis is followed by hypodermis. Hypodermis is made up of 1 layer of thick-walled polygonal parenchymatous cells. Hypodermal cells are smaller than ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with pleated outlines. Raphide bundles and starch grains are present in parenchymatous cells. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 82. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is oval-shaped in outline. The size of vascular bundle ranges from 133.20 μm – 236.43 μm (l) x 103.23 μm – 106.56 μm (w). The vascular bundle consists of xylem and phloem. Phloem lies facing towards periphery, 6.66 μm – 13.32 μm (l) x 4.99 μm – 6.66 μm (w) and xylem towards centre, 13.32 μm – 26.64 μm (l) x 9.99 μm – 19.98 μm (w) in small to large sized vascular bundles. The broad fibre cap, 29.97 μm – 33.30 μm (l) x 99.90 μm – 93.24 μm (w) is present surrounding phloem. Sclerenchymatous bundle sheath cells are present surrounding xylem (Plate 7A) (Table 9). Stegmata with rough-surfaced spherical silica bodies are present along outer margin of fibre cap of phloem (Plate 30O).

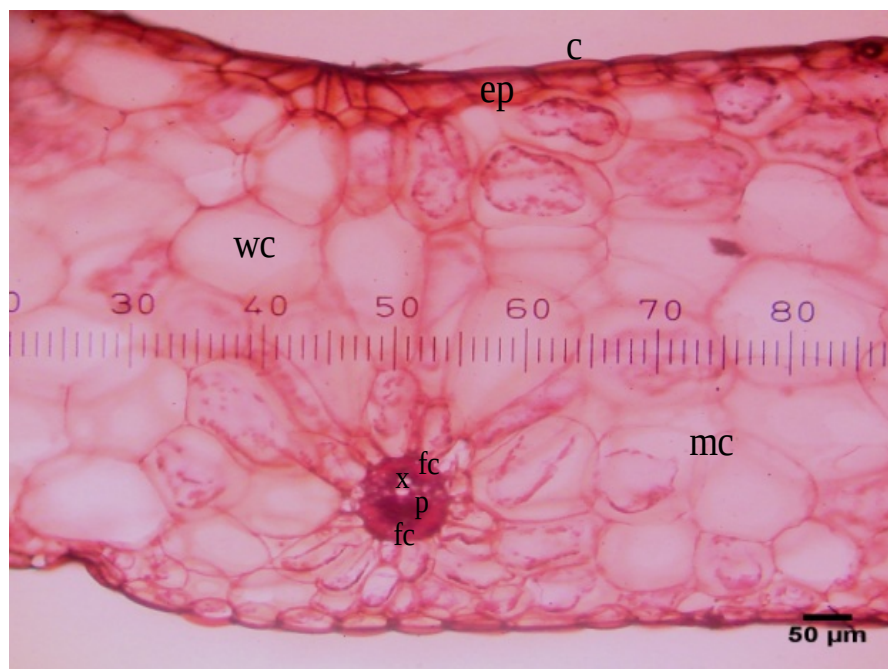
Plate 7. Anatomy of *Dendrobium aphyllum*

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc), water-storage cell (wc).



A



B

Dendrobium bicameratum

Transverse Section of Leaf

Cuticle: Cuticle is the outermost layer and present on both sides. It is thick and smooth. **Epidermis:** Leaf is covered with cutinous layer on both sides. A single layer of thick walled rectangular to polygonal shaped parenchymatous cells are present on both adaxial and abaxial surfaces. The cells are smaller towards mid-rib region on both sides. The adaxial cells are larger than those of abaxial cells. The adaxial cells are 13.32 μm – 49.95 μm (w) x 19.98 μm – 29.97 μm (l) and the abaxial cells 13.32 μm – 36.63 μm (w) x 9.99 μm – 13.32 μm (l). **Hypodermis:** Absent. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is homogenous. It consists of eight layers of oval, rectangular to polygonal chlorenchymatous cells but they are vertically elongated in adaxial side of mid-rib region. Intercellular spaces are present. Water-storage cells are absent. Some of mesophyll cells are hyaline. **Vascular Bundle:** Vascular bundles are arranged in one row with a large bundle in the midrib and large and small bundles are found alternating each other. The vascular bundle is conjoint, collateral, closed, oval in shape and composed of xylem and phloem. Mid-rib vascular bundle measures 119.88 μm (l) x 93.24 μm (w). Xylem lies towards the adaxial side, 6.66 μm – 13.32 μm (l) x 4.99 μm – 6.66 μm (w) and phloem towards abaxial side, 3.99 μm – 6.66 μm (l) x 2.66 μm – 3.33 μm (w) in the vascular bundle. The vascular bundle is surrounded by sclerenchymatous bundle sheath cells. C-shaped fibre cap is present surrounding xylem and phloem. Fibre cap is made up of sclerenchymatous cells. Xylem cap is 3-layered, 26.64 μm (l) x 89.91 μm (w) and phloem cap is 2-layered, 19.98 μm (l) x 93.24 μm (w) (Plate 8B) (Table 8). Stegmata with rough-surfaced spherical silica bodies are present along outer margin of fibre cap of xylem (Plate 30D).

Transverse Section of Stem

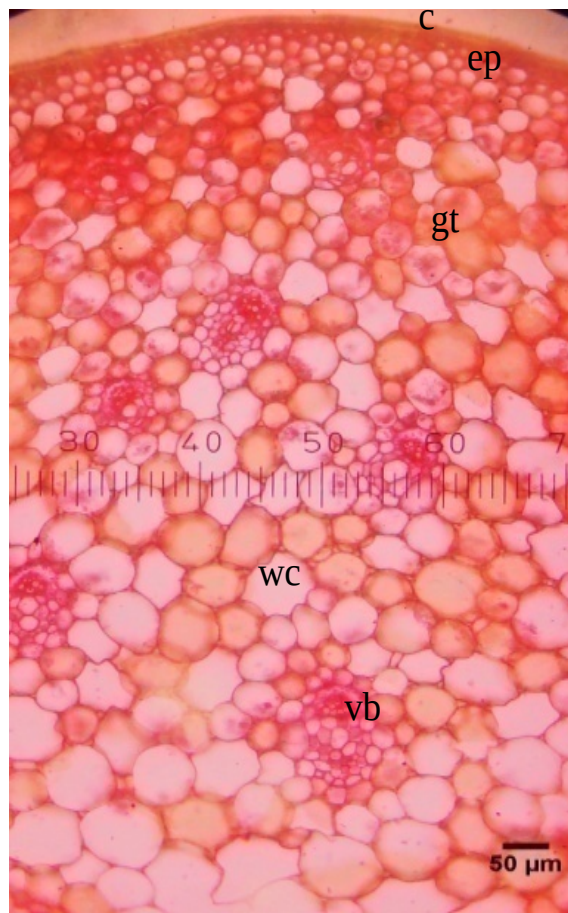
The surface layer of stem is irregular with ridges and furrows and surrounded by leaf sheaths. **Cuticle:** Cuticle is the outermost layer. It is thick and smooth. **Epidermis:** Cuticle is followed by epidermis. Epidermis is represented by a single layer of barrel shaped, thick-walled sclerified parenchymatous cells. The epidermal cell varies from 9.99 μm – 13.32 μm (w) x 6.66 μm - 9.99 μm (l) in size. **Hypodermis:** Below the epidermis is hypodermis. Hypodermis is made up of 2-3 layers of irregular or

polygonal shaped, moderately thick-walled sclerenchymatous cells. Outer hypodermal cells are smaller than inner cells. The hypodermal cells are smaller in size than ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with pleated outlines. Starch grains are present in parenchymatous cells. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. The vascular bundles are scattered in the ground tissue. The number of vascular bundle is 118. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is elongate shaped in outline. The size of vascular bundle ranges from 93.24 μm – 199.80 μm (l) x 83.25 μm – 93.24 μm (w). The vascular bundle consists of xylem and phloem. Xylem is facing towards centre, 13.32 μm – 33.30 μm (l) x 6.66 μm – 26.64 μm (w) and phloem towards periphery, 4.99 μm – 6.66 μm (l) x 3.33 μm – 6.66 μm (w) in small to large sized vascular bundles. Fibre cap is present surrounding the phloem, 16.65 μm – 33.30 μm (l) x 49.95 μm – 66.60 μm (w). Sclerenchymatous bundle sheath cells are present surrounding xylem (Plate 7A) (Table 9). Few stigmata with rough-surfaced silica bodies is present along outer margin of fibre cap of phloem (Plate 30P).

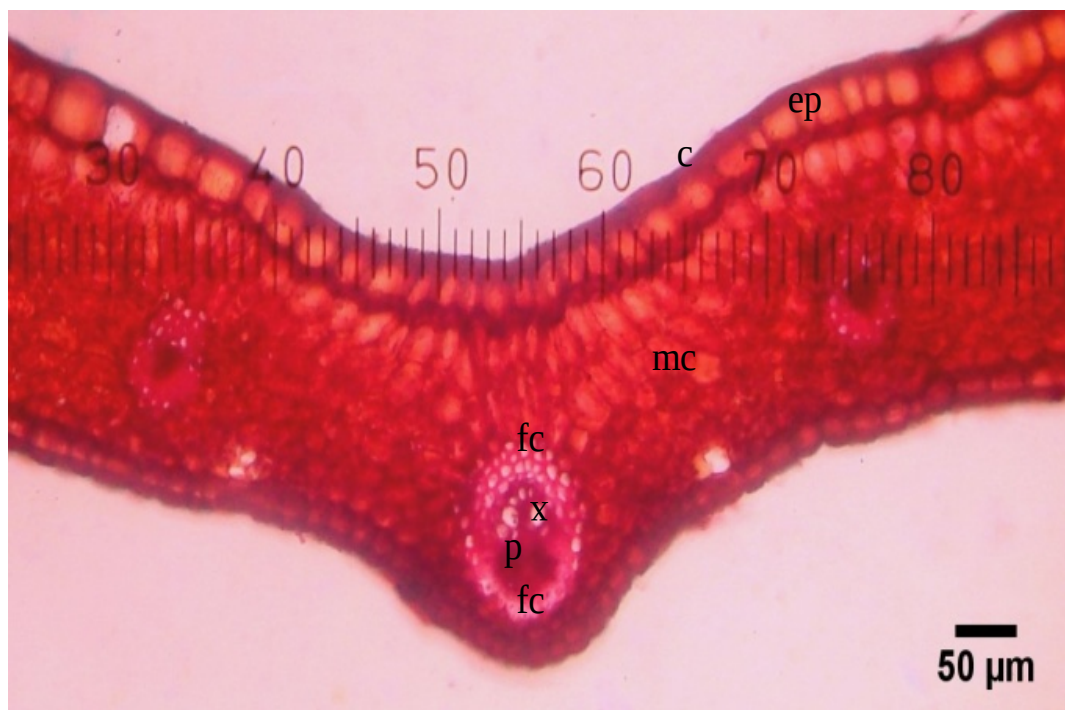
Plate 8. Anatomy of *Dendrobium bicameratum*.

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc), water-storage cell (wc).



A



B

Dendrobium chrysanthum

Transverse Section of Leaf

Cuticle: Cuticle is the outermost layer and present on both sides. It is thick and smooth but irregular in midrib region. **Epidermis:** A single layer of thin-walled, rectangular to polygonal parenchymatous cells is present on both adaxial and abaxial sides. The adaxial cells are larger than those of abaxial cells. The adaxial cells are $19.98\text{ }\mu\text{m} - 73.26\text{ }\mu\text{m}$ (w) x $16.65\text{ }\mu\text{m} - 26.64\text{ }\mu\text{m}$ (l) and the abaxial cells are $9.99\text{ }\mu\text{m} - 36.63\text{ }\mu\text{m}$ (w) x $9.99\text{ }\mu\text{m} - 19.98\text{ }\mu\text{m}$ (l). Epidermis in the mid-rib comprises square, hexagonal and polygonal cells. Cells at midrib region on both sides are smaller than other cells. **Hypodermis:** Absent. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is homogenous. It consists of eight layers of rectangular chlorenchymatous cells. Starch grains are present in mesophyll cells. Intercellular spaces and water-storage cells are absent. Some cells are hyaline without chloroplast. **Vascular Bundle:** Vascular bundles are arranged in one row with a large bundle in the midrib and large and small bundles are found alternating each other. Vascular bundle is conjoint, collateral, closed and oval in shape. Mid-rib vascular bundle is $219.79\text{ }\mu\text{m}$ (l) x $209.78\text{ }\mu\text{m}$ (w). Vascular bundle is composed of xylem and phloem. Xylem lies towards the adaxial side, $9.9\text{ }\mu\text{m} - 19.98\text{ }\mu\text{m}$ (l) x $8.32\text{ }\mu\text{m} - 19.98\text{ }\mu\text{m}$ (w) and phloem towards abaxial side, $6.66\text{ }\mu\text{m} - 9.99\text{ }\mu\text{m}$ (l) x $3.33\text{ }\mu\text{m} - 6.66\text{ }\mu\text{m}$ (w) in the vascular bundle. The vascular bundle is surrounded by chlorenchymatous bundle sheath cells. Bundle sheath cells are continuous around mid-rib bundle, larger and smaller lateral bundles. Sclereid caps are well developed at xylem and phloem poles of midrib bundle, larger and smaller lateral bundles. Sclereid cap is U-shaped towards xylem poles and C-shaped towards phloem poles. Xylem cap is 7-layered, $49.95\text{ }\mu\text{m}$ (l) x $186.48\text{ }\mu\text{m}$ (w) and phloem cap is 5-layered, $36.63\text{ }\mu\text{m}$ (l) x $183.15\text{ }\mu\text{m}$ (w) in midrib bundle (Plate 9B) (Table 8). Stigmata with rough-surfaced spherical silica bodies are present along the outer margin of xylem and phloem sclereid caps (Plate 30E).

Transverse Section of Stem

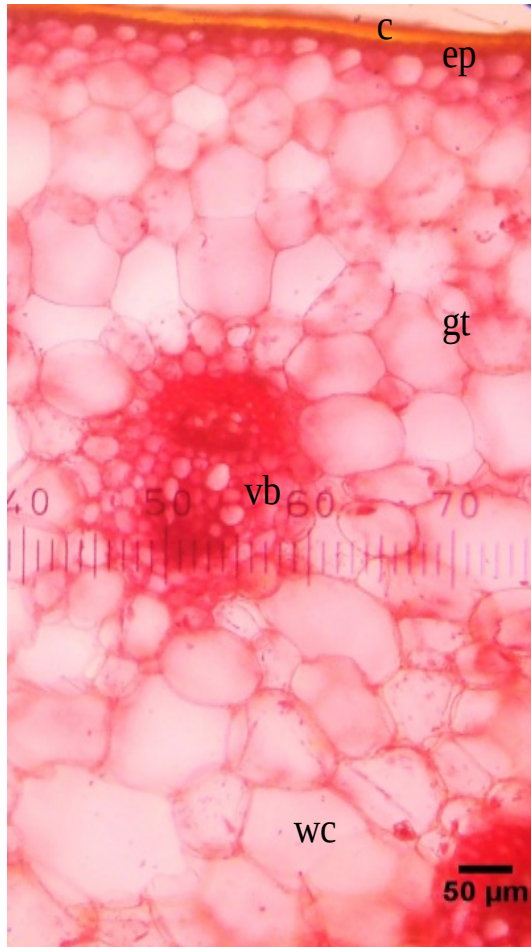
The surface layer of the stem is irregular with ridges and furrows and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is

represented by a single layer of thick-walled, barrel-shaped parenchymatous cells. The epidermal cell varies from 13.32 μm - 19.98 μm (w) x 9.99 μm - 13.32 μm (l) in size. **Hypodermis:** Epidermis is followed by hypodermis. Hypodermis is made up of 2 layers of oval, angular and polygonal shaped thick-walled sclerenchymatous cells. Outer hypodermal cells are smaller in size than the inner hypodermal cells. Hypodermal cells are smaller than ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and larger, scattered, dead, water-storage cells with pleated outlines. Starch grains and raphide bundles are present in parenchymatous cells. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. The number of vascular bundle is 70. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is elongate-shaped in outline. The size of vascular bundle ranges from 103.23 μm – 266.40 μm (l) x 83.25 μm – 133.20 μm (w). The vascular bundle consists of xylem and phloem. Phloem lies facing towards periphery, 4.99 μm – 9.99 μm (l) x 3.33 μm – 6.66 μm (w) and xylem towards centre, 9.99 μm – 33.30 μm (l) x 9.99 μm – 29.97 μm (w) in small to large sized vascular bundles. Fibre cap is present surrounding phloem, 16.65 μm – 33.30 μm (l) x 83.25 μm – 96.57 μm (w). Sclerenchymatous bundle sheath cells are present surrounding vascular bundles (Plate 9A) (Table 9). Stigmata is indistinct.

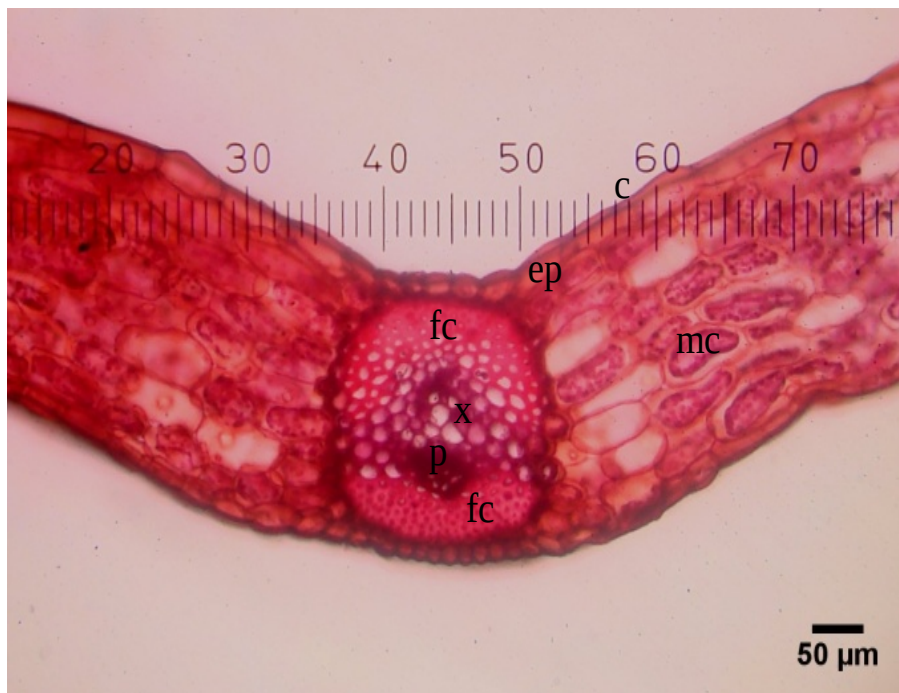
Plate 9. Anatomy of *Dendrobium chrysanthum*

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc).



A



B

Dendrobium crepidatum

Transverse Section of Leaf

Cuticle: Cuticle is the outermost layer and present on both sides. It is thin and smooth. **Epidermis:** A single layer of thin-walled, square, rectangular to polygonal parenchymatous cells with rounded angles is present on both adaxial and abaxial sides. The adaxial cells are larger than those of abaxial cells. The adaxial cells measure $19.98\ \mu\text{m} - 43.29\ \mu\text{m}$ (w) $\times$ $13.32\ \mu\text{m} - 43.29\ \mu\text{m}$ (l). The abaxial cells measure $8.32\ \mu\text{m} - 26.64\ \mu\text{m}$ (w) $\times$ $13.32\ \mu\text{m} - 26.64\ \mu\text{m}$ (l). Cells at midrib region on both sides are smaller than other cells. **Hypodermis:** Absent. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is homogenous. It consists of ten layers of rectangular, oval to polygonal thin-walled chlorenchymatous cells with abundant chloroplasts. Starch grains are present in mesophyll cells. Idioblast with raphide bundle is present in mesophyll cells. Raphide bundle is elongated parallel to midrib. Idioblast cells are larger than adjacent assimilatory cells. Intercellular spaces and water-storage cells are absent. **Vascular Bundle:** Vascular bundles are arranged in one row with a large bundle in the midrib and large and small bundles are found alternating each other. Vascular bundle is conjoint, collateral, closed and conical in shape. Mid-rib vascular bundle measures $233.10\ \mu\text{m}$ (l) $\times$ $166.50\ \mu\text{m}$ (w). Vascular bundle consists of xylem and phloem. Xylem lies towards the adaxial side, $13.32\ \mu\text{m} - 19.98\ \mu\text{m}$ (l) $\times$ $11.65\ \mu\text{m} - 13.32\ \mu\text{m}$ (w) and phloem towards abaxial sides, $4.99\ \mu\text{m} - 8.32\ \mu\text{m}$ (l) $\times$ $3.33\ \mu\text{m} - 4.99\ \mu\text{m}$ (w) in the vascular bundle. The vascular bundle is surrounded by chlorenchymatous bundle sheath cells. Bundle sheath cells are continuous around mid-rib bundle, larger and smaller lateral bundles. Fibre caps are well developed at phloem poles and less developed at xylem poles of midrib bundle, larger and smaller lateral bundles. Fibre cap is small towards xylem poles and C-shaped towards phloem poles. Xylem cap is 4-layered, $43.29\ \mu\text{m}$ (l) $\times$ $126.54\ \mu\text{m}$ (w) and phloem cap is 6-layered, $53.28\ \mu\text{m}$ (l) $\times$ $173.16\ \mu\text{m}$ (w), in midrib bundle (Plate 10B) (Table 8). Stigmata with rough-surfaced spherical silica bodies are present along the outer margin of phloem fibre cap (Plate 30F).

Transverse Section of Stem

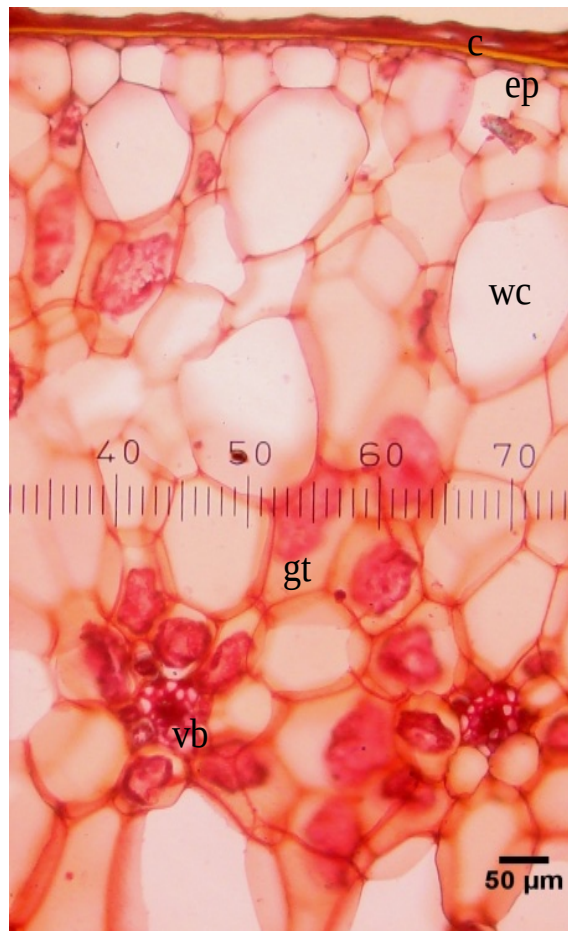
The surface layer of the stem is irregular with ridges and furrows and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is

represented by a single layer of thick-walled, rectangular to polygonal-shaped parenchymatous cells. The epidermal cell varies from 13.32 μm – 36.63 (w) x 6.66 μm - 16.65 μm (l) in size. **Hypodermis:** Epidermis is followed by hypodermis. Hypodermis is made up of one layer of oblong, square, angular and polygonal shaped parenchymatous cell. Hypodermal cells are smaller than ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells without intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with unpleated outlines. Starch grains are present in parenchymatous cells. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. The vascular bundles are scattered in the ground tissue. The number of vascular bundle is 60. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is oval-shaped in outline. The size of vascular bundle ranges from 123.21 μm – 209.79 μm (l) x 83.25 μm – 99.90 μm (w). The vascular bundle consists of xylem and phloem. Phloem lies facing towards periphery, 4.99 μm – 9.99 μm (l) x 3.33 μm – 9.32 μm (w) and xylem towards centre, 13.32 μm – 26.64 μm (l) x 6.66 μm – 19.98 μm (w). Fibre cap is present surrounding phloem, 19.98 μm – 26.64 μm (l) x 49.95 μm – 66.60 μm (w). Sclerenchymatous bundle sheath cells are present surrounding xylem and phloem. Around bundle sheath cells of vascular bundle, parenchymatous cells containing starch grains are present (Plate 10A) (Table 9). Stegmata is indistinct.

Plate 10. Anatomy of *Dendrobium crepidatum*.

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc).



A



C

Dendrobium denneanum

Transverse Section of Leaf

Cuticle: Cuticle is the outermost layer and present on both sides. It is thick on adaxial side and moderately thick on abaxial side, irregular and undulating. **Epidermis:** A single layer of thin-walled, rectangular to polygonal parenchymatous cells is present on both adaxial and abaxial sides. Cells at midrib region on both sides are smaller than other cells. The adaxial cells are larger than those of abaxial cells. The adaxial cells measure $19.98\text{ }\mu\text{m} - 33.30\text{ }\mu\text{m}$ (w) x $13.32\text{ }\mu\text{m} - 16.65\text{ }\mu\text{m}$ (l). The abaxial cells measure $16.65\text{ }\mu\text{m} - 26.64\text{ }\mu\text{m}$ (w) x $8.32\text{ }\mu\text{m} - 9.99\text{ }\mu\text{m}$ (l). **Hypodermis:** Absent. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is homogenous. It consists of eight layers of rectangular, oval to polygonal thin-walled chlorenchymatous cells. Druses are present in mesophyll cells. Intercellular spaces and water-storage cells are absent. Some cells are hyaline. **Vascular Bundle:** Vascular bundles are arranged in one row with a large bundle in the midrib, large and small bundles are found alternating each other. The vascular bundle is conjoint, collateral, closed, conical in shape and composed of xylem and phloem. Mid-rib vascular bundle measures $216.45\text{ }\mu\text{m}$ (l) x $189.81\text{ }\mu\text{m}$ (w). Xylem is facing towards the adaxial side, $6.66\text{ }\mu\text{m} - 19.98\text{ }\mu\text{m}$ (l) x $4.99\text{ }\mu\text{m} - 16.65\text{ }\mu\text{m}$ (w) and phloem towards abaxial sides, $3.33\text{ }\mu\text{m} - 6.66\text{ }\mu\text{m}$ (l) x $3.33\text{ }\mu\text{m} - 4.99\text{ }\mu\text{m}$ (w). The vascular bundle is surrounded by chlorenchymatous bundle sheath cells. Bundle sheath cells are continuous around mid-rib bundle, larger and smaller lateral bundles. Fibre caps are well developed at phloem poles and xylem poles of midrib bundle, larger and smaller lateral bundles. C-shaped fibre cap and C-shaped sclereid cap are present towards xylem poles and phloem poles respectively. Xylem cap is 4-layered, $49.95\text{ }\mu\text{m}$ (l) x $166.50\text{ }\mu\text{m}$ (w) and phloem cap is 5-layered, $33.30\text{ }\mu\text{m}$ (l) x $176.49\text{ }\mu\text{m}$ (w) (Plate 11B) (Table 8). Stigmata is indistinct.

Transverse Section of Stem

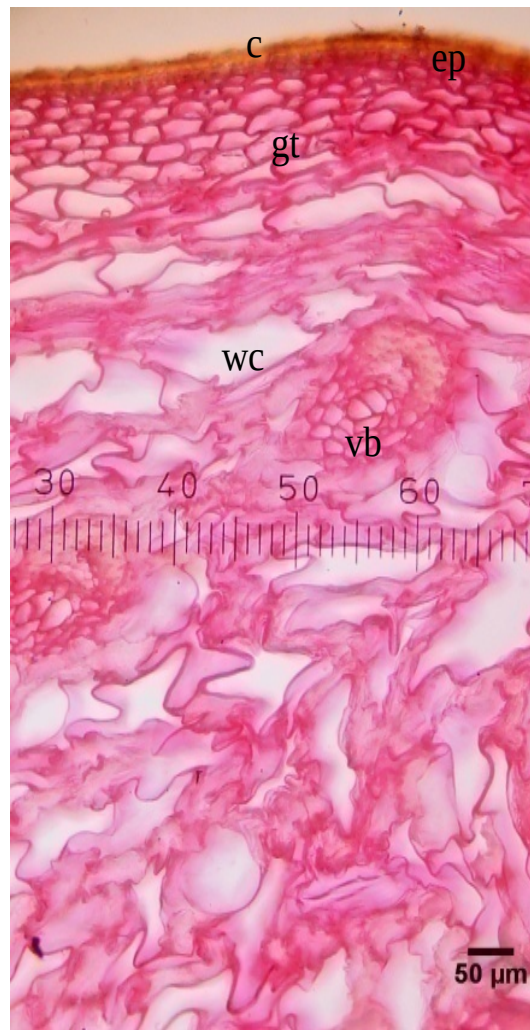
The surface layer of the stem is irregular with big ridges and furrows and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of barrel-shaped sclereid parenchymatous cells. The cells are thick-walled. The epidermal cell varies from $9.99\text{ }\mu\text{m} - 19.98\text{ }\mu\text{m}$ (w) x $6.66\text{ }\mu\text{m} -$

13.32 μm (l) in size. **Hypodermis:** Epidermis is followed by hypodermis. Hypodermis is made up of 4 layers of rectangular, square, angular and polygonal shaped sclerenchymatous cells. Outer hypodermal cells are smaller than inner cells. Hypodermal cells are smaller than ground tissues in size. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, larger, scattered dead, water-storage cells with pleated outlines. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 97. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is elongate-shaped in outline. The vascular bundle ranges from 163.17 μm – 299.70 μm (l) x 143.19 μm – 149.85 μm (w). The vascular bundle consists of xylem and phloem. Phloem lies facing towards periphery, 9.99 μm – 13.32 μm (l) x 6.66 μm – 9.99 μm (w) and xylem towards centre, 43.29 μm – 49.95 μm (l) x 23.31 μm – 26.64 μm (w). Fibre cap is present surrounding phloem, 39.96 μm – 49.95 μm (l) x 116.55 μm – 119.88 μm (w). Sclerenchymatous bundle sheath cells are present surrounding xylem (Plate 11A) (Table 9). Stegmata is indistinct.

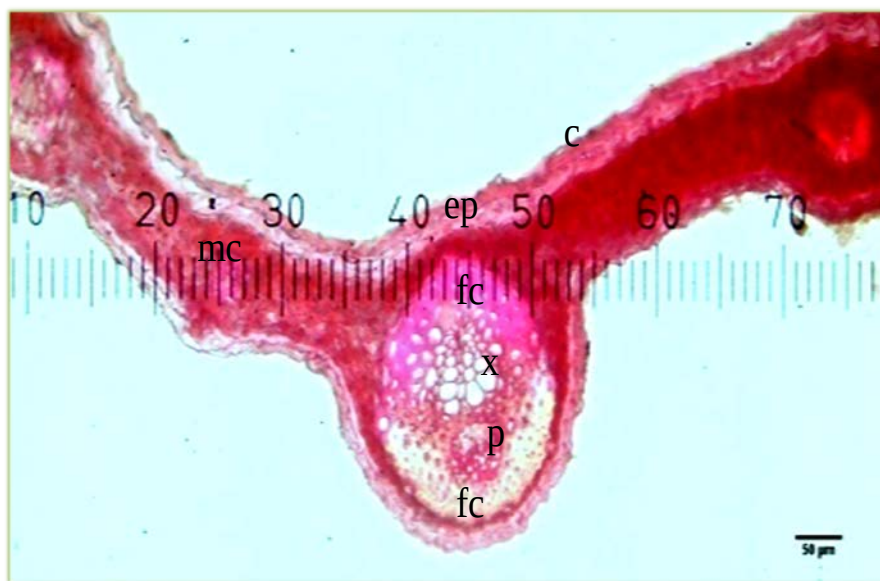
Plate 11. Anatomy of *Dendrobium denneanum*

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc).



A



B

Dendrobium densiflorum

Transverse Section of Leaf

Cuticle: Cuticle is the outermost layer and present on both sides. It is smooth, thick adaxially and thin, slightly undulating abaxially. **Epidermis:** A single layer of thick-walled, rectangular, square, oval to polygonal parenchymatous cells with rounded angles is present on both adaxial and abaxial sides. The adaxial cells are larger than those of abaxial cells. The adaxial cells are $23.31\ \mu\text{m} - 36.63\ \mu\text{m}$ (w) $\times$ $13.32\ \mu\text{m} - 23.31\ \mu\text{m}$ (l) and the abaxial cells are $16.65\ \mu\text{m} - 26.64\ \mu\text{m}$ (w) $\times$ $13.32\ \mu\text{m} - 19.98\ \mu\text{m}$ (l). Cells at midrib region on both sides are smaller than other cells. **Hypodermis:** A single layer of oval to polygonal parenchymatous cells is present. It is distinct in adaxial side and less distinct in abaxial side. Periclinal walls of cells are thicker than mesophyll cells. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is homogenous. It consists of thirteen layers of oval, rounded to polygonal thin-walled chlorenchymatous cells with abundant chloroplasts. Calcium oxalate crystals are found in different forms such as styloid, quadrate, spindle, prismatic and rhomboids in mesophyll. Intercellular spaces are small and water-storage cells are absent. **Vascular Bundle:** Vascular bundles are arranged in one row with a large bundle in the midrib, small and large bundles on either sides of midrib. Small and large lateral bundles are not alternating each other but large lateral bundle lies only after three small bundles from midrib. The vascular bundle is large, conjoint, collateral, closed and conical in shape. Mid-rib vascular bundle measures $586.52\ \mu\text{m}$ (l) $\times$ $386.57\ \mu\text{m}$ (w). The vascular bundle consists of xylem and phloem. Xylem lies towards the adaxial side, $16.65\ \mu\text{m} - 29.97\ \mu\text{m}$ (l) $\times$ $6.66\ \mu\text{m} - 16.65\ \mu\text{m}$ (w) and phloem towards abaxial side, $4.99\ \mu\text{m} - 9.99\ \mu\text{m}$ (l) $\times$ $3.33\ \mu\text{m} - 6.66\ \mu\text{m}$ (w). The vascular bundle is surrounded by chlorenchymatous bundle sheath cells. Bundle sheath cells are continuous around mid-rib bundle, larger and smaller lateral bundles. Sclereid caps are well developed at xylem and phloem poles of midrib bundle, larger and smaller lateral bundles. Sclereid cap is dome-shaped towards xylem poles and C-shaped towards phloem poles. Xylem cap is 11-layered, $213.28\ \mu\text{m}$ (l) $\times$ $319.92\ \mu\text{m}$ (w), and phloem cap is 12-layered, $146.63\ \mu\text{m}$ (l) $\times$ $413.23\ \mu\text{m}$ (w). Phloem is completely surrounded by sclerenchymatous cells (Plate 12B) (Table 8). Stegmata is indistinct.

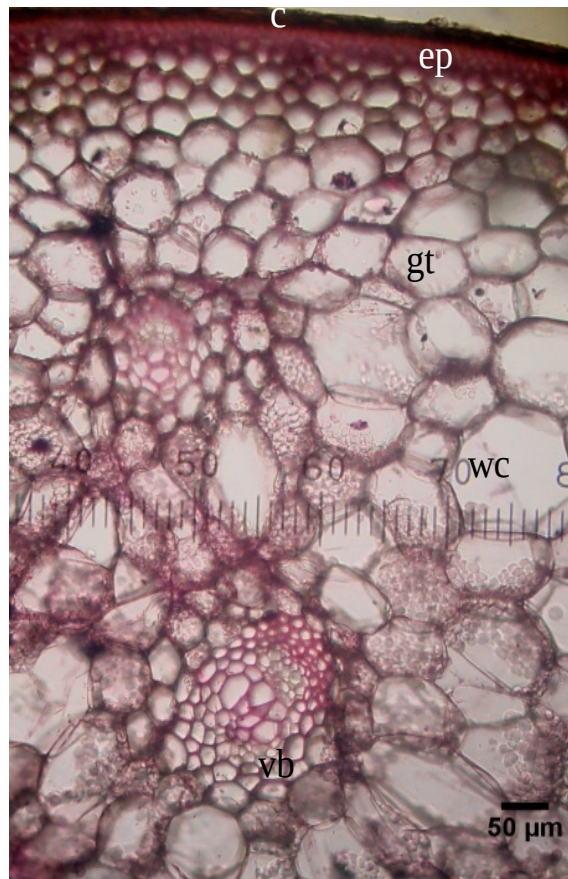
Transverse Section of Stem

The surface layer of the stem is irregular and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of rectangular, sclereid parenchymatous cells. The cells are thick-walled. The epidermal cell varies from 6.66 μm – 9.99 μm (w) x 16.65 μm – 16.65 μm (l) in size. **Hypodermis:** Epidermis is followed by hypodermis. Hypodermis is made up of 4 or 5 layers of rectangular, square, angular and polygonal shaped sclerenchymatous cells. Outer layer of cells are smaller than inner layer of cells. Hypodermal cells are smaller than ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with unpleated outlines. Large no. of starch grains is present in parenchymatous cells. Raphide bundles are present in parenchymatous cells. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 78. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is oval-shaped in outline, 106.56 μm – 206.46 μm (l) x 89.91 μm – 153.18 μm (w). The vascular bundle consists of xylem and phloem. Phloem lies facing towards periphery, 9.99 μm – 13.32 μm (l) x 4.99 μm – 9.99 μm (w) and xylem towards centre, 9.99 μm – 29.97 μm (l) x 6.66 μm – 26.64 μm (w). Fibre cap is present surrounding phloem, 26.64 μm – 36.63 μm (l) x 83.25 μm – 119.88 μm (w). Sclerenchymatous bundle sheath cells are present surrounding xylem (Plate 12A) (Table 9). Stegmata all with rough-surfaced spherical silica bodies are found along outer margin of fibre cap of phloem (Plate 30Q).

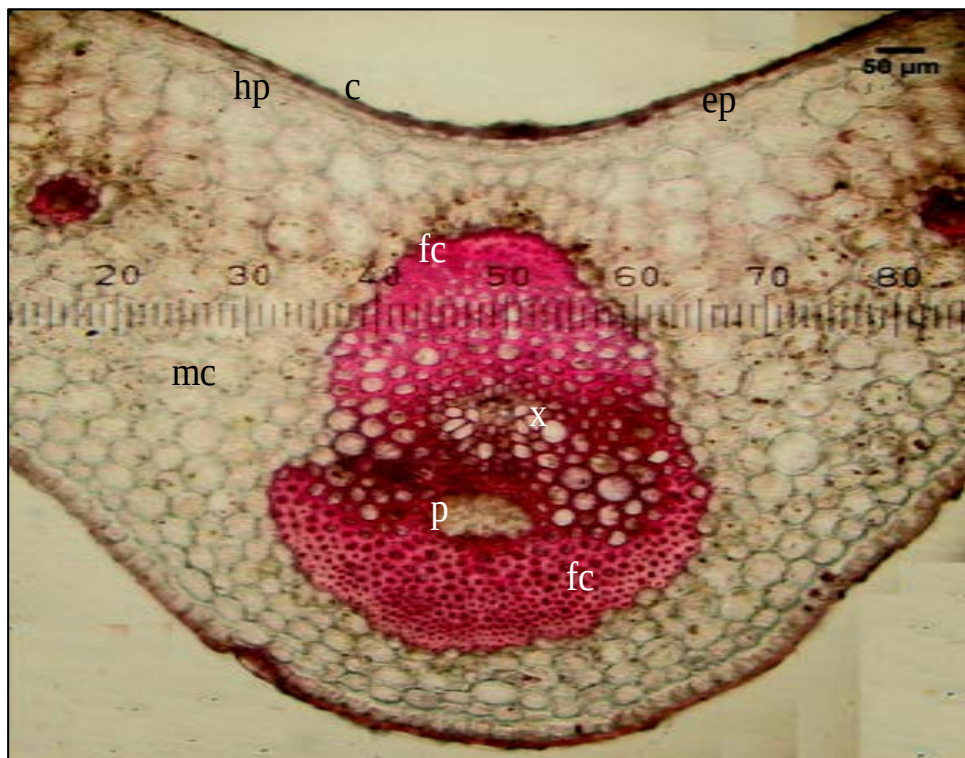
Plate 12. Anatomy of *Dendrobium densiflorum*.

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), hypodermis (hp), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc).



A



B

Dendrobium fimbriatum

Transverse Section of Leaf

Cuticle: Cuticle is the outermost layer and present on both sides. It is thin and smooth. **Epidermis:** A single layer of thin-walled, square, rectangular to polygonal parenchymatous cells with rounded angles is present on both adaxial and abaxial sides. The adaxial cells are larger than those of abaxial cells. The adaxial cells are 16.65 μm – 39.96 μm (w) x 13.32 μm – 26.64 μm (l) and abaxial cells are 9.99 μm – 23.31 μm (w) x 6.66 μm – 16.65 μm (l). Cells at midrib region on both sides are smaller than other cells. **Hypodermis:** Absent. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is homogenous. It consists of seven layers of rectangular, oval to polygonal thin-walled chlorenchymatous cells with abundant chloroplasts. Starch grains are present in mesophyll cells. Some of cells are hyaline without chloroplasts. Intercellular spaces and small and water-storage cells are absent. **Vascular Bundle:** Vascular bundles are arranged in one row with a large bundle in the midrib and large and small bundles are found alternating each other. The vascular bundle is conjoint, collateral, closed and oval in shape. Mid-rib vascular bundle measures 169.83 μm (l) x 123.21 μm (w). The vascular bundle is composed of xylem and phloem. Xylem lies towards the adaxial side, 9.99 μm – 19.98 μm (l) x 9.99 μm – 16.65 μm (w) and phloem towards abaxial side, 3.33 μm – 6.66 μm (l) x 1.66 μm – 4.99 μm (w). The vascular bundle is surrounded by chlorenchymatous bundle sheath cells. Bundle sheath cells are continuous around mid-rib, larger and smaller lateral bundles. Xylem and phloem are completely surrounded by sclereid cap in midrib, larger and smaller lateral bundles. Xylem cap is 5-layered, 43.29 μm (l) x 116.55 μm (w), and phloem cap is 4-layered, 33.30 μm (l) x 129.80 μm (w) (Plate 13B) (Table 8). Stigmata is indistinct.

Transverse Section of Stem

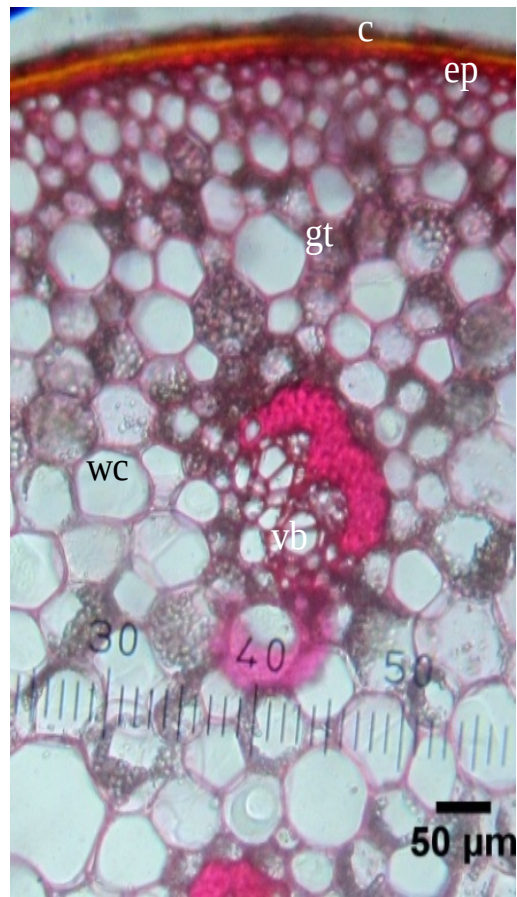
The surface layer of the stem is irregular and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of barrel-shaped parenchymatous cells. The cells are thick-walled. The epidermal cell varies from 13.32 μm – 16.65 μm (w) x 9.99 μm – 9.99 μm (l) in size. **Hypodermis:** Epidermis is followed by hypodermis. Hypodermis is made up of 4 or 5 layers of rectangular, square, angular and polygonal shaped sclerenchymatous cells. Outer layer

of cells are smaller than inner layer of cells. Hypodermal cells are smaller than ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled elongated parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal parenchymatous cells and fewer, large, scattered, dead, water-storage cells with unpleated outlines. Starch grains are present in parenchymatous cells. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 62. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is oval-shaped in outline. The size of vascular bundle ranges from 133.20 μm – 199.80 μm (l) x 109.89 μm – 133.20 μm (w). The vascular bundle consists of xylem and phloem. Phloem lies facing towards periphery, 6.66 μm – 16.65 μm (l) x 4.99 μm – 9.99 μm (w) and xylem towards centre, 26.64 μm – 49.95 μm (l) x 9.99 μm – 13.32 μm (w). Sclereid cap is present surrounding phloem, 39.96 μm – 43.29 μm (l) x 106.56 μm – 123.21 μm (w). Sclerenchymatous bundle sheath cells are present surrounding xylem (Plate 13A) (Table 9). Stegmata is indistinct. Commissural vascular bundle which connects two vascular bundles is present.

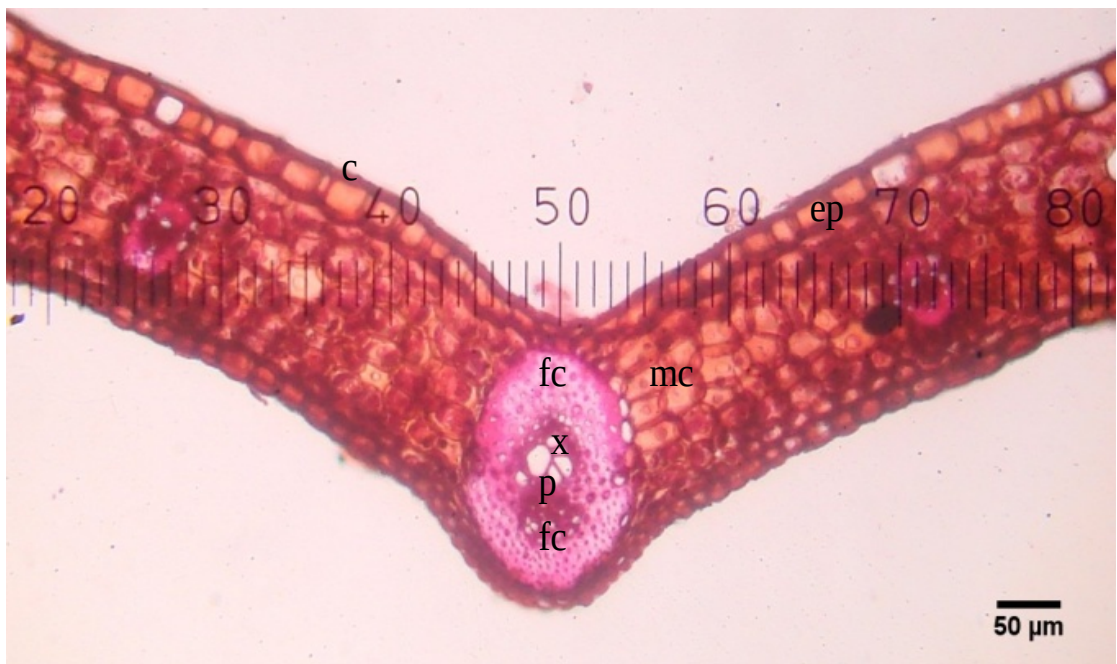
Plate 13. Anatomy of *Dendrobium fimbriatum*

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc).



A



B

Dendrobium gibsonii

Transverse Section of Leaf

Cuticle: Cuticle is the outermost layer and present on both sides. It is thin and smooth but undulating, smooth in adaxial side and irregular in abaxial side in midrib region.

Epidermis: A single layer of thin-walled, rectangular, square to polygonal parenchymatous cells with rounded angles is present on both adaxial and abaxial sides. The adaxial cells are larger than those of abaxial cells. The adaxial cells measure 23.31 μm – 66.60 μm (w) x 13.32 μm – 33.30 μm (l) and the abaxial cells measure 16.65 μm – 33.30 μm (w) x 13.32 μm – 16.65 μm (l). Cells at midrib region on both sides are smaller than other cells. **Hypodermis:** Absent. **Fibre Bundles:**

Absent. **Mesophyll:** Mesophyll is homogenous. It consists of eight layers of rectangular, oval to polygonal thin-walled chlorenchymatous cells with abundant chloroplasts. Idioblasts with mucilage are present in mesophyll. Some of cells are hyaline without chloroplasts. Intercellular spaces and small and water-storage cells are absent. **Vascular Bundle:** Vascular bundles are arranged in one row with a large bundle in the midrib and large and small bundles are found alternating each other. The vascular bundle is conjoint, collateral, closed and oval in shape. Midrib vascular bundle measures 289.71 μm (l) x 233.10 μm (w). The vascular bundle is composed of xylem and phloem. Xylem lies towards the adaxial side, 13.32 μm – 29.97 μm (l) x 6.66 μm – 23.31 μm (w) and phloem towards abaxial side, 4.99 μm – 9.99 μm (l) x 3.33 μm – 8.32 μm (w). The vascular bundle is surrounded by chlorenchymatous bundle sheath cells. Bundle sheath cells are discontinuous surrounding xylem of midrib, larger and smaller lateral bundles. Sclereid caps are well developed at phloem poles and fibre caps at xylem poles of midrib bundle, larger and smaller lateral bundles. C-shaped sclereid cap is present towards phloem pole and C-shaped fibre cap towards xylem pole of midrib bundle. Xylem cap is 5-layered, 83.25 μm (l) x 199.80 μm (w), and phloem cap is 4-layered, 49.95 μm (l) x 233.10 μm (w) (Plate 13B) (Table 8). Stegmata all with rough-surfaced, spherical silica bodies are present along outer margin of phloem cap. Stegmata is distinct in larger and smaller lateral bundles than midrib bundle (Plate 14J).

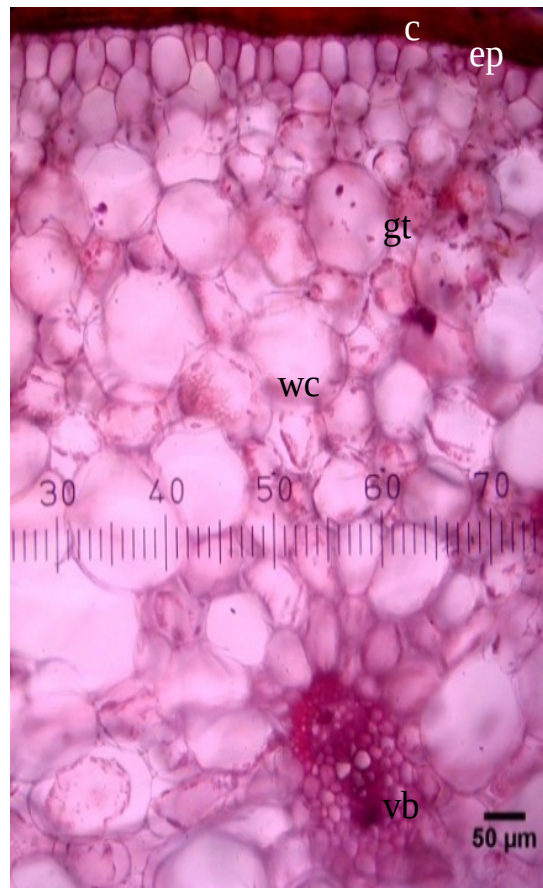
Transverse Section of Stem

The surface layer of stem is irregular and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of thick-walled rectangular to angular parenchymatous cells. The epidermal cell varies from 13.32 μm – 16.65 μm (w) x 6.66 μm – 13.32 μm (l) in size. **Hypodermis:** Below the epidermis is hypodermis. Hypodermis is made up of 2 layers of thick-walled elongated, polygonal sclerenchymatous cells. Outer layer of cells are smaller than inner layer of cells. The hypodermal cells are smaller in size than the ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with pleated outlines. Starch grains and raphide bundles are present in parenchymatous cells. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 30. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is oval-shaped in outline. The size of vascular bundle ranges from 123.31 μm – 316.35 μm (l) x 93.24 μm – 183.15 μm (w). The vascular bundle consists of xylem and phloem. Phloem lies towards periphery, 4.99 μm – 13.32 μm (l) x 3.33 μm – 9.99 μm (w) and xylem lies towards centre, 16.65 μm – 29.97 μm (l) x 9.99 μm – 19.98 μm (w). Fibre cap is present towards the upper side surrounding phloem, 16.65 μm – 69.93 (l) x 76.59 – 93.24 μm (w). Sclerenchymatous bundle sheath cells are present surrounding xylem on lower side (Plate 14A) (Table 9). Stegmata is indistinct.

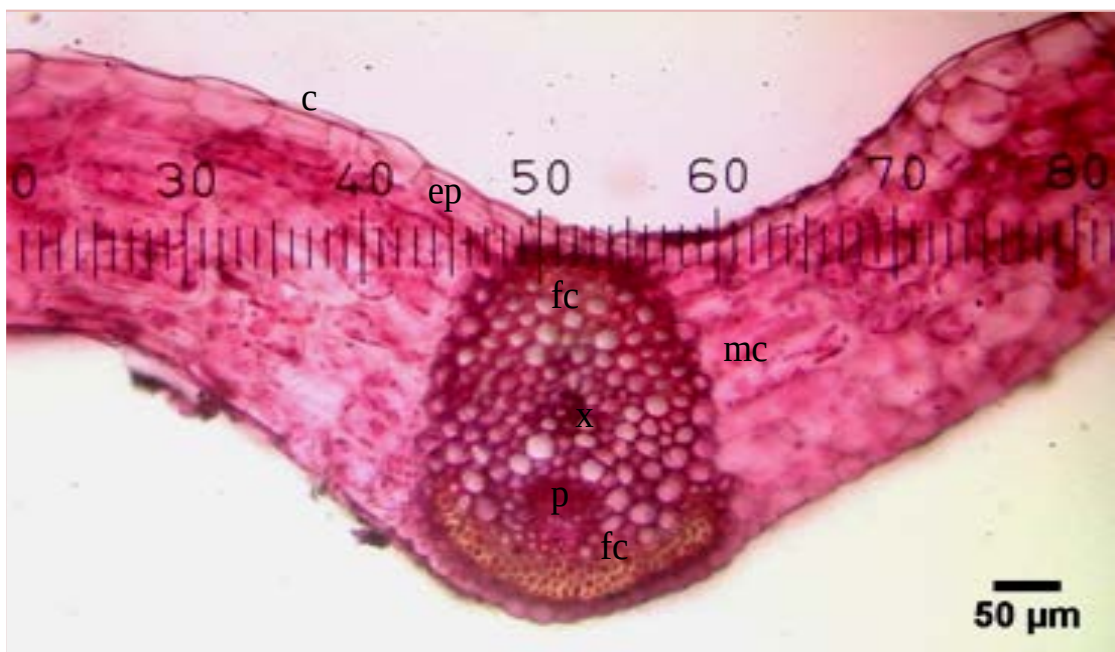
Plate 14. Anatomy of *Dendrobium gibsonii*

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc).



A



B

Dendrobium heterocarpum

Transverse Section of Leaf

Cuticle: Cuticle is the outermost layer and present on both sides. It is thin and smooth on adaxial side and undulating and irregular on abaxial side. **Epidermis:** A single layer of thin-walled, rectangular, square to polygonal parenchymatous cells is present on both adaxial and abaxial sides. The adaxial cells are larger than those of abaxial cells. The abaxial cells in midrib region are smaller than other cells. The adaxial cells measure $26.64\mu\text{m} - 73.26\mu\text{m}$ (w) $\times$ $26.64\mu\text{m} - 53.28\mu\text{m}$ (l) and the abaxial cells measure $9.99\mu\text{m} - 33.30\mu\text{m}$ (w) $\times$ $13.32\mu\text{m} - 26.64\mu\text{m}$ (l). The anticlinal walls of adaxial cells are sinuous. Cells at midrib region are bulliform on adaxial side. **Hypodermis:** Absent. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is homogenous. It consists of seven layers of rectangular, oval, to polygonal thin-walled chlorenchymatous cells with abundant chloroplasts. Idioblasts with mucilage are present in mesophyll. Some of cells are hyaline without chloroplasts. Intercellular spaces and small and water-storage cells are absent. **Vascular Bundle:** Vascular bundles are arranged in one row with a large bundle in the midrib, large and small bundles are found alternating each other. The vascular bundle is conjoint, collateral, closed and oval in shape. Midrib vascular bundle measures $149.85\mu\text{m}$ (l) $\times$ $116.55\mu\text{m}$ (w). Vascular bundle lies towards abaxial side. Vascular bundle consists of xylem and phloem. Xylem lies towards the adaxial side, $6.66\mu\text{m} - 19.98\mu\text{m}$ (l) $\times$ $4.99\mu\text{m} - 16.65\mu\text{m}$ (w) and phloem towards abaxial side, $3.99\mu\text{m} - 6.66\mu\text{m}$ (l) $\times$ $3.66\mu\text{m} - 4.99\mu\text{m}$ (w). Sclereid caps are well developed at phloem poles and fibre caps at xylem poles of midrib bundle, larger and smaller lateral bundles but phloem cap is better developed in larger lateral bundle. C-shaped sclereid cap is present towards phloem pole and C-shaped fibre cap towards xylem pole of midrib bundle. Xylem cap is 4-layered, $19.98\mu\text{m}$ (l) $\times$ $99.90\mu\text{m}$ (w) and phloem cap is 3-layered, $19.98\mu\text{m}$ (l) $\times$ $86.58\mu\text{m}$ (w). The vascular bundle is surrounded by chlorenchymatous bundle sheath cells. Bundle sheath cells are continuous in larger and smaller lateral bundles but discontinuous in midrib surrounding phloem only (Plate 15B) (Table 8). Stigmata is indistinct.

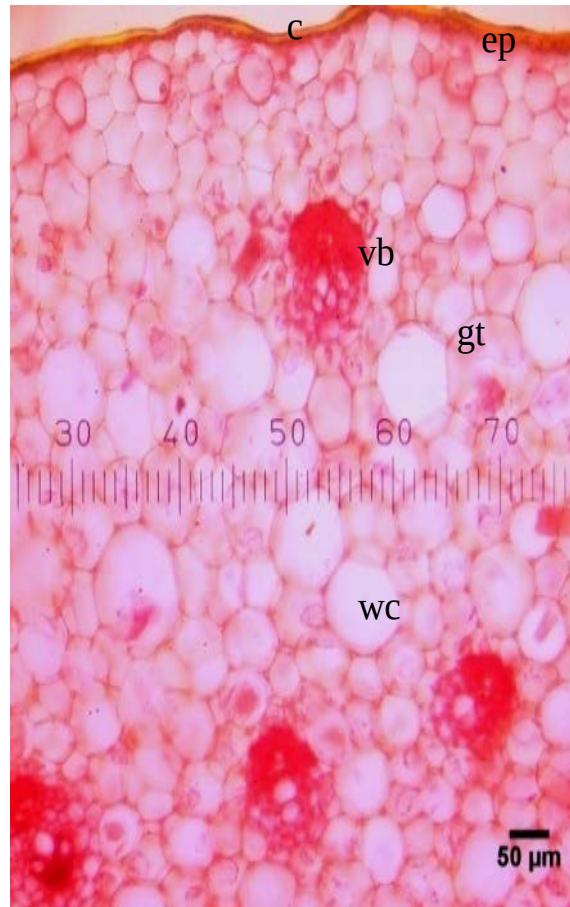
Transverse Section of Stem

The surface layer of stem is irregular and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of thick-walled rectangular to angular parenchymatous cells. The epidermal cell varies from 13.32 μm – 19.98 μm (w) x 6.66 μm – 13.32 μm (l) in size. **Hypodermis:** Below the epidermis is hypodermis. Hypodermis is made up of 2 layers of thick-walled elongated, polygonal sclerenchymatous cells. Outer layer of cells are smaller than inner layer of cells. The hypodermal cells are smaller in size than the ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with pleated outlines. Raphide bundles and starch grains are present in parenchymatous cells. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 80. The outer vascular bundles are smaller than the inner bundle. Each vascular bundle is oval-shaped in outline. The size of vascular bundle ranges from 116.55 μm – 179.82 (l) x 99.90 μm – 109.89 μm (w). The vascular bundle consists of xylem and phloem. Phloem lies towards periphery, 6.66 μm – 9.99 μm (l) x 4.99 μm – 6.66 μm (w) and xylem lies towards centre, 9.99 μm – 16.65 μm (l) x 4.99 μm – 13.32 μm (w). Fibre cap is present towards the upper side surrounding phloem, 16.65 μm – 43.29 (l) x 73.26 – 83.25 μm (w). Sclerenchymatous bundle sheath cells are present surrounding vascular bundle (Plate 15A) (Table 9). Stegmata is indistinct.

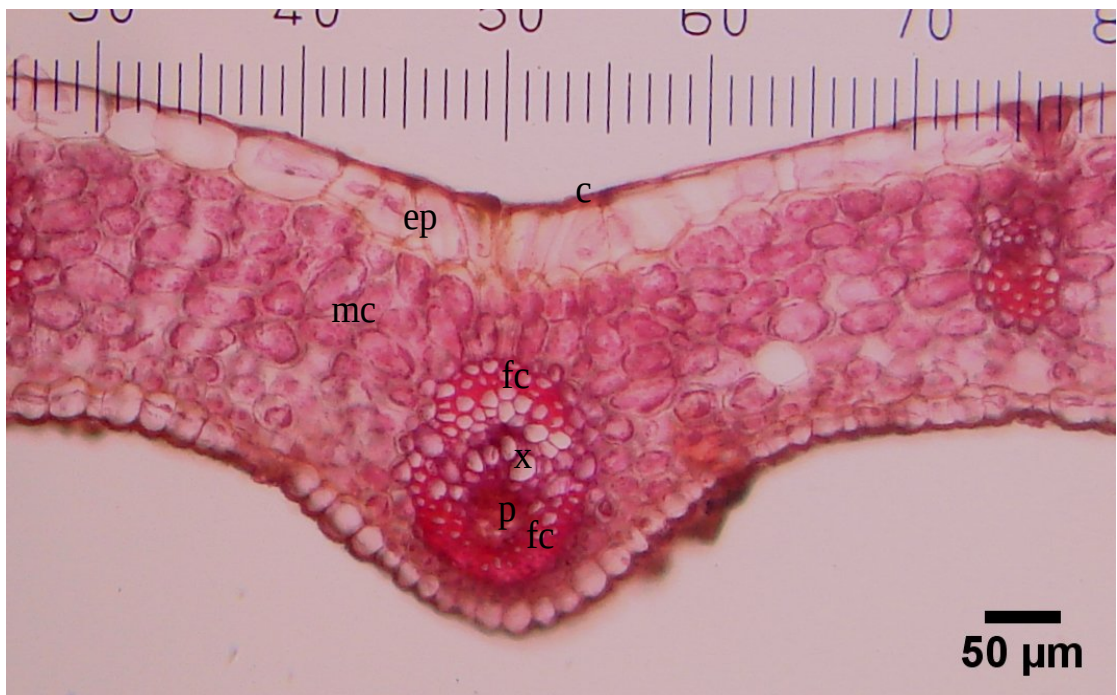
Plate 15. Anatomy of *Dendrobium heterocarpum*.

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc).



A



B

Dendrobium moniliforme

Transverse Section of Leaf

Cuticle: Cuticle is the outermost layer and present on both sides. It is thick and smooth in adaxial side and irregular in abaxial side. **Epidermis:** A single layer of thin-walled, rectangular to polygonal shaped parenchymatous cells with round angles is present on both adaxial and abaxial surfaces. The adaxial cells are larger than those of abaxial cells. The adaxial cells measure 23.31 μm –56.61 μm (w) x 36.63 μm –46.62 μm (l) and the abaxial cells measure 9.99 μm –26.64 μm (w) x 13.32 μm –19.98 μm (l). The cells are smaller towards mid-rib region on both sides. **Hypodermis:** Absent. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is homogenous. It consists of eight layers of rectangular to polygonal chlorenchymatous cells. Idioblasts with mucilage are present in mesophyll cells. Intercellular spaces and water-storage cells are absent. **Vascular Bundle:** Vascular bundles are arranged in one row with a large bundle in the midrib and large and small bundles are found alternating each other. The vascular bundle is conjoint, collateral, closed and oval in shape. Mid-rib vascular bundle measures 119.88 μm (l) x 133.20 μm (w). The vascular bundle is composed of xylem and phloem. Xylem lies towards the adaxial side, 9.99 μm – 10.65 μm (l) x 4.99 μm – 6.66 μm (w) and phloem towards abaxial side, 3.99 μm – 5.99 μm (l) x 2.66 μm – 3.33 μm (w). The vascular bundle is surrounded by chlorenchymatous bundle sheath cells. Fibre caps are well developed at xylem and phloem poles of midrib bundle but better developed at xylem and phloem poles of larger lateral bundles and well developed at phloem pole than xylem pole in smaller lateral bundles. C-shaped fibre cap is present surrounding xylem and phloem. Xylem cap is 3-layered, 26.64 μm (l) x 106.56 μm (w), and phloem cap is 5-layered, 23.31 μm (l) x 133.20 μm (w). Bundle sheath cells are discontinuous around midrib bundle and continuous around larger and smaller lateral bundles (Plate 16B) (Table 8). Stigmata is absent .

Transverse Section of Stem

The surface layer of stem is irregular with ridges and furrows and surrounded by leaf sheaths. **Cuticle:** Cuticle is the outermost layer. It is thick and smooth. **Epidermis:** Cuticle is followed by epidermis. Epidermis is represented by a single layer of rectangular to polygonal shaped thick-walled parenchymatous cells. The epidermal cell varies from 13.32 μm - 23.31 μm (w) x 6.66 μm - 13.32 μm (l) in size.

Hypodermis: Below the epidermis is hypodermis. Hypodermis is made up of 2 layers of irregular or polygonal shaped, moderately thick-walled sclerenchymatous cells. Inner hypodermal cells are larger than outer cells. The hypodermal cells are smaller in size than ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with pleated outlines. Starch grains and raphide bundles are present in parenchymatous cells. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 55. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is elongate shaped in outline. The size of vascular bundle ranges from 199.80 μm – 233.10 μm (l) x 113.22 μm – 166.50 μm (w). The vascular bundle consists of xylem and phloem. Xylem is facing towards centre, 19.80 μm – 23.31 μm (l) x 13.32 μm – 19.98 μm (w) and phloem towards periphery, 4.99 μm – 13.32 μm (l) x 4.99 μm – 9.99 μm (w). Fibre cap is present surrounding the phloem, 23.31 μm – 26.64 μm (l) x 49.95 μm – 66.60 μm (w). Sclerenchymatous bundle sheath cells are present surrounding xylem (Plate 16A) (Table 9). Stegmata is absent.

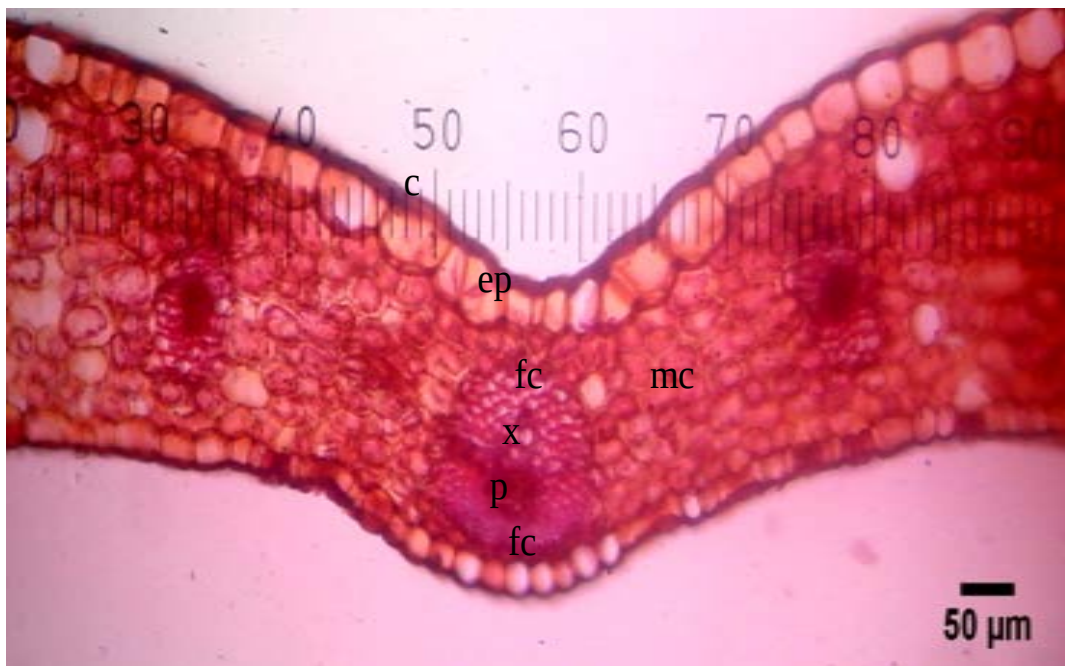
Plate 16. Anatomy of *Dendrobium moniliforme*

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc).



A



B

Dendrobium moschatum

Transverse Section of Leaf

Cuticle: Both sides of leaf have a surface covered with cuticle. It is thin and smooth.

Epidermis: A single layer of thin-walled square, rectangular to hexagonal parenchymatous cells with rounded angles is present on both adaxial and abaxial surfaces. The adaxial cells are larger than those of abaxial cells. The adaxial cells measure 26.64 μm – 66.60 μm (w) x 16.65 μm – 26.64 μm (l). The abaxial cells measure 16.65 μm – 23.31 μm (w) x 9.99 μm – 16.65 μm (l). **Hypodermis:** Absent.

Fibre Bundles: Absent. **Mesophyll:** Mesophyll is homogenous. It consists of sixteen layers of chlorenchymatous cells. The cells are polygonal, oval or rounded in shape. Intercellular spaces are present. Water storage cells are present. Idioblasts with mucilage and druses are present in mesophyll. **Vascular Bundle:** Vascular bundles are arranged in one row with a large midrib bundle in the centre. The smaller and larger bundles are found alternating each other. Vascular bundle is conjoint, collateral, closed and conical in shape. Midrib vascular bundle measures 506.54 μm (l) x 333.25 μm (w). Vascular bundle is composed of xylem, phloem. Vascular bundle is large in size. Xylem lies towards adaxial side, 19.98 μm – 39.96 μm (l) x 6.66 μm – 26.64 μm (w) and the phloem towards abaxial side, 4.99 μm – 9.99 μm (l) x 3.33 μm – 8.32 μm (w). Sclerenchymatous caps are well developed at xylem and phloem poles of midrib, larger and smaller lateral bundles. C-shaped sclereid cap is present at phloem pole and dome-shaped sclereid cap is present at xylem pole of midrib bundle. Xylem cap is 8 (4+4) layered, 159.96 μm (l) x 319.92 μm (w) and phloem cap is 8-layered, 106.64 μm (l) x 333.25 μm (w). Parenchymatous bundle sheath cells are discontinuous surrounding xylem and phloem of midrib and larger lateral bundles, but they are continuous in small lateral bundles (Plate 17B) (Table 8). Stegmata with rough-surfaced spherical silica bodies are present on outer margin of xylem cap and phloem cap (Plate 30K).

Transverse Section of Stem

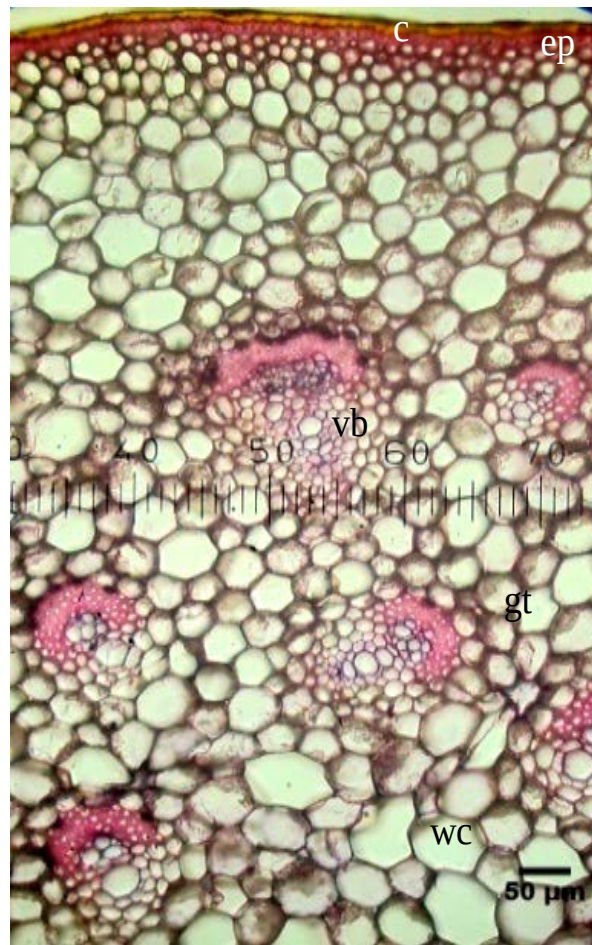
The surface layer of stem is irregular and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of barrel shaped sclereid parenchymatous cells. The cells are thick-walled. The epidermal cell varies from 9.99 μm – 13.32 μm (w) x 13.32 μm – 16.65 μm (l) in size.

Hypodermis: Below the epidermis is hypodermis. Hypodermis is made up of 3 layers of irregular or polygonal shaped sclerenchymatous cells. Outer cells are smaller than inner cells. Hypodermal cells are smaller in size than the ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with unpleated outlines. Starch grains and raphide bundles are present in parenchymatous cell. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 78. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is oval-shaped in outline. The size of vascular bundle ranges from 133.20 μm – 166.50 (l) x 113.22 μm – 133.20 μm (w). The vascular bundle consists of xylem and phloem. Phloem is facing towards periphery, 6.66 μm – 19.98 μm (l) x 3.33 μm – 16.65 μm (w) and xylem facing towards centre, 16.65 μm – 39.96 μm (l) x 9.99 μm – 36.63 μm (w). Sclereid cap is present towards the upper side surrounding phloem, 33.30 μm – 36.63 μm (l) x 113.22 μm – 133.20 μm (w). In large bundle small fibre cap is present around xylem, 26.64 μm – 43.29 μm (l) x 66.60 μm – 99.90 μm (w). Sclerenchymatous bundle sheath cells are present surrounding xylem on lower side (Plate 17A) (Table 9). Stigmata is indistinct. Commissural vascular bundle which connects two vascular bundles is present.

Plate 17. Anatomy of *Dendrobium moschatum*

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc), water storage cell (wc).



A



B

Dendrobium nobile

Transverse Section of Leaf

The surface layer of leaf is notched at midrib region on adaxial side. **Cuticle:** Both sides of leaf have a surface covered with cuticle. It is thin and smooth. **Epidermis:** A single layer of thin-walled square, rectangular to hexagonal parenchymatous cells with rounded angles is present on both adaxial and abaxial surfaces. The adaxial cells are larger than those of abaxial cells. The adaxial cells measure 36.63 μm – 83.25 μm (w) x 73.26 μm – 99.90 μm (l) and the abaxial cells measure 16.65 μm – 53.28 μm (w) x 23.31 μm – 46.62 μm (l). Bulliform cells are present at midrib region. The anticlinal walls of cells are sinuous. **Hypodermis:** Absent. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is homogenous. It consists of nine layers of chlorenchymatous cells. The cells are polygonal, oval or rounded in shape. Intercellular spaces are small. Idioblasts with mucilage are present in mesophyll. Druses are present in mesophyll. **Vascular Bundle:** Vascular bundles are arranged in one row with a large midrib bundle in the centre. The smaller and larger bundles are found alternating each other. Vascular bundle is conjoint, collateral, closed and oval in shape. Midrib vascular bundle measures 199.80 μm (l) x 166.50 μm (w). Vascular bundle is composed of xylem, phloem. Xylem lies towards adaxial side, 19.98 μm – 23.31 μm (l) x 9.99 μm – 19.98 μm (w) and the phloem towards abaxial side, 6.66 μm – 9.99 μm (l) x 4.99 μm – 6.66 μm (w). Vascular bundle lies towards abaxial side of midrib region. Sclerenchymatous caps are thinly developed at xylem and phloem poles of midrib and smaller lateral bundles but well developed at xylem and phloem poles of larger lateral bundle. C-shaped sclereid cap is present at phloem pole and U-shaped fibre cap is present at xylem pole of midrib bundle. Xylem cap is 2-layered, 49.95 μm (l) x 166.50 μm (w) and phloem cap is 3-layered, 26.64 μm (l) x 159.84 μm (w). Parenchymatous bundle sheath cells are continuous surrounding xylem and phloem of midrib, larger and smaller lateral bundles (Plate 18B) (Table 8). Stegmata with rough-surfaced spherical silica bodies is present along outer margin of phloem cap (Plate 30L).

Transverse Section of Stem

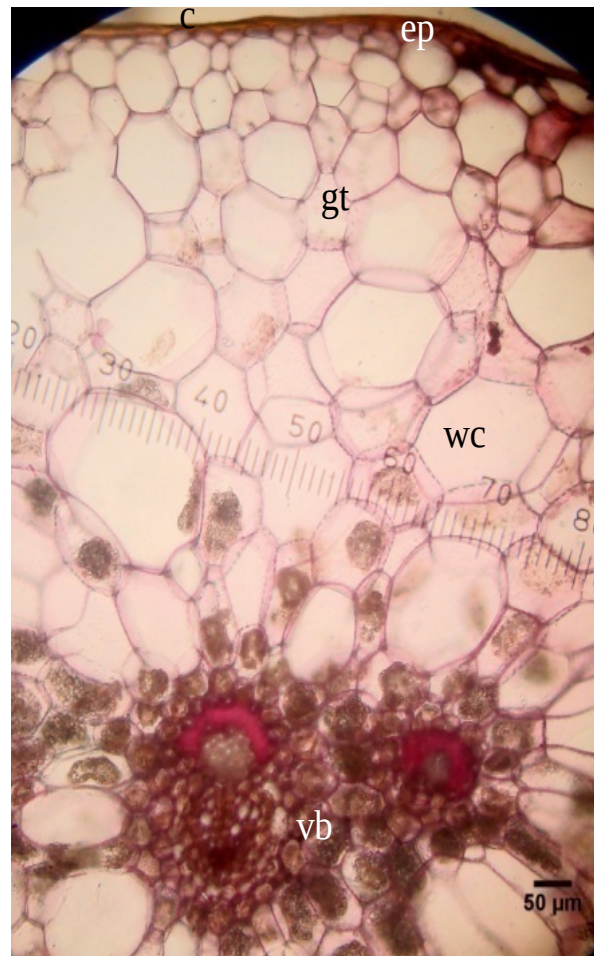
The surface layer of stem is irregular and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of

rectangular, square, polygonal shaped parenchymatous cells. The cells are thick-walled. The epidermal cell varies from $13.32\ \mu\text{m} - 26.64\ \mu\text{m}$ (w) x $6.66\ \mu\text{m} - 13.32\ \mu\text{m}$ (l) in size. **Hypodermis:** Below the epidermis is hypodermis. Hypodermis is made up of 2 layers of irregular or polygonal shaped sclerenchymatous cells. Outer cells are smaller than inner cells. Hypodermal cells are smaller in size than the ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with unpleated outlines. Large no. of starch grains is present in parenchymatous cell. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 82. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is oval-shaped in outline. The size of vascular bundle ranges from $116.55\ \mu\text{m} - 216.45\ \mu\text{m}$ (l) x $86.58\ \mu\text{m} - 166.50\ \mu\text{m}$ (w). The vascular bundle consists of xylem and phloem. Phloem lies towards periphery, $4.99\ \mu\text{m} - 6.66\ \mu\text{m}$ (l) x $3.33\ \mu\text{m} - 6.66\ \mu\text{m}$ (w) and xylem lies towards centre, $13.32\ \mu\text{m} - 19.98\ \mu\text{m}$ (l) x $9.99\ \mu\text{m} - 16.65\ \mu\text{m}$ (w). Sclereid cap is present towards the upper side surrounding phloem, $26.64\ \mu\text{m} - 33.30\ \mu\text{m}$ (l) x $79.92 - 99.90\ \mu\text{m}$ (w). Sclerenchymatous bundle sheath cells are present surrounding xylem on lower side (Plate 18A) (Table 9). Stegmata is indistinct. Commissural vascular bundle which connects two vascular bundles is present.

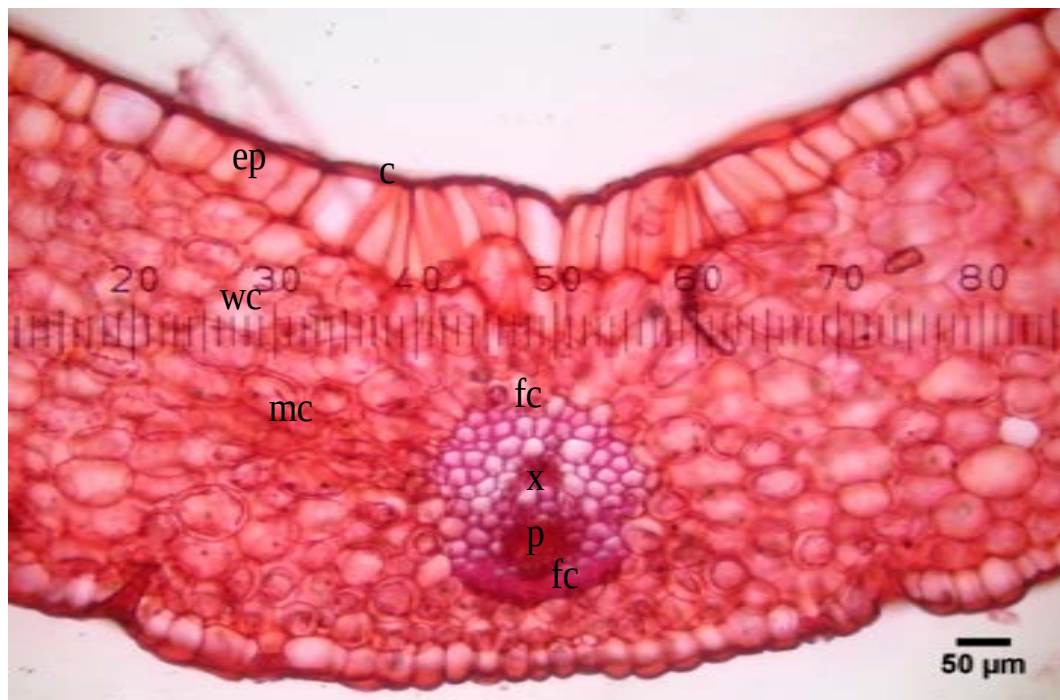
Plate 18. Anatomy of *Dendrobium nobile*

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc).



A



B

Dendrobium polyanthum

Transverse Section of Leaf

Cuticle: Both sides of leaf have a surface covered with cuticle. It is thin, undulating and irregular. **Epidermis:** A single layer of thin-walled square, rectangular to hexagonal parenchymatous cells with rounded angles is present on both adaxial and abaxial surfaces. The anticlinal walls of cells are sinuous. The adaxial cells are larger than those of abaxial cells. The adaxial cells measure $16.65\text{ }\mu\text{m} - 33.30\text{ }\mu\text{m}$ (w) x $9.99\text{ }\mu\text{m} - 26.64\text{ }\mu\text{m}$ (l). The abaxial cells measure $13.32\text{ }\mu\text{m} - 29.97\text{ }\mu\text{m}$ (w) x $9.99\text{ }\mu\text{m} - 13.32\text{ }\mu\text{m}$ (l). **Hypodermis:** Absent. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is homogenous. It consists of eight layers of chlorenchymatous cells. The cells are polygonal, oval, rounded to irregular in shape. Inter cellular spaces are small. Abundant starch grains are present in mesophyll. **Vascular Bundle:** Vascular bundles are arranged in one row with a large midrib bundle in the centre. The smaller and larger bundles are found alternating each other. Vascular bundle is conjoint, collateral, closed and circular in shape. Midrib vascular bundle measures $213.12\text{ }\mu\text{m}$ (l) x $199.80\text{ }\mu\text{m}$ (w). Vascular bundle is composed of xylem and phloem. Xylem lies towards adaxial side, $6.66\text{ }\mu\text{m} - 23.31\text{ }\mu\text{m}$ (l) x $3.33\text{ }\mu\text{m} - 6.66\text{ }\mu\text{m}$ (w) and the phloem towards abaxial side, $4.99\text{ }\mu\text{m} - 6.66\text{ }\mu\text{m}$ (l) x $3.33\text{ }\mu\text{m} - 4.99\text{ }\mu\text{m}$ (w). Vascular bundle lies in centre of midrib region. Sclerenchymatous caps are well developed at xylem and phloem poles of midrib, larger and smaller lateral bundles. Xylem cells are well developed at larger lateral bundles. C-shaped sclereid cap is present at phloem pole and U-shaped fibre cap is present at xylem pole of midrib bundle. Xylem cap is 7-layered, $83.25\text{ }\mu\text{m}$ (l) x $193.14\text{ }\mu\text{m}$ (w) and phloem cap is 5-layered, $43.29\text{ }\mu\text{m}$ (l) x $173.16\text{ }\mu\text{m}$ (w). Parenchymatous bundle sheath cells are continuous surrounding xylem and phloem of midrib, larger and smaller lateral bundles (Plate 19B) (Table 8). Stegmata is indistinct.

Transverse Section of Stem

The surface layer of stem is irregular and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of rectangular, square, polygonal shaped parenchymatous cells. The cells are thick-walled. The epidermal cell varies from $19.98\text{ }\mu\text{m} - 39.96\text{ }\mu\text{m}$ (w) x $13.32\text{ }\mu\text{m} - 16.65\text{ }\mu\text{m}$ (l) in size. **Hypodermis:** Below the epidermis is hypodermis. Hypodermis is

made up of 1 layer of irregular or polygonal shaped parenchymatous cells. Hypodermal cells are smaller in size than the ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with unpleated outlines. Starch grains and raphide bundles are present in parenchymatous cell. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 16. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is elongate-shaped in outline. The size of vascular bundle ranges from 99.90 μm – 289.71 (l) x 49.95 μm – 133.20 μm (w). The vascular bundle consists of xylem and phloem. Xylem is facing towards centre, 9.99 μm – 49.95 μm (l) x 6.66 μm – 23.31 μm (w) and phloem facing towards periphery, 4.99 μm – 16.65 μm (l) x 3.33 μm – 13.32 μm (w). Fibre cap is present towards the upper side surrounding phloem, 33.30 μm – 36.30 (l) x 63.27 – 119.88 μm (w). Sclerenchymatous bundle sheath cells are present surrounding xylem on lower side (Plate 19A) (Table 9). Stegmata with spherical silica bodies is present along outer margin of fibre cap of phloem (Plate 30U).

Plate 19. Anatomy of *Dendrobium polyanthum*

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc).



A



B

Dendrobium transparens

Transverse Section of Leaf

Cuticle: Both sides of leaf have a surface covered with cuticle. It is thin, smooth and pointed at some places in adaxial side. **Epidermis:** A single layer of thin-walled square, rectangular to hexagonal parenchymatous cells with rounded angles is present on both adaxial and abaxial surfaces. The adaxial cells are larger than those of abaxial cells. The adaxial cells measure $23.31\ \mu\text{m} - 66.60\ \mu\text{m}$ (w) x $36.63\ \mu\text{m} - 59.94\ \mu\text{m}$ (l) and the abaxial cells measure $13.32\ \mu\text{m} - 43.29\ \mu\text{m}$ (w) x $13.32\ \mu\text{m} - 23.31\ \mu\text{m}$ (l). Cells are elongated at adaxial side of midrib region. Cells are smaller than other cells in adaxial and abaxial sides at midrib region. **Hypodermis:** Absent. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is homogenous. It consists of eight layers of chlorenchymatous cells. The cells are polygonal, oval and rounded. Intercellular spaces are small. Raphide bundles and druses are present in mesophyll. **Vascular Bundle:** Vascular bundles are arranged in one row with a large midrib bundle in the centre. The smaller and larger bundles are found alternating each other. Vascular bundle is conjoint, collateral, closed and circular in shape. Midrib vascular bundle measures $149.85\ \mu\text{m}$ (l) x $146.52\ \mu\text{m}$ (w). Vascular bundle is composed of xylem and phloem. Xylem lies towards adaxial side, $13.32\ \mu\text{m} - 19.98\ \mu\text{m}$ (l) x $9.99\ \mu\text{m} - 16.65\ \mu\text{m}$ (w) and the phloem towards abaxial side, $3.33\ \mu\text{m} - 6.66\ \mu\text{m}$ (l) x $3.33\ \mu\text{m} - 4.99\ \mu\text{m}$ (w). Vascular bundle lies in abaxial side of midrib region. Sclerenchymatous caps are well developed at xylem and phloem poles of midrib and larger lateral bundles. In smaller lateral bundles sclerenchymatous caps are well developed at phloem pole and poorly developed at xylem pole. C-shaped sclereid caps are present at phloem and xylem poles of midrib bundle. Xylem cap is 4-layered, $33.30\ \mu\text{m}$ (l) x $149.85\ \mu\text{m}$ (w) and phloem cap is 5-layered, $26.64\ \mu\text{m}$ (l) x $146.52\ \mu\text{m}$ (w). Parenchymatous bundle sheath cells are continuous surrounding xylem and phloem of midrib, larger and smaller lateral bundles (Plate 20B) (Table 8). Stigmata is indistinct.

Transverse Section of Stem

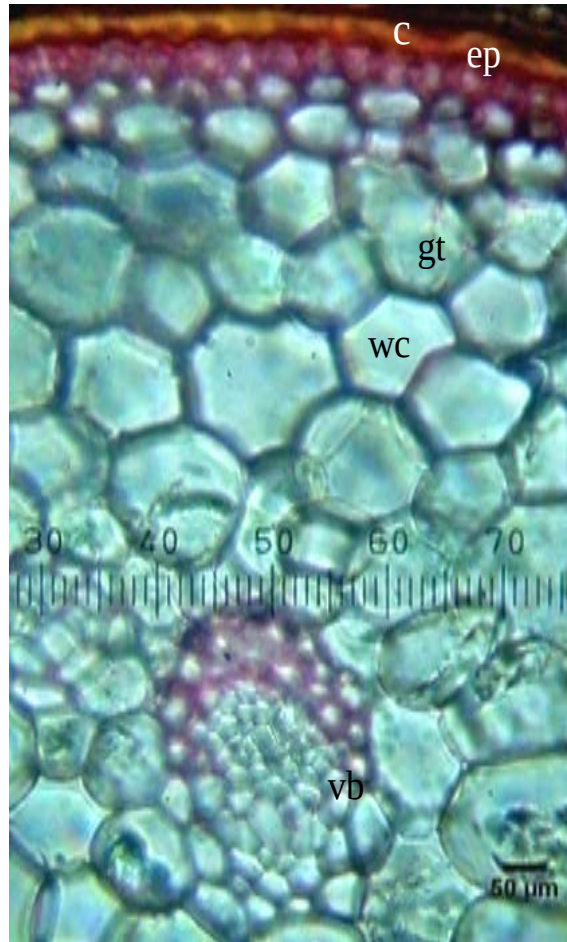
The surface layer of stem is irregular and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of thick-walled, rectangular to square-shaped sclereid parenchymatous cells. The epidermal cell varies from $13.32\ \mu\text{m} - 19.98\ \mu\text{m}$ (w) x $9.99\ \mu\text{m} - 19.98\ \mu\text{m}$ (l) in size.

Hypodermis: Below the epidermis is hypodermis. Hypodermis is made up of 2 layers of irregular or polygonal shaped sclerenchymatous cells. Outer cells of hypodermis are smaller than inner cells. Hypodermal cells are smaller in size than the ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with pleated outlines. Starch grains and raphide bundles are present in parenchymatous cells. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 50. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is elongate-shaped in outline. The size of vascular bundle ranges from 96.57 μm – 133.32 (l) x 63.27 μm – 79.92 μm (w). The vascular bundle consists of xylem and phloem. Phloem lies towards periphery, 6.66 μm – 8.32 μm (l) x 3.33 μm – 6.66 μm (w) and xylem towards centre, 9.99 μm – 16.65 μm (l) x 6.66 μm – 9.99 μm (w). Fibre cap is present towards the upper side surrounding phloem, 23.31 μm – 26.64 (l) x 59.94 – 76.59 μm (w). Sclerenchymatous bundle sheath cells are present surrounding xylem on lower side (Plate 20A) (Table 9). Stegmata with rough-surfaced, spherical silica bodies is present along outer margin of fibre cap of phloem (Plate 30W).

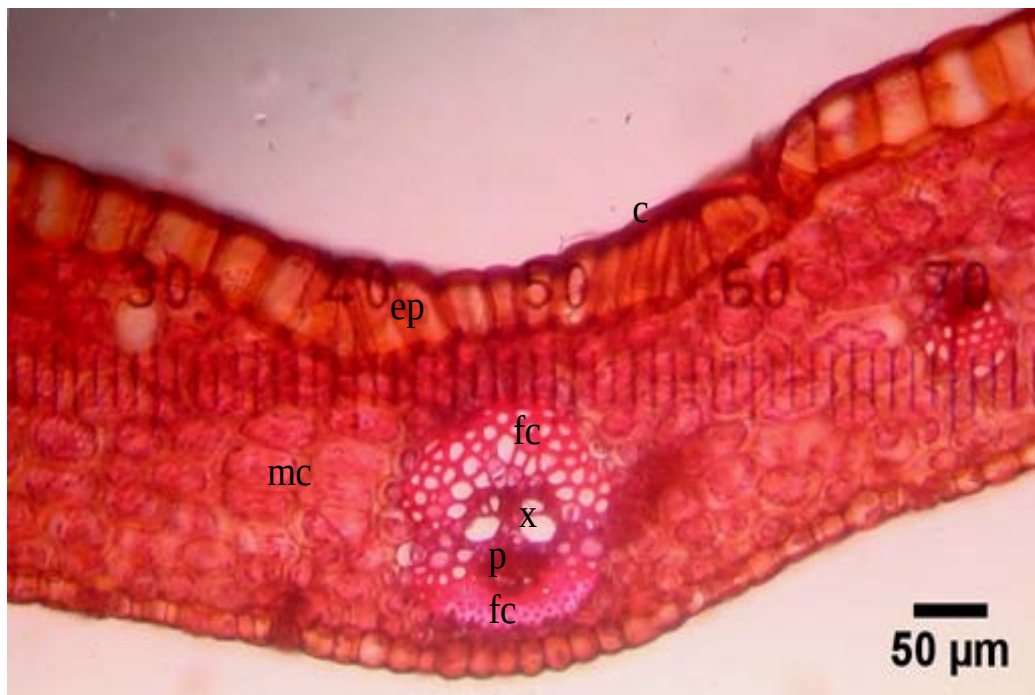
Plate 20. Anatomy of *Dendrobium transparens*

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc).



A



B

Section IV. *Formosae*

Dendrobium formosum

Transverse Section of Leaf

Cuticle: Both sides of leaf have a surface covered with cuticle. It is thin and smooth.

Epidermis: A single layer of thin-walled square, rectangular to polygonal cells with rounded angles is present on both adaxial and abaxial surfaces. The adaxial cells are larger than those of abaxial cells. The adaxial cells are $36.63\ \mu\text{m} - 76.59\ \mu\text{m}$ (w) x $33.30\ \mu\text{m} - 46.62\ \mu\text{m}$ (l) and the abaxial cells are $19.98\ \mu\text{m} - 43.29\ \mu\text{m}$ (w) x $19.98\ \mu\text{m} - 33.30\ \mu\text{m}$ (l). The anticlinal walls are sinuous in adaxial sides. **Hypodermis:**

Hypodermis is absent. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is

homogenous. It consists of nine layers of chlorenchymatous cells. The cells are polygonal, oval to round in shape. Idioblasts with mucilage are present in mesophyll.

Intercellular spaces are small. Water-storage cells are absent. **Vascular Bundle:**

Vascular bundles are arranged in one row with a large midrib bundle in the centre.

The smaller and larger bundles are found alternating each other. Vascular bundle is

conjoint, collateral, closed and oval in shape. Mid-rib vascular bundle measures

$216.45\ \mu\text{m}$ (l) x $193.14\ \mu\text{m}$ (w). The vascular bundle is composed of xylem, phloem.

Xylem lies towards adaxial side, $13.32\ \mu\text{m} - 29.97\ \mu\text{m}$ (l) x $6.66\ \mu\text{m} - 19.98\ \mu\text{m}$ (w)

and the phloem towards abaxial side, $3.33\ \mu\text{m} - 13.32\ \mu\text{m}$ (l) x $3.33\ \mu\text{m} - 9.99\ \mu\text{m}$

(w). Bundle sheath cells are parenchymatous and discontinuous surrounding xylem.

Fibre cap is well developed at xylem and sclereid cap at phloem poles of large midrib

and larger and smaller lateral bundles. U-shaped fibre cap towards xylem pole and C-

shaped sclereid cap towards phloem pole of midrib bundle are present. Xylem cap is

7-layered, $73.26\ \mu\text{m}$ (l) x $183.15\ \mu\text{m}$ (w), and phloem cap is 5-layered, $33.30\ \mu\text{m}$ (l) x

$206.46\ \mu\text{m}$ (w) (Plate 21B) (Table 8). Stigmata is indistinct.

Transverse Section of Stem

The surface layer of stem is irregular and surrounded by leaf sheaths. **Cuticle:**

Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of

thick-walled rectangular to polygonal parenchymatous cells. The epidermal cell varies

from $16.65\ \mu\text{m} - 39.96\ \mu\text{m}$ (w) x $9.99\ \mu\text{m} - 16.65\ \mu\text{m}$ (l) in size. **Hypodermis:**

Below the epidermis is hypodermis. Hypodermis is made up of 2 layers of thick-

walled polygonal parenchymatous cells. Outer hypodermal cells are smaller than

inner cells in size. The hypodermal cells are smaller in size than the ground tissues.

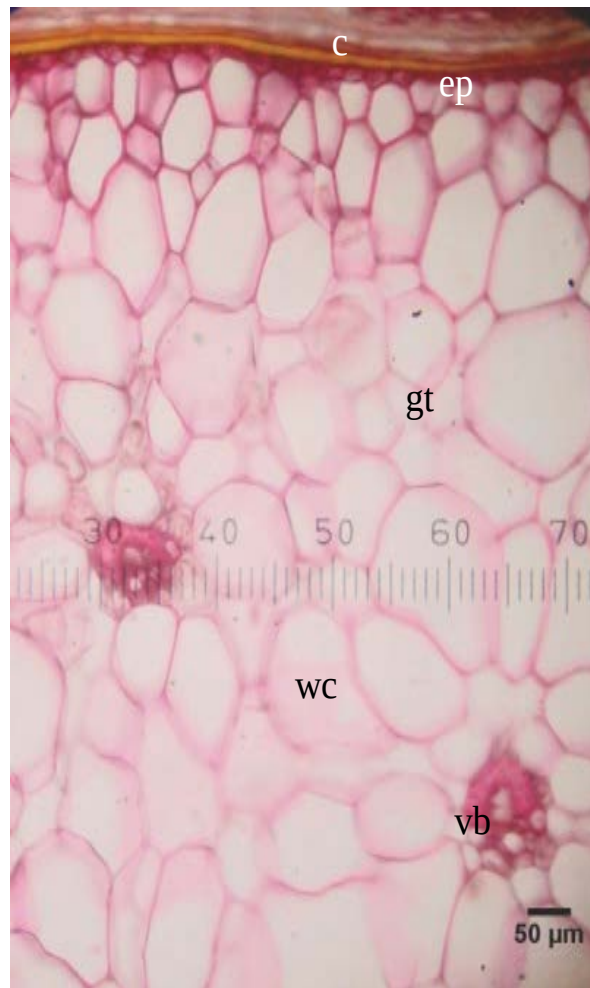
Ground Tissue: There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with pleated outlines. Starch grains are present in the parenchymatous cells.

Vascular Bundle: Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 64. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is oval-shaped in outline. The size of vascular bundle ranges from 166.50 μm – 233.10 μm (l) x 119.88 μm – 153.18 μm (w). The vascular bundle consists of xylem and phloem. Phloem lies towards periphery, 6.66 μm – 16.65 μm (l) x 4.99 μm – 9.99 μm (w) and xylem lies towards centre, 26.64 μm – 49.95 μm (l) x 9.99 μm – 13.32 μm (w). Sclereid cap is present towards the upper side surrounding phloem, 33.30 μm – 53.28 μm (l) x 89.91 μm – 109.89 μm (w). Sclerenchymatous bundle sheath cells are present surrounding xylem (Plate 21A) (Table 9). Few no. of stegmata with rough-surfaced spherical silica bodies is present along outer margin of sclereid cap of phloem (Plate 30R).

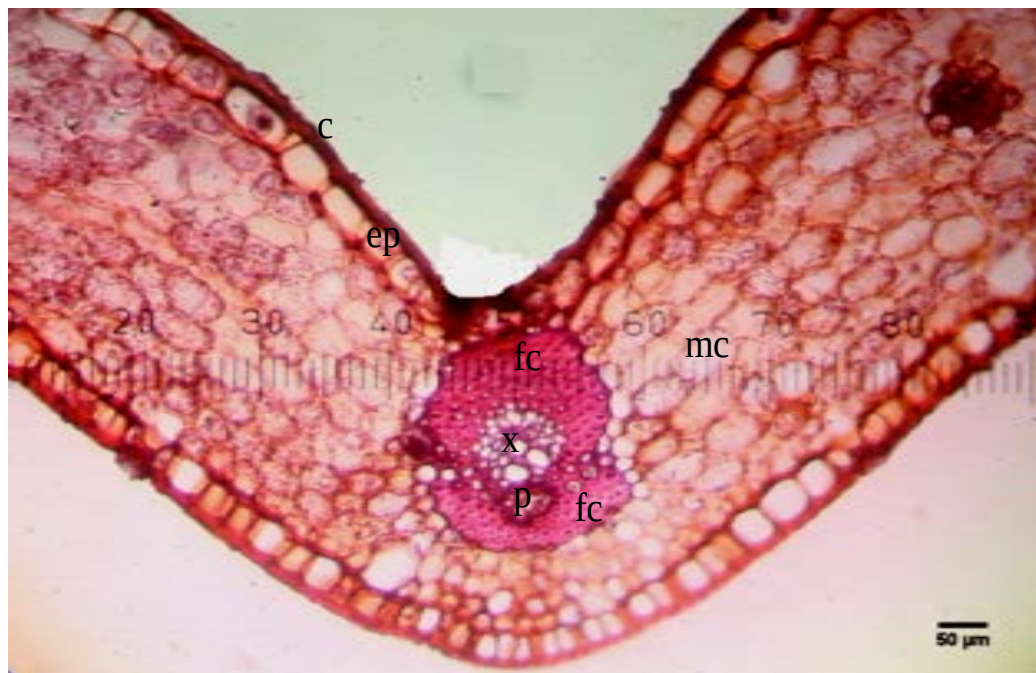
Plate 21. Anatomy of *Dendrobium formosum*

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc).



A



B

Dendrobium longicornu

Transverse Section of Leaf

Cuticle: Both sides of leaf have a surface covered with cuticle. It is thin, undulating, smooth in adaxial side and irregular in abaxial side. **Epidermis:** A single layer of thin walled square, rectangular to hexagonal cells with rounded angles is present on both adaxial and abaxial surfaces. The anticlinal walls of adaxial side are sinous. The adaxial cells are larger than those of abaxial cells. The adaxial cells measure 23.31 μm – 53.28 μm (w) x 19.98 μm – 46.62 μm (l). The abaxial cells measure 19.98 μm – 49.95 μm (w) x 13.32 μm – 33.30 μm (l). Cells at midrib region on adaxial and abaxial sides are smaller than other cells. **Hypodermis:** Absent. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is homogenous. It consists of eight layers of chlorenchymatous cells. Cells are polygonal, oval or rounded in shape with abundant chloroplast. Idioblasts with mucilage are present in mesophyll. Water-storage cells are usually lacking. Intercellular spaces are small. **Vascular Bundle:** Vascular bundles are arranged in one row with a large midrib bundle in the centre. The smaller and larger bundles are found alternating each other. Vascular bundle lies towards adaxial side. Vascular bundle is conjoint, collateral, closed and circular in shape. Midrib vascular bundle measures 166.50 μm (l) x 166.50 μm (w). Vascular bundle is composed of xylem and phloem. Xylem lies towards adaxial side, 9.99 μm – 23.31 μm (l) x 6.66 μm – 16.65 μm (w) and the phloem towards abaxial side, 4.99 μm – 6.66 μm (l) x 3.33 μm – 6.66 μm (w). Parenchymatous bundle sheath cells are present surrounding vascular bundle. Vascular bundle is completely surrounded by sclereid caps. Sclereid caps are well developed at both xylem and phloem poles of midrib bundle and larger lateral bundles but phloem cap is better developed than xylem cap in smaller lateral bundles. Sclereid cap is U-shaped towards xylem pole and C-shaped towards phloem pole of midrib bundle. Xylem cap is 4-layered, 33.30 μm (l) x 156.51 μm (w) and phloem cap is 4-layered, 33.30 μm (l) x 156.51 μm (w) (Plate 22B) (Table 8). Stegmata is indistinct.

Transverse Section of Stem

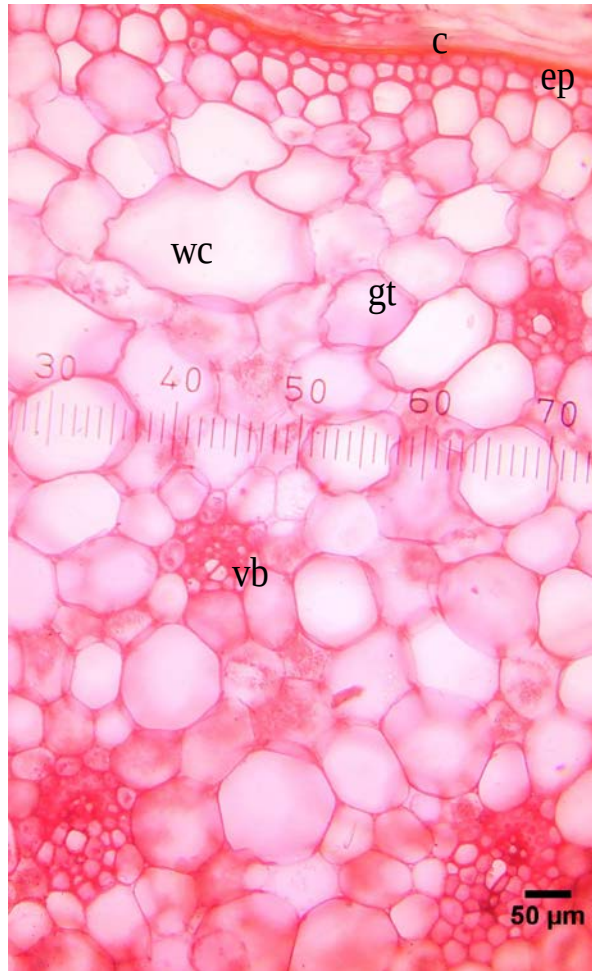
The surface layer of stem is irregular and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of rectangular, hexagonal to polygonal-shaped parenchymatous cells. The cells are thick-

walled. The epidermal cell varies from 13.32 μm – 19.98 μm (w) x 6.66 μm – 13.32 μm (l) in size. **Hypodermis:** Below the epidermis is hypodermis. Hypodermis is made up of 2 layers of irregular or polygonal shaped sclerenchymatous cells. Outer hypodermal cells are larger than inner cells. The hypodermal cells are smaller in size than the ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with pleated outlines. Starch grains and raphide bundles are present in parenchymatous cells. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 68. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is elongate-shaped in outline. The size of vascular bundle ranges from 76.59 μm – 183.15 (l) x 89.91 μm – 119.88 μm (w). The vascular bundle consists of xylem and phloem. Phloem lies towards periphery, 4.99 μm – 11.65 μm (l) x 3.33 μm – 9.99 μm (w) and xylem lies towards centre, 9.99 μm – 26.64 μm (l) x 4.99 μm – 19.98 μm (w). Fibre cap is present above phloem, 16.65 μm – 46.62 (l) x 79.92 – 83.25 μm (w). Sclerenchymatous bundle sheath cells are present surrounding vascular bundles (Plate 22A) (Table 9). Stegmata with rough-surfaced spherical silica bodies is present associated with phloem fibre cap (Plate 30T).

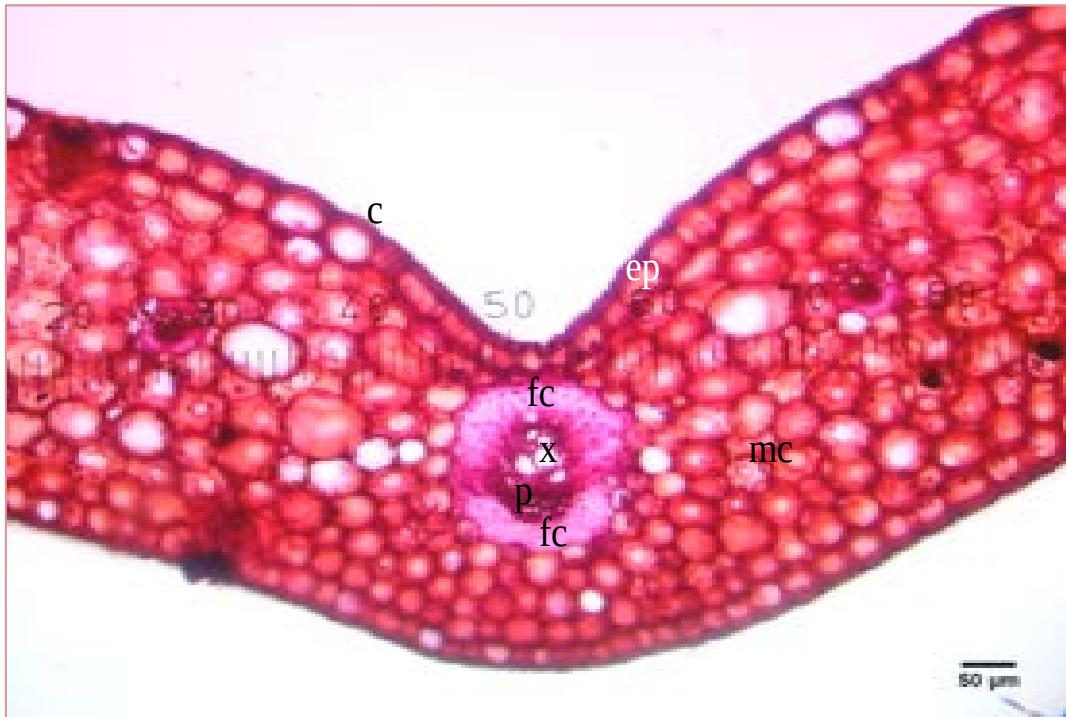
Plate 22. Anatomy of *Dendrobium longicornu*

A. T.S. Stem showing cuticle (c), epidermis (ep), leaf trace bundle (ltb), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc).



A



B

Section V. *Sarcopodium*

Dendrobium amplum

Transverse Section of Leaf

Cuticle: Both sides of leaf have a surface covered with cuticle. It is thick, smooth in adaxial side and irregular in abaxial side. **Epidermis:** A single layer of thin-walled rectangular, square and polygonal cells are present on both adaxial and abaxial surfaces. The adaxial cells are larger than those of abaxial cells. The adaxial cells measure $19.98\ \mu\text{m} - 56.61\ \mu\text{m}$ (w) x $16.65\ \mu\text{m} - 29.97\ \mu\text{m}$ (l). The abaxial cells measure $16.65\ \mu\text{m} - 49.95\ \mu\text{m}$ (w) x $9.99\ \mu\text{m} - 19.98\ \mu\text{m}$ (l). Cells in abaxial sides are smaller than other cells at midrib region. Cell lumina are occluded with safranin-staining materials in adaxial and abaxial sides but little amount in adaxial cells at midrib region. **Hypodermis:** Absent. **Mesophyll:** Mesophyll is heterogenous. Palisade cells are thin walled, polygonal, oval, rounded to columnar and 2-layered. Cells are columnar in midrib region. Spongy cells are thin walled, polygonal, oval to rounded and 7-layered. Water-storage cells are usually lacking. Intercellular spaces are small. Abundant chloroplasts are present in mesophyll. **Vascular Bundle:** Vascular bundles are arranged in one row with a large midrib bundle in the centre. The smaller and larger bundles are found alternating each other. Vascular bundle lies at abaxial side of midrib region. Vascular bundle is conjoint, collateral, closed and flask-shaped in shape. Midrib vascular bundle measures $199.80\ \mu\text{m}$ (l) x $143.19\ \mu\text{m}$ (w). Vascular bundle is composed of xylem and phloem. Xylem lies towards adaxial side, $6.66\ \mu\text{m} - 23.31\ \mu\text{m}$ (l) x $4.99\ \mu\text{m} - 19.98\ \mu\text{m}$ (w) and phloem towards abaxial side, $3.33\ \mu\text{m} - 6.66\ \mu\text{m}$ (l) x $2.66\ \mu\text{m} - 4.99\ \mu\text{m}$ (w). Sclereid caps are found surrounding xylem and phloem completely. Sclereid caps are U-shaped towards xylem and phloem poles of midrib bundle. Xylem cap is 4-layered, $16.65\ \mu\text{m}$ (l) x $139.86\ \mu\text{m}$ (w) and phloem cap is 6-layered, is $46.62\ \mu\text{m}$ (l) x $166.50\ \mu\text{m}$ (w). Clusters of sclerenchymatous cells are found continuous with xylem of lateral bundles and exceeding towards adaxial side. Parenchymatous bundle sheath cells are discontinuous surrounding xylem of midrib, larger and smaller lateral bundles (Plate 23B) (Table 8). Stigmata is indistinct.

Transverse Section of Pseudobulb

The surface layer of pseudobulb is irregular and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of square to rectangular, very thick-walled sclereid parenchymatous cells. The epidermal cell varies from 9.99 μm – 19.98 μm (w) x 9.99 μm – 13.32 μm (l) in size. **Hypodermis:** Below the epidermis is hypodermis. Hypodermis is made up of 2 layers of irregular, polygonal sclerenchymatous cells. Outer layer of hypodermal cells are smaller than inner cells. Hypodermal cells are smaller in size than the ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with pleated outlines. Starch grains are present in parenchymatous cells. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. There are many vascular bundles scattered in the ground tissue. Number of vascular bundle is 50. Large vascular bundles are present in outer side along with small vascular bundles and small vascular bundles in inner side. Each vascular bundle is elongate-shaped in outline. The size of vascular bundle ranges from 133.20 μm – 333.00 (l) x 66.60 μm – 149.85 μm (w). The vascular bundle consists of xylem and phloem. Phloem lies towards periphery, 3.33 μm – 9.99 μm (l) x 3.33 μm – 6.66 μm (w) and xylem towards centre, 11.65 μm – 26.64 μm (l) x 9.99 μm – 16.65 μm (w). Sclereid cap is present towards the upper side surrounding phloem, 33.30 μm – 99.90 μm (l) x 83.25 – 116.55 μm (w). Fibre cap is present surrounding xylem in large bundle, 43.29 μm – 56.61 μm (l) x 106.56 μm – 133.20 μm (w). Sclerenchymatous bundle sheath cells are present surrounding xylem on lower side (Plate 23A) (Table 9). Stegmata with rough-surfaced, spherical silica bodies is present along outer margin of sclereid cap of phloem (Plate 30N).

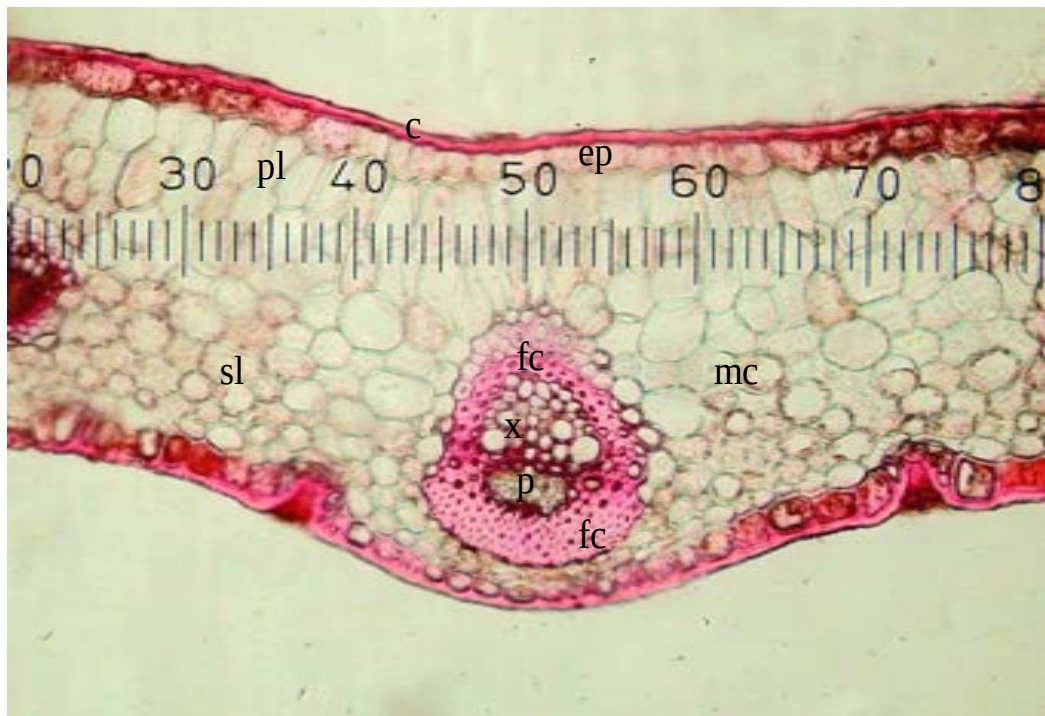
Plate 23. Anatomy of *Dendrobium amplum*

A. T.S. Pseudobulb showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc), palisade layer (pl), spongy layer (sl).



A



B

Dendrobium fuscescens

Transverse Section of Leaf

Cuticle: Both sides of leaf have a surface covered with cuticle. It is thick, smooth in adaxial side and irregular in abaxial side. **Epidermis:** A single layer of thin-walled rectangular, square and polygonal cells are present on both adaxial and abaxial surfaces. The adaxial cells are larger than those of abaxial cells. The adaxial cells measure 23.31 μm – 43.29 μm (w) x 16.65 μm – 26.64 μm (l). The abaxial cells measure 16.65 μm – 39.96 μm (w) x 16.65 μm – 23.31 μm (l). Cells in adaxial and abaxial sides are smaller than other cells at midrib region. Cell lumina are occluded with safranin-staining materials in adaxial and abaxial sides. **Hypodermis:** Absent. **Mesophyll:** Mesophyll is heterogenous. Palisade cells are thin walled, polygonal to oval and 2-layered. Spongy cells are thin walled, polygonal, oval to rounded and 7-layered. Water-storage cells are usually lacking. Intercellular spaces are small. Abundant chloroplasts are present in mesophyll. **Vascular Bundle:** Vascular bundles are arranged in one row with a large midrib bundle in the centre. The smaller and larger bundles are found alternating each other. Vascular bundle lies at abaxial side of midrib region. Vascular bundle is conjoint, collateral, closed and flask-shaped in shape. Midrib vascular bundle measures 209.79 μm (l) x 156.51 μm (w). Vascular bundle is composed of xylem and phloem. Xylem lies towards adaxial side, 9.99 μm – 23.31 μm (l) x 6.66 μm – 16.65 μm (w) and phloem towards abaxial side, 4.99 μm – 9.99 μm (l) x 4.99 μm – 6.66 μm (w). Sclereid caps are found surrounding xylem and phloem completely. Sclereid caps are U-shaped towards xylem and C-shaped towards phloem poles of midrib bundle. Xylem cap is 5-layered, 56.61 μm (l) x 113.22 μm (w), and phloem cap is 6-layered, 49.95 μm (l) x 179.82 μm (w). Clusters of sclerenchymatous cells are found continuous with xylem of lateral bundles and exceeding towards adaxial side up to epidermal cells. Parenchymatous bundle sheath cells are discontinuous surrounding xylem of midrib, larger and smaller lateral bundles (Plate 24B) (Table 8). Stigmata with rough-surfaced spherical silica bodies is found along outer margin of phloem cap of midrib and larger lateral bundles (Plate 30I).

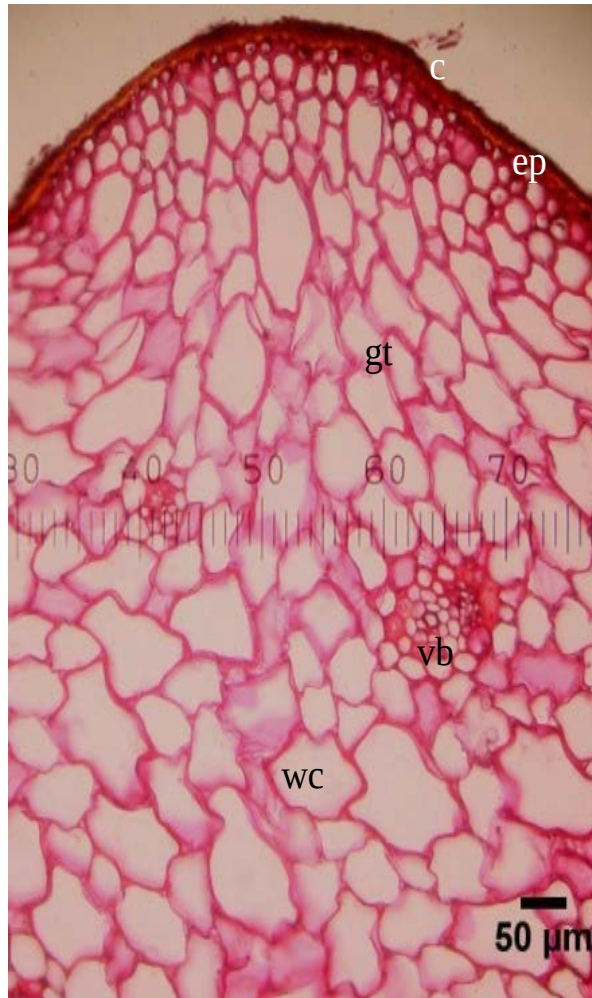
Transverse Section of Pseudobulb

The surface layer of pseudobulb is irregular with ridges and furrows and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of rectangular, square, polygonal shaped parenchymatous cells. The cells are thick-walled. The epidermal cell varies from 9.99 μm – 26.64 μm (w) x 6.66 μm – 19.98 μm (l) in size. **Hypodermis:** Below the epidermis is hypodermis. Hypodermis is made up of 2 layers of irregular or polygonal shaped sclerenchymatous cells. Outer cells are smaller than inner cells. Hypodermal cells are smaller in size than the ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: fewer, small, living, round to polygonal assimilatory parenchymatous cells and many, large, scattered, dead, water-storage cells with pleated outlines. Starch grains are present in parenchymatous cells. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 83. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is oval-shaped in outline. The size of vascular bundle ranges from 99.90 μm – 243.09 (l) x 89.91 μm – 116.55 μm (w). The vascular bundle consists of xylem and phloem. Xylem is facing towards centre, 6.66 μm – 23.31 μm (l) x 6.66 μm – 16.65 μm (w) and phloem towards periphery, 3.33 μm – 9.99 μm (l) x 3.33 μm – 6.66 μm (w). Sclereid cap is present towards the upper side surrounding phloem, 16.65 μm – 26.64 (l) x 59.94 μm – 66.60 μm (w). Sclereid cap is present surrounding xylem on lower side in large bundle, 16.65 μm – 49.95 μm (l) x 59.94 μm – 116.55 μm (w). The xylem and phloem bundles are separated by sclerenchymatous band in large vascular bundle (Plate 23A). Sclerenchymatous bundle sheath cells are present surrounding vascular bundle (Plate 24A) (Table 9). Stegmata is indistinct.

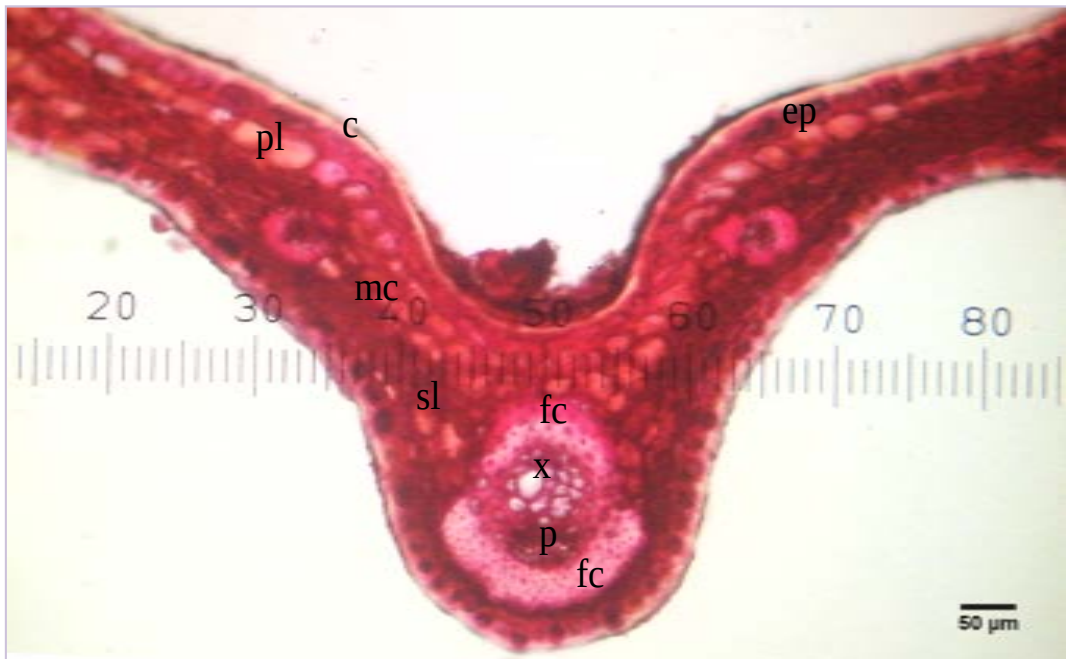
Plate 24. Anatomy of *Dendrobium fuscescens*

A. T.S. Pseudobulb showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), palisade layer (pl), xylem (x), phloem (p), fibre cap (fc), spongy layer (sl).



A



B

Dendrobium rotundatum

Transverse Section of Leaf

Cuticle: Both sides of leaf have a surface covered with cuticle. It is thick, smooth in adaxial side and irregular in abaxial side. **Epidermis:** A single layer of thin-walled rectangular, square and polygonal cells are present on both adaxial and abaxial surfaces. The adaxial cells are larger than those of abaxial cells. The adaxial cells measure $23.31\ \mu\text{m} - 49.95\ \mu\text{m}$ (w) $\times$ $16.65\ \mu\text{m} - 33.30\ \mu\text{m}$ (l) and the abaxial cells measure $9.99\ \mu\text{m} - 39.96\ \mu\text{m}$ (w) $\times$ $16.65\ \mu\text{m} - 26.64\ \mu\text{m}$ (l). Cells in abaxial sides are smaller than other cells at midrib region. Cell lumina are occluded with safranin-staining materials in adaxial and abaxial sides. **Hypodermis:** Absent. **Mesophyll:** Mesophyll is heterogenous. Palisade cells are thin walled, polygonal, oval to columnar and 2-layered. Cells are columnar at midrib region. Spongy cells are thin walled, polygonal, oval to rounded and 8-layered. Some of spongy cell contain rosette aggregates of calcium oxalate. Water-storage cells are usually lacking. Intercellular spaces are small. Abundant chloroplasts are present in mesophyll. Druses are present in mesophyll. **Vascular Bundle:** Vascular bundles are arranged in one row with a large midrib bundle in the centre. The smaller and larger bundles are found alternating each other. Vascular bundle lies at abaxial side of midrib region. Vascular bundle is conjoint, collateral, closed and flask-shaped. Midrib vascular bundle measures $183.15\ \mu\text{m}$ (l) $\times$ $133.20\ \mu\text{m}$ (w). Vascular bundle is composed of xylem and phloem. Xylem lies towards adaxial side, $13.32\ \mu\text{m} - 26.64\ \mu\text{m}$ (l) $\times$ $6.66\ \mu\text{m} - 19.98\ \mu\text{m}$ (b) and phloem towards abaxial side, $4.99\ \mu\text{m} - 6.66\ \mu\text{m}$ (l) $\times$ $3.33\ \mu\text{m} - 4.99\ \mu\text{m}$ (w). Sclerenchymatous cells are well developed at phloem pole and weakly developed at xylem pole. Sclereid caps are found surrounding xylem and phloem completely. Sclereid caps are U-shaped towards xylem and C-shaped towards phloem poles of midrib bundle. Xylem cap is 5-layered, $39.96\ \mu\text{m}$ (l) $\times$ $193.14\ \mu\text{m}$ (w) and phloem cap is 6-layered, is $53.28\ \mu\text{m}$ (l) $\times$ $126.54\ \mu\text{m}$ (w). Clusters of sclerenchymatous cells are found continuous with xylem of lateral bundles and extending towards adaxial side. Parenchymatous bundle sheath cells are discontinuous surrounding phloem and xylem of midrib, larger and smaller lateral bundles (Plate 25B) (Table 8). Stigmata is indistinct.

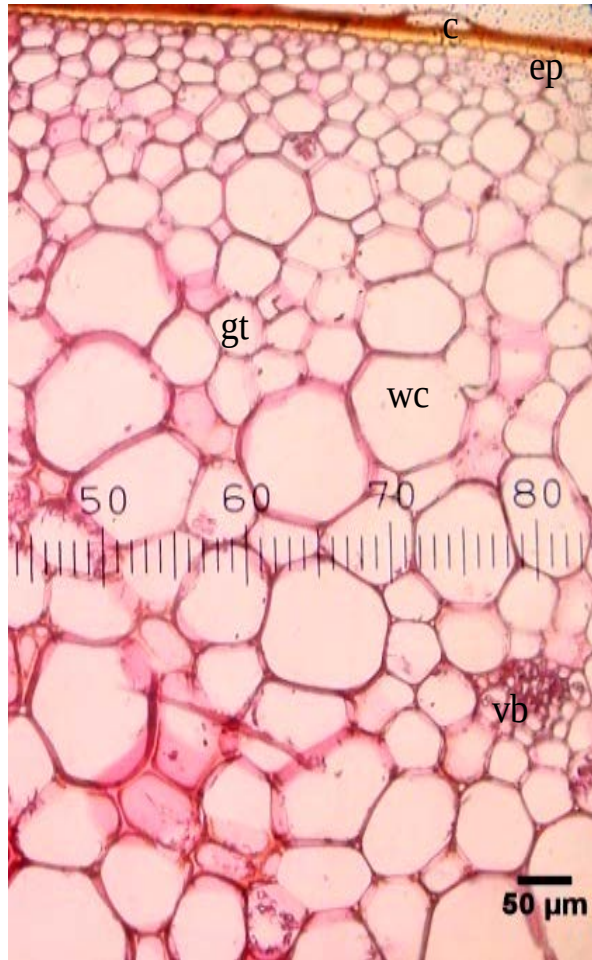
Transverse Section of Pseudobulb

The surface layer of pseudobulb is irregular and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of rectangular, square, polygonal shaped parenchymatous cells. The cells are thick-walled. The epidermal cell varies from 16.65 μm – 29.97 μm (w) x 9.99 μm – 16.65 μm (l) in size. **Hypodermis:** Below the epidermis is hypodermis. Hypodermis is made up of 2 layers of irregular or polygonal shaped sclerenchymatous cells. Outer hypodermal cells are smaller than inner cells. Hypodermal cells are smaller in size than the ground tissues. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with pleated outlines. Starch grains and raphide bundles are present in parenchymatous cells. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 82. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is oval-shaped in outline. The size of vascular bundle ranges from 99.90 μm – 166.50 μm (l) x 83.25 μm – 116.55 μm (w). The vascular bundle consists of xylem and phloem. Xylem is facing towards centre, 16.65 μm – 23.31 μm (l) x 13.32 μm – 19.98 μm (w) and phloem towards periphery, 3.33 μm – 13.32 μm (l) x 3.33 μm – 9.99 μm (w). Sclereid cap is present towards the upper side surrounding phloem, 13.32 μm – 39.96 μm (l) x 33.30 μm – 99.90 μm (w). Sclerenchymatous bundle sheath cells are present surrounding xylem (Plate 25A) (Table 9). Stegmata all with rough-surfaced spherical silica bodies are present along outer margin of sclereid cap of phloem (Plate 30V).

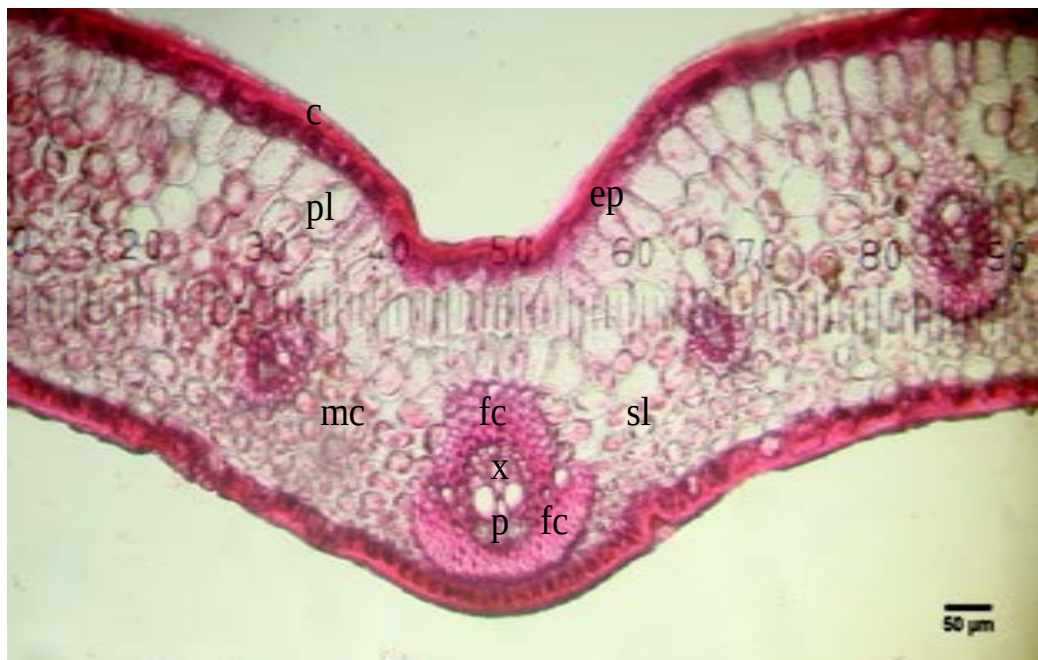
Plate 25. Anatomy of *Dendrobium rotundatum*

A. T.S. Pseudobulb showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc), palisade layer (pl), spongy layer (sl).



A



B

Section VI. *Stachyobium*

Dendrobium denudans

Transverse Section of Leaf

Cuticle: Cuticle is the outermost layer and present on both sides. It is thin, undulating and irregular in adaxial and abaxial side. **Epidermis:** A single layer of thin-walled, rectangular to polygonal parenchymatous cells is present on both adaxial and abaxial sides. The adaxial cells are larger than those of abaxial cells. The adaxial cells measure 23.31 μm – 43.29 μm (w) x 9.99 μm – 19.98 μm (l). The abaxial cells measure 23.31 μm – 29.97 μm (w) x 9.99 μm – 16.65 μm (l). Cells at midrib region on both sides are smaller than other cells. **Hypodermis:** Absent. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is homogenous. It consists of seven layers of rectangular, oval, rounded to polygonal, irregular, thin-walled chlorenchymatous cells with abundant chloroplasts. Idioblast cell with mucilage is present in mesophyll. Druse crystals are found in mesophyll cells. Intercellular spaces are small and water-storage cells are absent. **Vascular Bundle:** Vascular bundles are arranged in one row with a large bundle in the midrib, large and small bundles are found alternating each other. Vascular bundle is conjoint, collateral, closed and oblong in shape. Mid-rib vascular bundle measures 126.54 μm (l) x 53.28 μm (w). The vascular bundle is composed of xylem and phloem. Xylem lies towards the adaxial side, 13.32 μm – 19.98 μm (l) x 4.99 μm – 6.66 μm (w) and phloem towards abaxial sides, 4.99 μm – 6.66 μm (l) x 3.99 μm – 4.99 μm (w). Bundle sheath cells are absent. Fibre caps are well developed at xylem and phloem poles of midrib bundle, larger and smaller lateral bundles. C-shaped fibre caps are present towards xylem and phloem poles. Xylem cap is 3-layered, 23.31 μm (l) x 53.28 μm (w), and phloem cap is 3-layered, 23.31 μm (l) x 56.61 μm (w) (Plate 26B) (Table 8). Stigmata is present along outer margin of phloem cap (Plate 30G).

Transverse Section of Stem

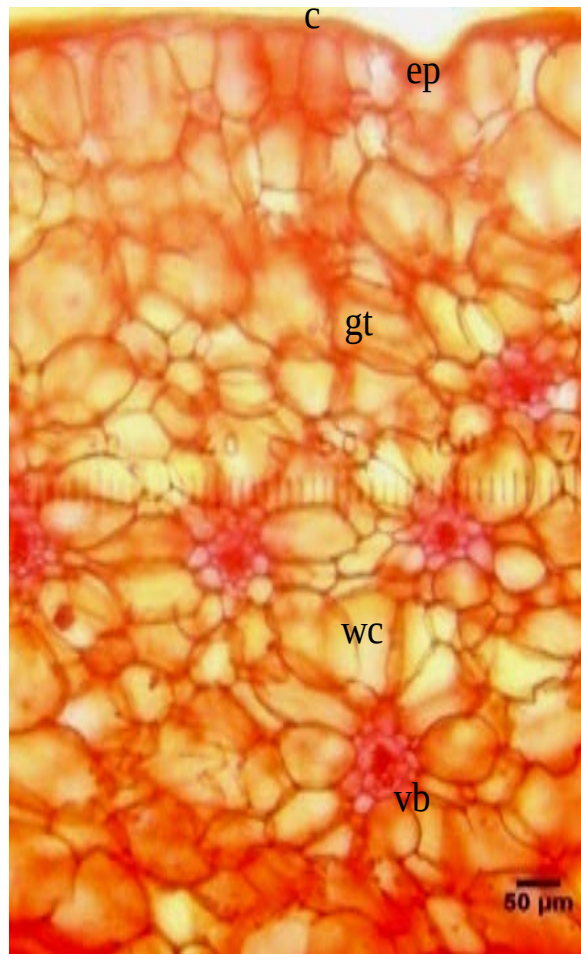
The surface layer of the stem is irregular with ridges and furrows and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of rectangular parenchymatous cells. The cells are thick-walled. The epidermal cell varies from 13.32 μm – 26.64 μm (w) x 8.32 μm – 13.32 μm (l) in size. **Hypodermis:** There is no distinct hypodermis below epidermis.

Ground Tissue: There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled elongated parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with pleated outlines. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 50. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is oval-shaped in outline. The size of vascular bundle ranges from 66.60 μm – 119.88 μm (l) x 56.61 μm – 76.59 μm (w). The vascular bundle consists of xylem and phloem. Phloem lies facing towards periphery, 3.33 μm – 4.99 μm (l) x 2.66 μm – 3.33 μm (w) and xylem towards centre, 9.99 μm – 13.32 μm (l) x 6.66 μm – 9.99 μm (w). Fibre cap is present surrounding phloem, 16.65 μm – 16.65 μm (l) x 49.95 μm – 56.61 μm (w). Sclerenchymatous bundle sheath cells are present surrounding vascular bundle. Around bundle sheath cells of vascular bundle distinct round parenchymatous cells are present (Plate 26A) (Table 9). Stegmata is indistinct.

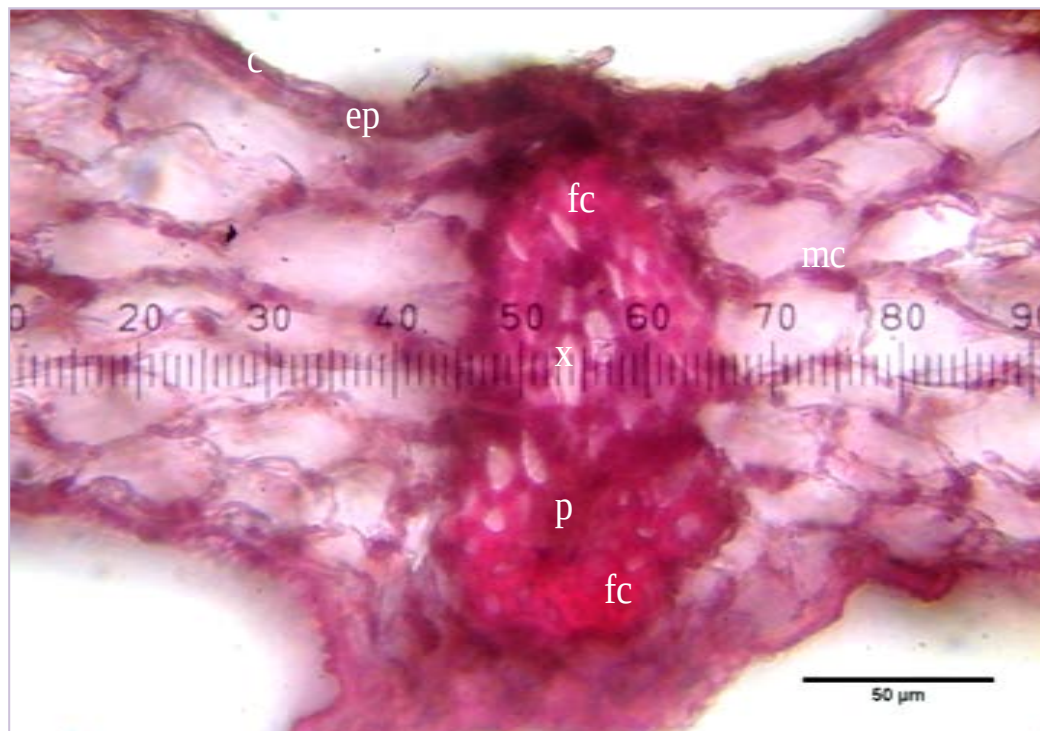
Plate 26. Anatomy of *Dendrobium denudans*

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc).



A



B

Dendrobium eriiflorum

Transverse Section of Leaf

Cuticle: Cuticle is the outermost layer and present on both sides. It is thin, undulating and irregular in adaxial and abaxial side. **Epidermis:** A single layer of thin-walled, rectangular to polygonal parenchymatous cells is present on both adaxial and abaxial sides. The adaxial cells are larger than those of abaxial cells. The adaxial cells are 19.98 μm – 43.29 μm (w) x 26.64 μm – 43.29 μm (l) and the abaxial cells are 13.32 μm – 23.31 μm (w) x 19.98 μm – 29.97 μm (l). Cells at midrib region on both sides are smaller than other cells. **Hypodermis:** Absent. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is homogenous. It consists of seven layers of rectangular, oval, rounded to polygonal, irregular, thin-walled chlorenchymatous cells with abundant chloroplasts. Idioblast cells with raphide bundle and mucilage are present in mesophyll. Intercellular spaces are small and water-storage cells are absent. **Vascular Bundle:** Vascular bundles are arranged in one row with a large bundle in the midrib and large and small bundles are found alternating each other. The vascular bundle is conjoint, collateral, closed and oval in shape. Mid-rib vascular bundle measures 116.55 μm (l) x 69.93 μm (w). The vascular bundle is composed of xylem and phloem. Xylem lies towards the adaxial side, 6.66 μm – 19.98 μm (l) x 4.99 μm – 13.32 μm (w) and phloem towards abaxial sides, 3.33 μm – 6.66 μm (l) x 2.66 μm – 4.99 μm (w). Bundle sheath cells are absent. Sclereid caps are well developed at xylem and phloem poles of midrib bundle, larger and smaller lateral bundles. C-shaped sclereid cap is present towards phloem pole and dome-shaped towards xylem pole. Xylem cap is 4-layered, 43.39 μm (l) x 59.94 μm (w) and phloem cap is 4-layered, 23.31 μm (l) x 76.59 μm (w) (Plate 27B) (Table 8). Stigmata is absent.

Transverse Section of Stem

The surface layer of the stem is irregular with ridges and furrows and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of rectangular parenchymatous cells. The cells are thick-walled. The epidermal cell varies from 13.32 μm – 26.64 μm (w) x 6.66 μm – 13.32 μm (l) in size. **Hypodermis:** There is no distinct hypodermis below epidermis. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue

comprises mass of thin walled elongated parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal parenchymatous cells and fewer, large, scattered, dead, water-storage cells with pleated outlines. Raphide bundles are present in parenchymatous cells near epidermis. Starch grains are present in parenchymatous cells. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. The vascular bundles are scattered in the ground tissue. The number of vascular bundle is 70. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is oval-shaped in outline. The size of vascular bundle ranges from 113.22 μm – 199.80 μm (l) x 86.58 μm – 126.54 μm (w). The vascular bundle consists of xylem and phloem. Phloem lies facing towards periphery, 3.33 μm – 6.66 μm (l) x 3.33 μm – 4.99 μm (w) and xylem towards centre, 13.32 μm – 16.65 μm (l) x 9.99 μm – 13.32 μm (w). Fibre cap is present surrounding phloem, 23.31 μm - 29.97 μm (l) x 49.95 μm - 59.94 μm (w). Fibre cap is larger in small vascular bundle than large vascular bundle. Sclerenchymatous bundle sheath cells are present surrounding vascular bundle (Plate 27A) (Table 9). Stegmata is absent.

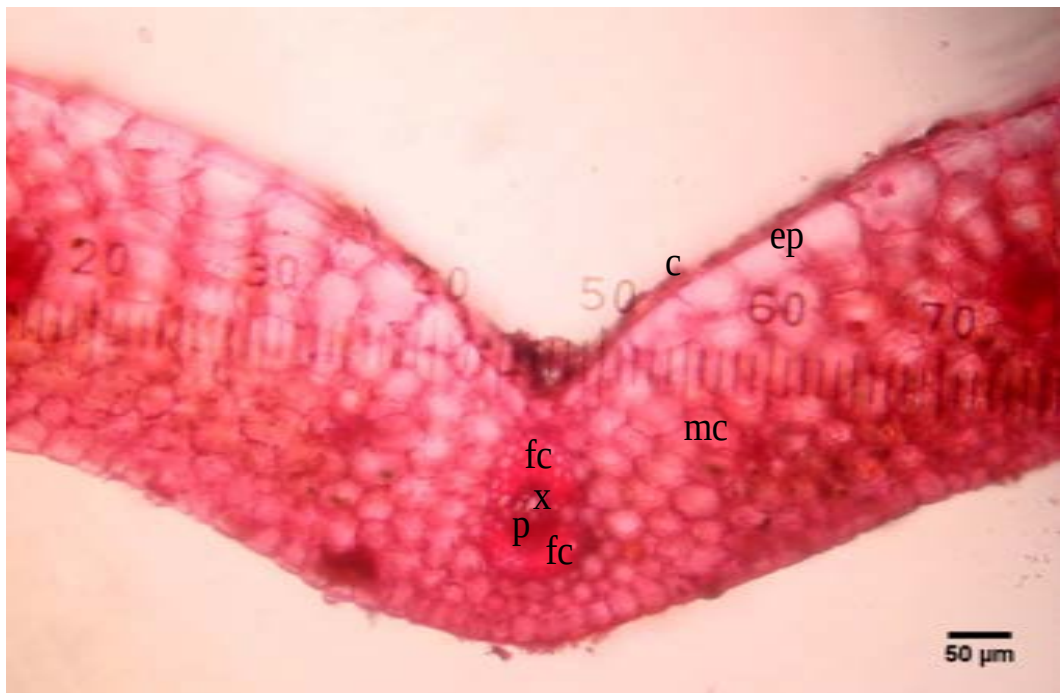
Plate 27. Anatomy of *Dendrobium eriiflorum*

A. T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc).



A



B

Dendrobium monticola

Transverse Section of Leaf

Cuticle: Cuticle is the outermost layer and present on both sides. It is thin, irregular and undulating in both adaxial and abaxial side. **Epidermis:** A single layer of thin-walled, rectangular, square to polygonal parenchymatous cells is present on both adaxial and abaxial sides. The adaxial cells are larger than those of abaxial cells. The abaxial cells in midrib region are smaller than other cells. The adaxial cells measure $13.32\ \mu\text{m} - 53.28\ \mu\text{m}$ (w) $\times$ $19.98\ \mu\text{m} - 33.30\ \mu\text{m}$ (l) and the abaxial cells measure $13.32\ \mu\text{m} - 19.98\ \mu\text{m}$ (w) $\times$ $9.99\ \mu\text{m} - 19.98\ \mu\text{m}$ (l). The anticlinal walls of adaxial cells are sinuous. **Hypodermis:** Absent. **Fibre Bundles:** Absent. **Mesophyll:** Mesophyll is homogenous. It consists of six layers of rectangular, oval, polygonal to rounded, irregular thin-walled chlorenchymatous cells with abundant chloroplasts. Starch grains are present in mesophyll. Some of cells are hyaline without chloroplasts. Intercellular spaces are small and water-storage cells are absent. **Vascular Bundle:** Vascular bundles are arranged in one row with a large bundle in the midrib, large and small bundles are found alternating each other. Vascular bundle is conjoint, collateral, closed and oval in shape. Midrib vascular bundle measures $99.90\ \mu\text{m}$ (l) $\times$ $66.60\ \mu\text{m}$ (w). Vascular bundle lies towards adaxial side. Vascular bundle is composed of xylem and phloem Xylem lies towards the adaxial side, and phloem towards abaxial side, $4.99\ \mu\text{m} - 6.66\ \mu\text{m}$ (l) $\times$ $3.33\ \mu\text{m} - 4.99\ \mu\text{m}$ (w). Sclereid caps and fibre caps are poorly developed at phloem poles and xylem poles of midrib bundle, larger and smaller lateral bundles. C-shaped sclereid cap is present towards phloem pole and C-shaped fibre cap towards xylem pole of midrib bundle. Xylem cap is 3-layered, $23.31\ \mu\text{m}$ (l) $\times$ $53.28\ \mu\text{m}$ (w) and phloem cap is 3-layered, $13.32\ \mu\text{m}$ (l) $\times$ $66.60\ \mu\text{m}$ (w). The vascular bundle is surrounded by chlorenchymatous bundle sheath cells. Bundle sheath cells are continuous in larger and smaller lateral bundles but discontinuous in midrib surrounding phloem only (Plate 28B) (Table 8). Stegmata is absent.

Transverse Section of Pseudobulb

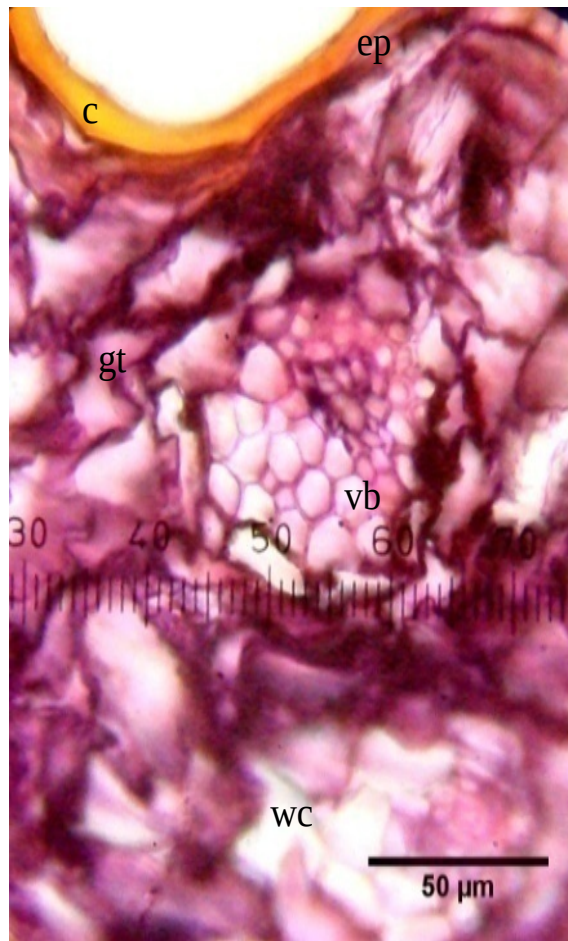
The surface layer of pseudobulb is irregular with large ridges and furrows. It is surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of rectangular-shaped parenchymatous cells. The cells are thick-walled. The epidermal cell varies from $16.65\ \mu\text{m} - 36.63\ \mu\text{m}$

(w) x 6.66 μm – 9.99 μm (l) in size. **Hypodermis:** Hypodermis absent. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory thin-walled parenchymatous cells with wavy margins and fewer, large, scattered, dead, water-storage cells with pleated outlines. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 20. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is elongate-shaped in outline. The size of vascular bundle ranges from 66.60 μm – 89.91 (l) x 49.95 μm – 53.28 μm (w). The vascular bundle consists of xylem and phloem. Xylem lies towards centre, 6.66 μm – 13.32 μm (l) x 4.99 μm – 9.99 μm (w) and phloem lies towards periphery, 4.99 μm – 6.66 μm (l) x 3.33 μm – 4.99 μm (w). Fibre cap is present above phloem, 13.32 μm – 16.65 (l) x 43.29 – 49.95 μm (w). Sclerenchymatous bundle sheath cells are present surrounding xylem (Plate 28A) (Table 9). Stegmata is absent.

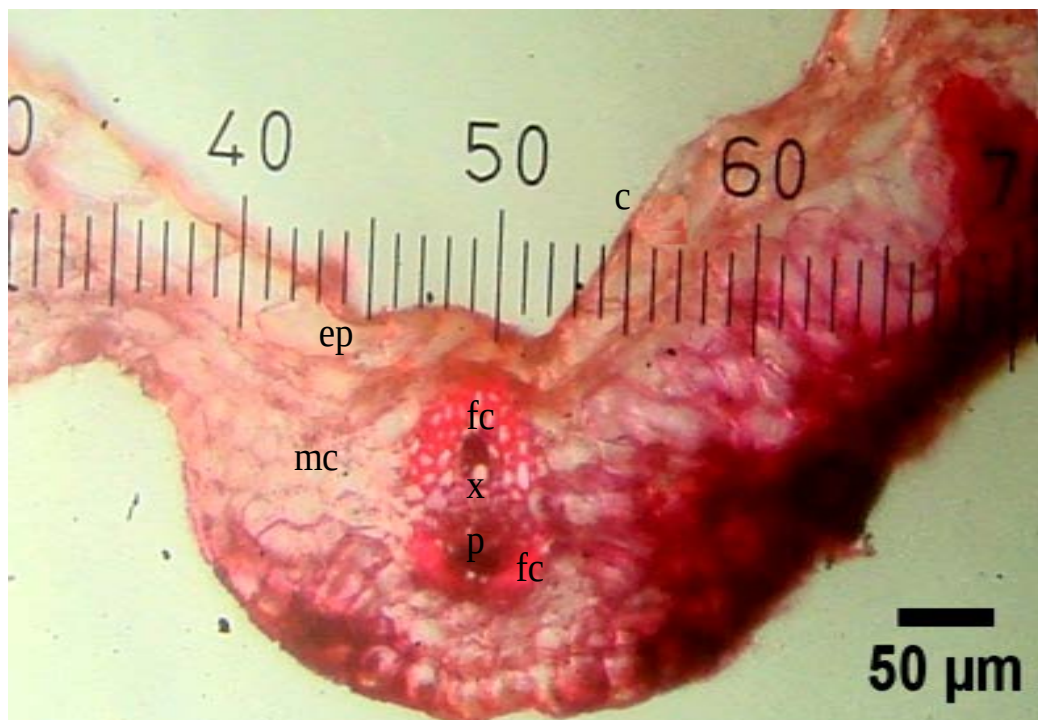
Plate 28. Anatomy of *Dendrobium monticola*

A. T.S. Pseudobulb showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc).



A



B

Dendrobium porphyrochilum

Transverse Section of Leaf

Cuticle: Both sides of leaf have a surface covered with cuticle. It is thin and smooth.

Epidermis: A single layer of thin-walled square, rectangular to hexagonal parenchymatous cells with rounded angles is present on both adaxial and abaxial surfaces. The adaxial cells are larger than those of abaxial cells. The adaxial cells measure $49.95\ \mu\text{m} - 73.26\ \mu\text{m}$ (w) x $19.98\ \mu\text{m} - 39.96\ \mu\text{m}$ (l) and the abaxial cells measure $23.31\ \mu\text{m} - 39.96\ \mu\text{m}$ (w) x $16.65\ \mu\text{m} - 23.31\ \mu\text{m}$ (l). **Hypodermis:** Absent.

Fibre Bundles: Absent. **Mesophyll:** Mesophyll is homogenous. It consists of six layers of chlorenchymatous cells. The cells are oval, rounded to irregular in shape. Intercellular spaces are small. Idioblasts with mucilage and raphide bundles surrounded with mucilage are found in mesophyll. **Vascular Bundle:** Vascular bundles are arranged in one row with a large midrib bundle in the centre. The smaller and larger bundles are found alternating each other. Vascular bundles are small in size. Vascular bundle is conjoint, collateral, closed and elongate in shape. Midrib vascular bundle measures $99.90\ \mu\text{m}$ (l) x $93.24\ \mu\text{m}$ (w). Vascular bundle is composed of xylem and phloem. Xylem lies towards adaxial side, $4.99\ \mu\text{m} - 13.32\ \mu\text{m}$ (l) x $3.99\ \mu\text{m} - 9.99\ \mu\text{m}$ (w) and the phloem towards abaxial side, $3.33\ \mu\text{m} - 4.99\ \mu\text{m}$ (l) x $2.66\ \mu\text{m} - 3.33\ \mu\text{m}$ (w). Vascular bundle lies towards adaxial side of midrib region. Sclerenchymatous caps are absent. Sclerenchymatous bundle sheath cells are continuous surrounding xylem and phloem of midrib, larger and smaller lateral bundles (Plate 29B) (Table 8). Stigmata is indistinct.

Transverse Section of Pseudobulb

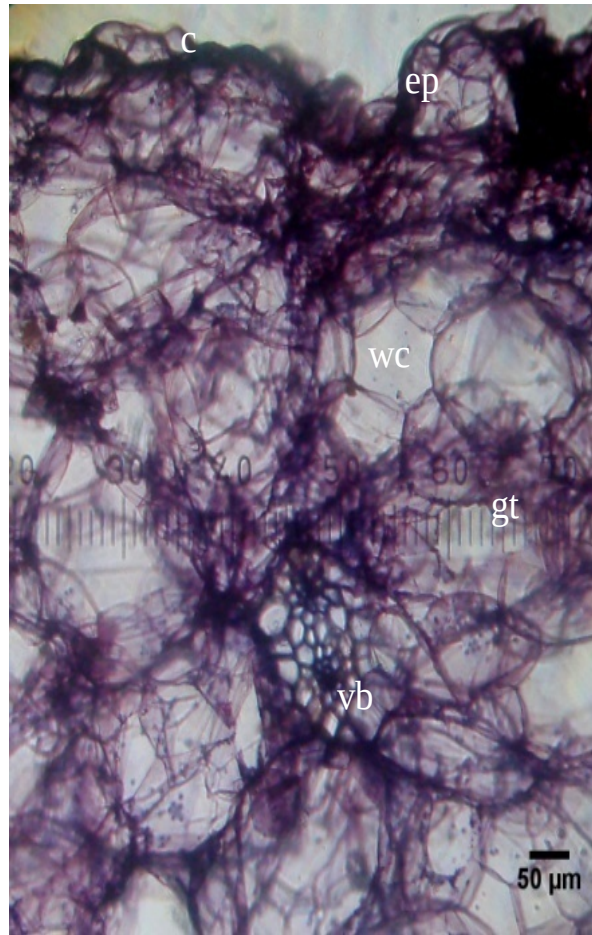
The surface layer of pseudobulb is irregular and surrounded by leaf sheaths. **Cuticle:** Cuticle is thick and smooth. **Epidermis:** Epidermis is represented by a single layer of rectangular, square, polygonal shaped parenchymatous cells. The cells are thick-walled. The epidermal cell varies from $29.97\ \mu\text{m} - 46.62\ \mu\text{m}$ (w) x $19.98\ \mu\text{m} - 23.31\ \mu\text{m}$ (l) in size. **Hypodermis:** Hypodermis is absent. **Ground Tissue:** There is no differentiation of cortex, endodermis, pericycle and pith. Ground tissue lies below hypodermis and extends up to the centre. Ground tissue comprises mass of thin walled parenchymatous cells with intercellular spaces. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large,

scattered, dead, water-storage cells with pleated outlines. Calcium oxalate crystals are present scattered in parenchymatous cell. **Vascular Bundle:** Vascular bundles are conjoint, collateral and closed. Vascular bundles are scattered in the ground tissue. Number of vascular bundle is 40. The outer vascular bundles are smaller than the inner bundles. Each vascular bundle is elongate-shaped in outline. The size of vascular bundle ranges from 89.91 μm – 166.50 (l) x 66.60 μm – 83.25 μm (w). The vascular bundle consists of xylem and phloem. Phloem lies towards periphery, 6.66 μm – 8.32 μm (l) x 3.33 μm – 6.66 μm (w) and xylem lies towards centre, 9.99 μm – 16.65 μm (l) x 6.66 μm – 9.99 μm (w). Fibre cap is absent towards the upper side surrounding phloem. Sclerenchymatous bundle sheath cells are present surrounding vascular bundles (Plate 29A) (Table 9). Stegmata is indistinct.

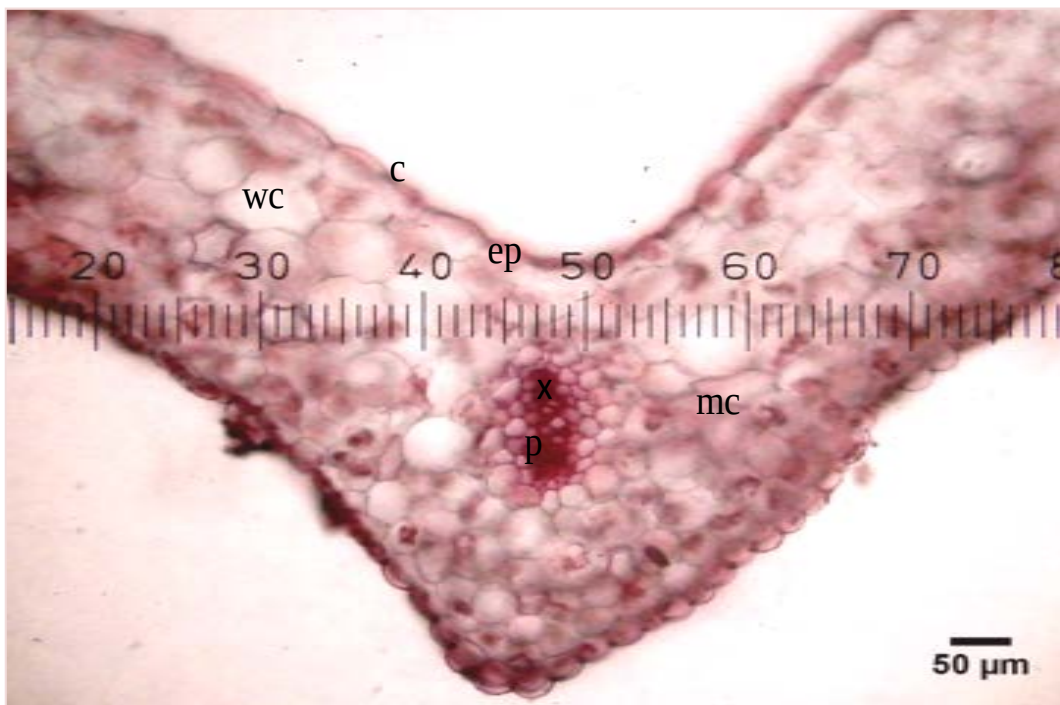
Plate 29. Anatomy of *Dendrobium porphyrochilum*.

A. T.S. Pseudobulb showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

B. T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc).



A



B

Plate 30: Stegmata in T.S. Leaf and T. S. Stem of *Dendrobium* species.

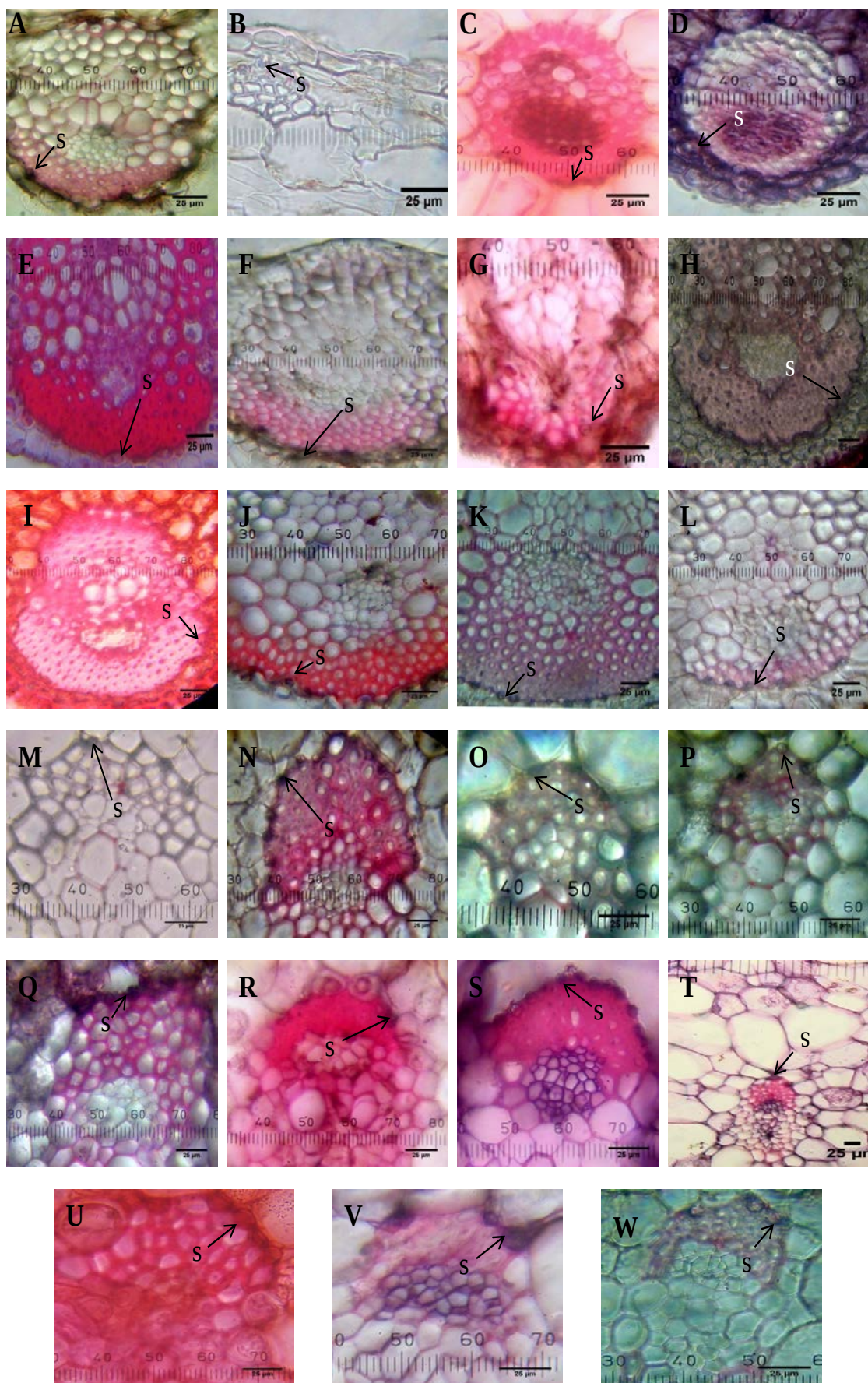
T.S. Leaf (A-L).

A. *D. amoenum*, B. *D. anceps*, C. *D. aphyllum*, D. *D. bicameratum*, E. *D. chrysanthum*, F. *D. crepidatum*, G. *D. denudans*, H. *D. fugax*, I. *D. fuscescens*, J. *D. gibsonii*, K. *D. moschatum*, L. *D. nobile*

T.S. Stem (M-W).

M. *D. amoenum*, N. *D. amplum*, O. *D. aphyllum*, P. *D. bicameratum*, Q. *D. densiflorum*, R. *D. formosum*, S. *D. fugax*, T. *D. longicornu*, U. *D. polyanthum*, V. *D. rotundatum*, W. *D. transparens*.

T.S. Leaf showing stigmata (s) and T.S. Stem showing stigmata (s).



Excluded species:

Dendrobium plicate Lindl., Edward's Bot. Reg. 26 (Misc.): 10 (1840).

This species was already described in gross morphological study with acquired image. But for anatomical studies, it should be needed to have specimens. The species could not be collected from field and other sources due to extraction of species from their natural habitat for commercial purposes and export them outside the country illegally or by deforestation. Because of lack of sample, this species had been excluded in the anatomical study.

Dendrobium chryseum Rolfe, Gard. Chron. ser. 3, 3: 233 (1888).

This species was also already described in gross morphological study with acquired image. This species also could not be collected from field and other sources. This species had been excluded in the anatomical study due to lack of sample.

Dendrobium darjeelingense Pradhan, Indian Orchids: Guide Identif. & Cult. 2: 336 (1979).

This specimen was described in gross morphological study from voucher specimen deposited at KATH. This specimen also could not be collected from field sites and other sources. So this specimen had been excluded in the anatomical study.

Table 8. Anatomical characters of leaf of *Dendrobium*

S.N.	Taxa	Cuticle layer	Epidermal cell			Hypodermis		Fibre bundle	Mesophyll		Mid Vascular bundle		Fibre cap size		Xylem size (l x w) μm	Phloem size (l x w) μm
			Shape	Size (w x l) μm												
				Adaxial	Abaxial	Position	Layer		Shape	Layer	Shape	Size (l x w) μm	Xylem cap (l x w) μm	Phloem cap (l x w) μm		
1	<i>Dendrobium amoenum</i> Wallich ex Lindley	Thin	Rect. to Poly.	19.98–69.93 x 19.98–33.30	13.32–43.29 x 9.99–23.31	N.P	N.P	N.P	Colu. to Poly.	7	Oval	193.14 x 133.20	83.25 x 143.19	33.30 x 133.20	9.99 – 29.97 x 6.66 – 26.64	4.99–6.66 x 3.33–4.99
2	<i>D. amplum</i> Lindley	Thick	Rect. to Poly.	19.98–56.61 x 16.65–29.97	16.65–49.95 x 9.99–19.98	N.P	N.P	N.P	Pali. Poly. to Colu. Spon.Oval to Poly.	Pali. 2 Spon. 7	Flask-shaped	199.80 x 143.19	16.65 x 139.86	46.62 x 166.50	6.66–23.31 x 4.99–19.98	3.33–6.66 x 2.66–4.99
3	<i>D. anceps</i> Swartz	Thick	Poly.	16.65–36.63 x 6.66–13.32	16.65–23.31 x 6.66 – 13.32	Abaxial	1	Present	Oval to Poly.	18	Circular	139.06 x 136.53	23.31 x 119.88	26.64 x 139.86	6.66 – 9.99 x 4.99 - 9.99	3.33-4.99 x 2.66-3.33
4	<i>D. aphyllum</i> (Roxburgh) C.E.C.	Thin	Rect. to	46.62–76.59 x 36.63–	23.31–66.60 x 13.32–	N.P	N.P	N.P	Oval to Poly.	9	Oval	126.54 x	19.98 x 86.58	19.98 x 89.91	9.99–19.98 x 6.66 –	4.99–6.66 x 3.33–

	Fischer		Hexa.	49.95	29.97							106.56			16.65	4.99
5	<i>D. bicameratum</i> Lindley	Thick	Rect. to Poly.	13.32– 49.95 x 19.98– 29.97	13.32– 36.63 x 9.99– 13.32	N.P	N.P	N.P	Oval to Poly.	8	Oval	119.88 x 93.24	26.64 x 89.91	19.98 x 93.24	6.66 – 13.32 x 4.99 – 6.66	3.99– 6.66 x 2.66– 3.33
6	<i>D. chrysanthum</i> Wallich ex Lindley	Thin	Rect. to Poly.	19.98– 73.26 x 16.65– 26.64	9.99– 36.63 x 9.99– 19.98	N.P	N.P	N.P	Rect.	8	Oval	219.79 x 209.78	49.95 x 186.48	36.63 x 183.15	9.9– 19.98 x 8.32– 19.98	6.66– 9.99 x 3.33– 6.66
7	<i>D. crepidatum</i> Lindley & Paxton	Thin	Rect. to Poly.	19.98– 43.29 x 13.32– 43.29	8.32– 26.64 x 13.32– 26.64	N.P	N.P	N.P	Rect. to Poly.	10	Conical	233.10 x 166.50	43.29 x 126.54	53.28 x 173.16	13.32– 19.98 x 11.65– 13.32	4.99– 8.32 x 3.33– 4.99
8	<i>D. denneanum</i> Kerr	Thick	Rect. to Poly.	19.98– 33.30 x 13.32– 16.65	16.65– 26.64 x 8.32– 9.99	N.P	N.P	N.P	Rect. to Poly.	8	Conical	216.45 x 189.81	49.95 x 166.50	33.30 x 176.49	6.66– 19.98 x 4.99– 16.65	3.33– 6.66 x 3.33– 4.99
9	<i>D. densiflorum</i> Wallich	Thick	Rect. to Poly.	23.31– 36.63 x 13.32– 23.31	16.65– 26.64 x 13.32– 19.98	Adaxial	1	N.P	Oval to Poly.	13	Conical	586.52 x 386.57	213.28 x 319.92	146.63 x 413.23	16.65– 29.97 x 6.66– 16.65	4.99– 9.99 x 3.33– 6.66
10	<i>D. denudans</i> D. Don	Thin	Rect. to Poly.	23.31– 43.29 x 9.99–	23.31– 29.97 x 9.99–	N.P	N.P	N.P	Rect. to Poly.	7	Oblong	126.54 x 53.28	23.31 x 53.28	23.31 x 56.61	13.32– 19.98 x 4.99–	4.99– 6.66 x 3.99–

				19.98	16.65										6.66	4.99
11	<i>D. eriiflorum</i> Griffith	Thin	Rect. to Poly.	19.98– 43.29 x 26.64– 43.29	13.32– 23.31 x 19.98– 29.97	N.P	N.P	N.P	Rect. to Poly.	7	Oval	116.55 x 69.93	43.39 x 59.94	23.31 x 76.59	6.66– 19.98 x 4.99– 13.32	3.33– 6.66 x 2.66– 4.99
12	<i>D. fimbriatum</i> Hooker	Thin	Rect. to Poly.	16.65– 39.96 x 13.32– 26.64	9.99– 23.31 x 6.66– 16.65	N.P	N.P	N.P	Rect. to Poly.	7	Oval	169.83 x 123.21	43.29 x 116.55	33.30 x 129.80	9.99– 19.98 x 9.99– 16.65	3.33– 6.66 x 1.66– 4.99
13	<i>D. formosum</i> Roxburgh ex Lindley	Thin	Rect. to Poly.	36.63– 76.59 x 33.30– 46.62	19.98– 43.29 x 19.98– 33.30	N.P	N.P	N.P	Oval to Poly.	9	Oval	216.45 x 193.14	73.26 x 183.15	33.30 x 206.46	13.32– 29.97 x 6.66– 19.98	3.33– 13.32 x 3.33– 9.99
14	<i>D. fugax</i> Reichenbach	Thick	Rect. to Squa.	19.98– 33.30 x 9.99– 16.65	13.32– 23.31 x 9.99– 16.65	N.P	N.P	N.P	Oval to Poly.	15	Flask- shaped	223.11 x 166.50	56.61 x 166.50	36.63 x 199.80	9.99– 26.64 x 9.99– 16.65	4.99– 9.99 x 3.33– 6.66
15	<i>D. fuscescens</i> Griffith	Thick	Rect. to Poly.	23.31– 43.29 x 16.65– 26.64	16.65– 39.96 x 16.65– 23.31	N.P	N.P	N.P	Pali. Poly. to Oval Spon.Oval to Poly.	Pali. 2 Spon. 7	Flask- shaped	209.79 x 156.51	56.61 x 113.22	49.95 x 179.82	9.99– 23.31 x 6.66– 16.65	4.99– 9.99 x 4.99– 6.66
16	<i>D. gibsonii</i> Paxton	Thin	Rect. to Poly.	23.31– 66.60 x 13.32–	16.65– 33.30 x 13.32–	N.P	N.P	N.P	Rect. to Poly.	8	Oval	289.71 x 233.10	83.25 x 199.80	49.95 x 233.10	13.32– 29.97 x 6.66–	4.99– 9.99 x 3.33–

				33.30	16.65										23.31	8.32
17	<i>D. heterocarpum</i> Wallich ex Lindley	Thin	Rect. to Poly.	26.64– 73.26 x 26.64– 53.28	9.99– 33.30 x 13.32– 26.64	N.P	N.P	N.P	Rect. to Poly.	7	Oval	149.85 x 116.55	19.98 x 99.90	19.98 x 86.58	6.66– 19.98 x 4.99– 16.65	3.99– 6.66 x 3.66– 4.99
18	<i>D. longicornu</i> Lindley	Thin	Rect. to Hexa.	23.31– 53.28 x 19.98– 46.62	19.98– 49.95 x 13.32– 33.30	N.P	N.P	N.P	Oval to Poly.	8	Circular	166.50 x 166.50	33.30 x 156.51	33.30 x 126.54	9.99– 23.31 x 6.66– 16.65	4.99– 6.66 x 3.33– 6.66
19	<i>D. moniliforme</i> (L.) Swartz	Thick	Rect. to Poly.	23.31– 56.61 x 36.63– 46.62	9.99– 26.64 x 13.32– 19.98	N.P	N.P	N.P	Rect. to Poly.	8	Oval	119.88 x 133.20	26.64 x 106.56	23.31 x 133.20	9.99– 10.65 x 4.99– 6.66	3.99– 5.99 x 2.66– 3.33
20	<i>D. monticola</i> Hunt & Summerhayes	Thin	Rect. to Poly.	13.32– 53.28 x 19.98– 33.30	13.32– 19.98 x 9.99– 19.98	N.P	N.P	N.P	Rect. to Poly.	6	Oval	99.90 x 66.60	23.31 x 53.28	13.32 x 66.60	6.66– 9.99 x 3.33– 8.32	4.99– 6.66 x 3.33– 4.99
21	<i>D. moschatum</i> (Buchanan-Hamilton) Swartz	Thin	Rect. to Hexa.	26.64– 66.60 x 16.65– 26.64	16.65– 23.31 x 9.99– 16.65	N.P	N.P	N.P	Oval to Poly.	16	Conical	506.54 x 333.25	159.96 x 319.92	106.64 x 333.25	19.98– 39.96 x 6.66– 26.64	4.99– 9.99 x 3.33– 8.32
22	<i>D. nobile</i> Lindley	Thin	Rect. to Hexa.	36.63– 83.25 x 73.26–	16.65– 53.28 x 23.31–	N.P	N.P	N.P	Oval to Poly.	9	Oval	199.80 x 166.50	49.95 x 166.50	26.64 x 159.84	19.98– 23.31 x 9.99–	6.66– 9.99 x 4.99–

				99.90	46.62										19.98	6.66
23	<i>D. polyanthum</i> Wallich ex Lindley	Thin	Rect. to Hexa.	16.65– 33.30 x 9.99– 26.64	13.32– 29.97 x 9.99– 13.32	N.P	N.P	N.P	Oval to Poly.	8	Circular	213.12 x 199.80	83.25 x 193.14	43.29 x 173.16	6.66– 23.31 x 3.33– 6.66	4.99– 6.66 x 3.33– 4.99
24	<i>D. porphyrochilum</i> Lindley	Thin	Rect. to Hexa.	49.95– 73.26 x 19.98– 39.96	23.31– 39.96 x 16.65– 23.31	N.P	N.P	N.P	Oval to Poly.	6	Oblong	99.90 x 93.24	N.P	N.P	4.99– 13.32 x 3.99– 9.99	3.33– 4.99 x 2.66– 3.33
25	<i>D. rotundatum</i> (Lindley) Hooker	Thick	Rect. to Poly.	23.31– 49.95 x 16.65– 33.30	9.99– 39.96 x 16.65– 26.64	N.P	N.P	N.P	Pali. Poly. to Colu. Spon.Oval to Poly.	Pali. 2 Spon. 8	Flask- shaped	183.15 x 133.20	39.96 x 193.14	53.28 x 126.54	13.32– 26.64 x 6.66– 19.98	4.99– 6.66 x 3.33– 4.99
26	<i>D. transparens</i> Wallich ex Lindley	Thin	Rect. to Hexa.	23.31– 66.60 x 36.63– 59.94	13.32– 43.29 x 13.32– 23.31	N.P	N.P	N.P	Oval to Poly.	8	Circular	149.85 x 146.52	33.30 x 149.85	26.64 x 146.52	13.32– 19.98 x 9.99– 16.65	3.33– 6.66 x 3.33– 4.99

Abbreviations used: N.P=Not Present; Rect.=Rectangular; Poly.=Polygonal; Squa.= Square; Hexa.=Hexagonal; Colu.=Columnar; Pali.=Palisade layer; Spon.=Spongy layer.

Table 9. Anatomical characters of stem of *Dendrobium*

S.N.	Taxa	Cuticle	Epidermal cell		Hypodermis		Vascular bundle			Fibre cap size		Xylem size (l x w) μm	Phloem size (l x w) μm
			Shape	Size (w x l) μm	Shape	Layer	Shape	No.	Size (l x w) μm	Xylem cap (l x w) μm	Phloem cap (l x w) μm		
1	<i>Dendrobium amoenum</i> Wallich ex Lindley	Thick	Rect. to Poly.	9.99–19.98 x 4.99–9.99	Poly.	2	Oval	76	143.19–183.15 x 93.24–113.22	N.P	26.64–33.30 x 83.25–96.57	9.99–29.97 x 6.66–23.31	6.66–16.65 x 4.99–9.99
2	<i>D. amplum</i> Lindley	Thick	Rect. to Squa.	9.99–19.98 x 9.99–13.32	Poly.	2	Elongate	50	133.20–333.00 x 66.60–149.85	43.29–56.61 x 106.56–133.20	33.30–99.90 x 83.25–116.55	11.65–26.64 x 9.99–16.65	3.33–9.99 x 3.33–6.66
3	<i>D. anceps</i> Swartz	Thick	Barr.	9.99–16.65 x 6.66–9.99	Poly.	2	Oval	64	116.55–199.80 x 73.26–99.90	16.65–26.64 x 79.92–86.58	19.98–49.95 x 73.26–99.90	13.32–16.65 x 4.99–13.32	4.99–6.66 x 3.33–6.66
4	<i>D. aphyllum</i> (Roxburgh) C.E.C. Fischer	Thick	Barr.	9.99–13.32 x 16.65–26.64	Poly.	1	Oval	82	133.20–236.43 x 103.23–106.56	N.P	29.97–33.30 x 99.90–93.24	13.32–26.64 x 9.99–19.98	6.66–13.32 x 4.99–6.66
5	<i>D. bicameratum</i> Lindley	Thick	Barr.	9.99–13.32 x 6.66–9.99	Poly.	2 to 3	Elongate	118	93.24–199.80 x 83.25–93.24	N.P	16.65–33.30 x 49.95–66.60	13.32–33.30 x 6.66–26.64	4.99–6.66 x 3.33–6.66
6	<i>D. chrysanthum</i> Wallich ex Lindley	Thick	Barr.	13.32–19.98 x 9.99–13.32	Oval to poly.	2	Elongate	70	103.23–266.40 x 83.25–133.20	N.P	16.65–33.30 x 83.25–96.57	9.99–33.30 x 9.99–29.97	4.99–9.99 x 3.33–6.66
7	<i>D. crepidatum</i> Lindley & Paxton	Thick	Rect. to Poly.	13.32–36.63 x 6.66–6.65	Oblo. to Poly.	1	Oval	60	123.21–209.79 x 83.25–99.90	N.P	19.98–26.64 x 49.95–66.60	13.32–26.64 x 6.66–19.98	4.99–9.99 x 3.33–9.32

8	<i>D. denneanum</i> Kerr	Thick	Barr.	9.99–19.98 x 6.66–13.32	Rect. to Poly.	4	Elongate	97	163.17–299.70 x 143.19–149.85	N.P	39.96–49.95 x 116.55–119.88	43.29–49.95 x 23.31–23.31	9.99–13.32 x 6.66–9.99
9	<i>D. densiflorum</i> Wallich	Thick	Rect.	6.66–9.99 x 16.65–16.65	Rect. to Poly.	4 to 5	Oval	78	106.56–206.46 x 89.91–153.18	N.P	26.64–36.63 x 83.25–119.88	9.99–13.32 x 6.66–9.99	3.33–4.99 x 2.66–3.33
10	<i>D. denudans</i> D. Don	Thick	Rect.	13.32–26.64 x 6.66–13.32	N.P	N.P	Oval	50	66.60–119.88 x 56.61–76.59	N.P	16.65–16.65 x 49.95–56.6	9.99–13.32 x 6.66–9.99	3.33–4.99 x 2.66–3.33
11	<i>D. eriiflorum</i> Griffith	Thick	Rect.	13.32–26.64 x 6.66–13.32	N.P	N.P	Oval	70	113.22–199.80 x 86.58–126.54	N.P	19.98–29.97 x 49.95–66.60	13.32–16.65 x 9.99–13.32	3.33–6.66 x 3.33–4.99
12	<i>D. fimbriatum</i> Hooker	Thick	Barr.	13.32–16.65 x 9.99–11.65	Rect. to Poly.	4 to 5	Oval	62	133.20–199.80 x 109.89–133.20	N.P	39.96–43.29 x 106.56–123.21	26.64–49.95 x 9.99–13.32	6.66–16.65 x 4.99–9.99
13	<i>D. formosum</i> Roxburgh ex Lindley	Thick	Rect. to Poly.	16.65–39.96 x 9.99–16.65	Poly.	2	Oval	64	166.50–233.10 x 119.88–153.18	N.P	33.30–53.28 x 89.91–109.89	26.64–49.95 x 9.99–13.32	6.66–16.65 x 4.99–9.99
14	<i>D. fugax</i> Reichenbach	Thick	Barr.	13.32–23.31 x 9.99–16.65	Poly.	2	Elongate	71	116.55–216.45 x 86.58 – 166.50	N.P	26.64–33.30 x 79.92 – 99.90	13.32–23.31 x 9.99–16.65	4.99–6.66 x 3.33–6.66
15	<i>D. fuscescens</i> Griffith	Thick	Rect. to Squa.	9.99–26.64 x 6.66–19.98	Poly.	2	Oval	83	99.90–243.09 x 89.91–116.55	16.65– 49.95 x 59.94– 116.55	16.65–26.64 x 59.94–66.60	6.66–23.31 x 6.66–16.65	3.33–9.99 x 3.33–6.66
16	<i>D. gibsonii</i> Paxton	Thick	Rect. to Angu.	13.32–16.65 x 6.66–13.32	Poly.	2	Oval	30	123.31–316.35 x 93.24–183.15	N.P	16.65–69.93 x 76.59–93.24	16.65–29.97 x 9.99–19.98	4.99–13.32 x 3.33–9.99
17	<i>D. heterocarpum</i> Wallich ex Lindley	Thick	Rect. to Angu.	13.32–19.98 x 6.66–13.32	Poly.	2	Oval	80	116.55–179.82 x 99.90–109.89	N.P	16.65–43.29 x 73.26–83.25	9.99–16.65 x 4.99–13.32	6.66–9.99 x 4.99–6.66
18	<i>D. longicornu</i> Lindley	Thick	Rect. to Poly.	13.32–19.98 x 6.66–13.32	Poly.	2	Elongate	68	76.59–183.15 x 89.91–119.88	N.P	16.65–46.62 x 79.92–83.25	9.99–26.64 x 4.99–19.98	4.99–11.65 x 3.33–9.99

19	<i>D. moniliforme</i> (L.) Swartz	Thick	Rect. to Poly.	13.32–23.31 x 6.66–13.32	Poly.	2	Elongate	55	199.80–233.10 x 113.22–166.50	N.P	23.31–29.97 x 49.95–66.60	19.80–23.31 x 13.32–19.98	9.99–13.32 x 4.99–9.99
20	<i>D. monticola</i> Hunt & Summerhayes	Thick	Rect.	16.65–36.63 x 6.66–9.99	N.P	N.P	Elongate	20	66.60–89.91 x 49.95–53.28	N.P	13.32–16.65 x 43.29 – 49.95	6.66–13.32 x 4.99–9.99	4.99–6.66 x 3.33–4.99
21	<i>D. moschatum</i> (Buchanan-Hamilton) Swartz	Thick	Barr.	9.99–13.32 x 13.32–16.65	Poly.	3	Oval	78	133.20–166.50 x 113.22–133.20	26.64- 43.29 x 66.60– 99.90	33.30–36.63 x 113.22–133.20	13.32–16.65 x 9.99–13.32	3.33–6.66 x 3.33–4.99
22	<i>D. nobile</i> Lindley	Thick	Rect. to Poly.	13.32–26.64 x 6.66–13.32	Poly.	2	Oval	82	116.55–216.45 x 86.58–166.50	N.P	26.64–33.30 x 79.92 – 99.90	13.32–19.98 x 9.99–16.65	4.99–6.66 x 3.33–6.66
23	<i>D. polyanthum</i> Wallich ex Lindley	Thick	Rect. to Poly.	19.98–39.96 x 13.32–16.65	Poly.	1	Elongate	16	99.90–289.71 x 49.95–133.20	N.P	33.30–36.30 x 63.27–119.88	9.99–39.96 x 6.66–23.31	4.99–16.65 x 3.33–13.32
24	<i>D. porphyrochilum</i> Lindley	Thin	Rect. to Poly.	29.97–46.62 x 19.98–23.31	N.P	N.P	Elongate	40	89.91–166.50 x 66.60– 83.25	N.P	N.P	9.99–16.65 x 6.66–9.99	6.66–8.32 x 3.33–6.66
25	<i>D. rotundatum</i> (Lindley) Hooker	Thick	Rect. to Squa.	16.65–29.97 x 9.99–16.65	Poly.	2	Oval	82	99.90–166.50 x 83.25–116.55	N.P	13.32–39.96 x 33.30–99.90	16.65–23.31 x 13.32–19.98	3.33–13.32 x 3.33–9.99
26	<i>D. transparens</i> Wallich ex Lindley	Thick	Rect. to Squa.	13.32–19.98 x 9.99–19.98	Poly.	2	Elongate	50	96.57–133.32 x 63.27–79.92	N.P	23.31–26.64 x 59.94–76.59	9.99–16.65 x 6.66–9.99	6.66–8.32 x 3.33–6.66

Abbreviations used: N.P = Not present; Rect. = Rectangular; Poly. = Polygonal; Angu. = Angular; Squa. = Square; Barr. = Barrel-shaped.

From the present study, anatomical characters of leaves and stems were found to be taxonomically important for delimiting the taxa. Based on anatomical characters of leaves and stems, an anatomical key has been prepared to delimit the taxa within genus *Dendrobium*.

Keys for identification of spp. of *Dendrobium*

1a. Leaf with thick cuticle -----	2
1b. Leaf with thin cuticle -----	10
2a. Thick cuticle with homogenous mesophyll in leaf -----	3
2b. Thick cuticle with heterogenous mesophyll in leaf -----	8
3a. Homogenous mesophyll with major vascular bundle at one leaf pole ---	<i>D. anceps</i>
3b. Homogenous mesophyll without major vascular bundle at one leaf pole -----	4
4a. Elongate shaped vascular bundle in stem -----	5
4b. Oval shaped vascular bundle in stem -----	<i>D. densiflorum</i>
5a. Stem hypodermal layers 4 -----	<i>D. denneanum</i>
5b. Stem hypodermal layers < 4 -----	6
6a. Oval shaped vascular bundle in leaf -----	7
6b. Flask-shaped vascular bundle in leaf -----	<i>D. fugax</i>
7a. Barrel shaped epidermal cells in stem -----	<i>D. bicameratum</i>
7b. Rectangular to polygonal shaped epidermal cells in stem -----	<i>D. moniliforme</i>
8a. Fibre cap surrounding xylem and phloem in stem -----	9
8b. Fibre cap surrounding phloem in stem -----	<i>D. rotundatum</i>
9a. Stem vascular bundle 333.0 µm long -----	<i>D. amplum</i>
9b. Stem vascular bundle 243.09 µm long -----	<i>D. fuscescens</i>
10a. Thin leaf cuticle without hypodermis in stem -----	11
10b. Thin leaf cuticle with hypodermis in stem -----	14
11a. Fibre caps surrounding xylem and phloem present in leaf -----	12
11b. Fibre caps surrounding xylem and phloem absent in leaf -----	<i>D. porphyrochilum</i>
12a. Number of vascular bundles 20 in stem -----	<i>D. monticola</i>
12b. Number of vascular bundles > 20 in stem -----	13
13a. Stem vascular bundle 119.88 µm long -----	<i>D. denudans</i>
13b. Stem vascular bundle 199.80 µm long -----	<i>D. eriiflorum</i>
14a. Midrib vascular bundle 506.54 µm long in leaf -----	<i>D. moschatum</i>

14b. Midrib vascular bundle < 506.54 µm long in leaf -----	15
15a. Mesophyll layers 10 in leaf -----	<i>D. crepidatum</i>
15b. Mesophyll layers < 10 in leaf -----	16
16a. Phloem fibre cap 233.10 µm wide in leaf -----	<i>D. gibsonii</i>
16b. Phloem fibre cap < 233.10 µm wide in leaf -----	17
17a. Xylem 16.65 µm long in stem -----	<i>D. transparens</i>
17b. Xylem > 16.65 µm long in stem -----	18
18a. Xylem fibre cap 86.58 µm wide in leaf -----	<i>D. aphyllum</i>
18b. Xylem fibre cap > 86.58 µm wide in leaf -----	19
19a. Stem vascular bundle 289.71 µm long -----	<i>D. polyanthum</i>
19b. Stem vascular bundle < 289.71 µm long -----	20
20a. Hypodermal layers 2 in stem -----	21
20b. Hypodermal layers 5 in stem -----	<i>D. fimbriatum</i>
21a. Oval shaped midrib vascular bundle in leaf -----	22
21b. Circular shaped midrib vascular bundle in leaf -----	<i>D. longicornu</i>
22a. Phloem fibre cap 206.46 µm wide in leaf -----	<i>D. formosum</i>
22b. Phloem fibre cap < 206.46 µm wide in leaf -----	23
23a. Oval shaped vascular bundle in stem -----	24
23b. Elongate shaped vascular bundle in stem -----	<i>D. chrysanthum</i>
24a. Mesophyll layer 7 in leaf -----	25
24b. Mesophyll layer 9 in leaf -----	<i>D. nobile</i>
25a. Mesophyll cell columnar to polygonal in leaf -----	<i>D. amoenum</i>
25b. Mesophyll cell rectangular to polygonal in leaf -----	<i>D. heterocarpum</i>

4.2.4. Discussion

The anatomical study could be performed only on 26 species out of 29 species of *Dendrobium* of Nepal Himalaya due to unavailability of three species: *D. darjeelingense*, *D. chryseum* and *D. plicatile*. The anatomical characters have proved to be very useful in discriminating evolutionary trends and interrelationships of taxa at and species level and at higher taxonomic categories (Taia, 2005). The anatomical data with gross morphology, pollen, cytology, physiology, chemistry and molecular biology enables to make revision of plant classification to elucidate phylogenetic relationships in more systematic way (Rouhan and Gaudeul, 2014).

Leaf Anatomy

Leaf (T.S.)

Cuticle: Cuticle was found thin in most species but thick in *D. anceps* (Section *Aporum*), *D. fugax* (Section *Crinifera*), *D. bicameratum*, *D. denneanum*, *D. densiflorum*, *D. moniliforme* (Section *Dendrobium*), *D. amplum*, *D. fuscescens* and *D. rotundatum* (Section *Sarcopodium*). Even though the cuticles are thick, the species *D. anceps* of Section *Aporum* was distinguished from other species by intermittently domed cuticle (Pradhan and Bajracharya, 2020a). Morris *et al.* (1996) reported intermittently domed cuticle in *D. anceps*. Cuticle is followed by epidermis, hypodermis, mesophyll and vascular bundle.

Epidermis: Epidermal cells possessed thin walls in most species but thick walls in *D. bicameratum*, *D. densiflorum*, *D. moniliforme* and *D. moschatum* (Section *Dendrobium*) and *D. amplum*, *D. fuscescens*, *D. rotundatum* (Section *Sarcopodium*). In *D. anceps* (Section *Aporum*), somewhat suberized epidermal cells were present. Ramesh *et al.* (2020) reported suberized epidermal cells in *D. anceps*. Solereder and Meyer (1930) reported suberized epidermal cells in *D. aloifolium* belonging to Section *Aporum*. Metcalfe (1960) described suberin deposits in cell wall of leaves in Gramineae. Carlsward *et al.* (1997) reported suberin-like substances in cell walls of *D. distichum* and *D. rosellum* (Section *Aporum*) but in present study it was found in *D. anceps* also. The presence of suberin-like substances could be adaptations to xeric conditions (Carlsward *et al.*, 1997).

In the investigated taxa, bulliform cells in adaxial surface were reported in *D. heterocarpum* and *D. nobile* of Section *Dendrobium*. Mohana Rao and Khasim (1987b) reported bulliform cells in adaxial surface in *Anthogonium gracile* of Thuiinae but Morris *et al.* (1996) did not mentioned the bulliform cells. By bulliform cells in adaxial surfaces of leaf, *D. heterocarpum* and *D. nobile* of Section *Dendrobium* can be distinguished from species of other Sections of *Dendrobium*.

In the presently studied taxa, cell lumina occluded with safranin-staining materials in adaxial and abaxial surfaces of epidermis was found in *D. fugax* (Section *Crinifera*), *D. amplum*, *D. fuscescens* and *D. rotundatum* (Section *Sarcopodium*), both Sections having distinct pseudobulbs and absent in other species. This result supports the findings of Morris *et al.* (1996). Section *Crinifera* and Section *Sarcopodium* can be distinguished from other Sections of *Dendrobium* by this character.

The size of adaxial epidermal cells was comparatively larger than abaxial ones in most of species but in some cases the adaxial cells were found 2-3 times larger in their size than the abaxial epidermal cells in *D. amoenum*, *D. bicameratum*, *D. chrysanthum*, *D. gibsonii*, *D. heterocarpum*, *D. moniliforme*, *D. moschatum*, *D. nobile* (Section *Dendrobium*) and *D. monticola* (Section *Stachyobium*). Such type of larger epidermal cells was also reported in *D. gibsonii* (Isaiah, 1993).

Epidermis with sinuous anticlinal walls in adaxial surface was found in *D. fomosum*, *D. longicornu* (Section *Formosae*) and *D. monticola* (Section *Stachyobium*). Morris *et al.* (1996) reported sinuous anticlinal walls in epidermis in *D. formosum*.

Hypodermis: Hypodermis was absent in most species but one layered hypodermis was present in abaxial surface in *D. anceps* (Section *Aporum*) and adaxial surface in *D. densiflorum* (Section *Dendrobium*). Morris *et al.* (1996) found weakly defined one layered abaxial hypodermis in *D. densiflorum* but in present study adaxial hypodermis was found distinct but abaxial hypodermis was not so distinct. Fibre bundles were present in one series both on adaxial and abaxial sides subtending the hypodermis in *D. anceps* (Section *Aporum*) and absent in remaining species (Pradhan and Bajracharya, 2020a). Stegmata with rough-surfaced, spherical silica bodies were present along outer margin of fibre bundle facing towards epidermis. Isaiah (1993) reported fibre bundles in *Agrostophyllum khasianum*, *Bulbophyllum bhotanense* and *Epidendrum xanthum*. Morris *et al.* (1996) reported fibre bundles in abaxial side subtending the hypodermis in *D. anceps*. Carlsward *et al.* (1997) reported abaxial fibre bundles in all species of Section *Aporum*. Thus the presence of fibre bundles in adaxial and abaxial sides did not support the Morris *et al.* (1996) and Carlsward *et al.* (1997) findings. Stern *et al.* (1994) also observed adaxial epidermis in some *Dendrobium* species belonging to Section *Rhizobium* but fibre bundles are completely absent in these species. The fibre bundles provide mechanical strength to plant body.

Mesophyll: Mesophyll was homogenous, not differentiated into palisade and spongy parenchyma in most species but heterogenous, differentiated into palisade and spongy parenchyma in some species like *D. amplum*, *D. fuscescens* and *D. rotundatum* (Section *Sarcopodium*). Thus Section *Sarcopodium* can be distinguished from other Sections of *Dendrobium* by the type of mesophyll. In species with homogenous mesophyll, the number of chlorenchymatous layers varied from 6-18. The chlorenchymatous layer was 18 in *D. anceps* (Section *Aporum*), 15 in *D. fugax*

(Section *Crinifera*), 7-13 in Section *Dendrobium*, 8-9 in Section *Formosae*, 6-7 in Section *Stachyobium*. In Section *Sarcopodium*, the mesophyll was heterogenous with 2 palisade layers and 7 spongy layers in *D. amplum*, *D. fuscescens* and 2 palisade layers and 8 spongy layers in *D. rotundatum*. Water storage cells with smooth or pleated walls, raphide bundles, starch grains, druses, idioblasts with mucilage, calcium oxalate crystals were found scattered in the mesophyll of *Dendrobium* species. Water storage cells with smooth or pleated walls were scattered in mesophyll of *D. anceps* (Section *Aporum*). This result supports the study of Carlsward *et al.* (1997). In Section *Crinifera*, raphide bundles and druses were found in mesophyll. In Section *Dendrobium*, water storage cells with pleated outlines were found in *D. aphyllum* and *D. moschatum* and absent in other species. In Section *Formosae*, idioblasts with mucilage were present in mesophyll. Abundant chloroplasts were present in mesophyll of Section *Sarcopodium*. Raphide bundles, druses, idioblasts with mucilage and starch grains were found in Section *Stachyobium*. Water storage cells in mesophyll were reported by Kaushik (1983) in several Himalayan orchids.

Vascular bundles: Vascular bundles were found arranged in a single series with a large midrib bundle in the centre in all studied species except in *D. anceps* (Section *Aporum*) in which vascular bundles were arranged in two symmetrical rows with a major large vascular bundle at one pole of leaf. Thus Section *Aporum* can be distinguished from other Sections of *Dendrobium* by this character. The staggered vascular bundle was present in *D. aphyllum*. This result supports the study of Morris *et al.* (1996). Vascular bundle was conjoint, collateral and closed in all studied species.

The shape of vascular bundles was found variable in different species belonging to different Sections of *Dendrobium*. The vascular bundle was found mostly oval-shaped in most species but circular-shaped in *D. anceps* (Section *Aporum*), *D. polyanthum*, *D. transparens* (Section *Dendrobium*), *D. longicornu* (Section *Formosae*); flask-shaped in *D. fugax* (Section *Crinifera*), *D. amplum*, *D. fuscescens*, *D. rotundatum* (Section *Sarcopodium*); conical-shaped in *D. crepidatum*, *D. denneanum*, *D. densiflorum*, *D. moschatum* (Section *Dendrobium*); oblong-shaped in *D. denudans* and elongate-shaped in *D. porphyrochilum* (Section *Stachyobium*). In all vascular bundles of leaf, phloem was situated towards abaxial side and xylem towards adaxial side. The xylem and phloem were surrounded by fibre caps in all species except in *D.*

porphyrochilum (Section *Stachyobium*). In vascular bundle, number of xylem fibre caps and phloem fibre caps differed in different species. In *D. anceps* (Section *Aporum*) the xylem fibre cap layer was 1 and phloem fibre cap layers 2 whereas in *D. fugax* (Section *Crinifera*) the xylem fibre cap layers were 6 and phloem fibre cap layers 6. In the species belonging to Section *Dendrobium*, the number of xylem fibre cap layers differed from 2-11 and phloem cap layers 2-12. The xylem fibre cap layers were 4-7 and phloem fibre cap layers 4-5 in Section *Formosae*; 4-5 xylem fibre cap layers and 6 phloem fibre cap layers in Section *Sarcopodium*; 3-4 xylem fibre cap layers and 3-4 phloem fibre cap layers in Section *Stachyobium*. By the number and size of xylem fibre cap and phloem fibre cap, the species of *Dendrobium* can be distinguished from each other.

Stegmata with rough-surfaced silica bodies were found around midrib vascular bundle in most species of Sections of *Dendrobium* like Section *Dendrobium*, Section *Sarcopodium*, Section *Stachyobium*; indistinct in Section *Aporum*, Section *Crinifera*, Section *Dendrobium* (*D. bicameratum*, *D. moniliforme*), Section *Sarcopodium* (*D. rotundatum*), Section *Stachyobium* (*D. denudans*, *D. eriiflorum*, *D. monticola*); absent in Section *Dendrobium* (*D. densiflorum*, *D. polyanthum*), Section *Formosae* (*D. formosum*, *D. longicornu*). Presence of stegmata with spherical bodies in this study was supported by the result of Kohl (1889).

Stem/Pseudobulb Anatomy

In most of studied species of *Dendrobium*, the stems were erect or pendulous without bulbous nature. Pseudobulbs were found distinct in Section *Sarcopodium*, Section *Crinifera*, Section *Stachyobium* (*D. monticola* and *D. porphyrochilum*).

Stem/Pseudobulb T.S.

Cuticle: Cuticle was thick and smooth in all species of *Dendrobium*. The cuticle was intermittently undulating in *D. anceps* (Section *Aporum*). Morris *et al.* (1996) reported intermittently undulating thick cuticle in *D. anceps*.

Epidermis: Epidermal cells were rectangular, square, angular to polygonal in most species and barrel shaped in Section *Aporum*, Section *Crinifera*, Section *Dendrobium* (*D. aphyllum*, *D. bicameratum*, *D. chrysanthum*, *D. denneanum*, *D. fimbriatum* and *D. moschatum*). Epidermal cells were thick in all species except in *D. anceps*. Morris *et al.* (1996) reported thin-walled epidermal cells in *D. anceps*. The size of epidermal

cells varied in different species. The largest epidermal cell was found in *D. porphyrochilum* (Section *Stachyobium*) and smallest in *D. anceps* (Section *Aporum*), *D. densiflorum* and *D. fimbriatum* (Section *Dendrobium*).

Hypodermis: Below epidermis hypodermis was found. Hypodermis was present in most species and absent in Section *Stachyobium*. Below epidermis the region was stated as outer region of ground tissue by Morris *et al.* (1996) but in present study it was called as hypodermis. Hypodermis layers ranged from 1-5. Hypodermis was one layered in Section *Dendrobium* (*D. aphyllum*, *D. crepidatum*, *D. polyanthum*); two layered in Section *Aporum*, Section *Crinifera*, Section *Dendrobium* (*D. amoenum*, *D. chrysanthum*, *D. gibsonii*, *D. heterocarpum*, *D. moniliforme*, *D. nobile*, *D. transparens*), Section *Formosae*, Section *Sarcopodium*; two to three layered in *D. bicameratum* (Section *Dendrobium*); three layered in *D. moschatum* (Section *Dendrobium*); four layered in *D. denneanum* (Section *Dendrobium*) and four to five layered in *D. densiflorum*, *D. fimbriatum* (Section *Dendrobium*) (Pradhan and Bajracharya, 2020b). Hypodermis was sclerenchymatous in most species and parenchymatous in Section *Aporum*, Section *Dendrobium* (*D. aphyllum*, *D. crepidatum*, *D. polyanthum*), Section *Formosae* (*D. formosum*).

Ground Tissue: Ground tissue was not delimited into cortex, endodermis, pericycle and pith. In ground tissue, water storage cells pleated or unpleated, raphide bundles, starch grains and calcium oxalate crystals were present. Water storage cells with pleated outlines were found in most species and with unpleated outlines in *D. anceps* (Section *Aporum*), *D. crepidatum*, *D. densiflorum*, *D. fimbriatum*, *D. moschatum*, *D. nobile* and *D. polyanthum* (Section *Dendrobium*). Water storage cells with pleated or unpleated outlines were also the significant character for distinguishing the species of *Dendrobium*. This result supports the study of Morris *et al.* (1996). Stern and Morris (1992) reported water storage cells in Orchidaceae.

Vascular Bundle: Numerous large and small collateral vascular bundles were scattered in ground tissue, smaller towards periphery and larger towards centre. The numbers of vascular bundles were varied in different species (16-118), smallest numbers in *D. polyanthum* (Section *Dendrobium*) and highest numbers in *D. bicameratum*. The shape of vascular bundle was oval in most species but elongate in Section *Crinifera*, Section *Dendrobium* (*D. bicameratum*, *D. chrysanthum*, *D. denneanum*, *D. moniliforme*, *D. polyanthum*, *D. transparens*), Section *Formosae* (*D.*

longicornu), Section *Sarcopodium* (*D. amplum*), Section *Stachyobium* (*D. porphyrochilum*). Fibre cap was found above the phloem in all species except in *D. anceps* (Section *Aporum*) with fibre caps above the phloem and xylem. Ramesh *et al.* (2020) reported three phloem cap layers and single layered xylem fibre cap layer in *D. anceps*. In *D. fugax* (Section *Crinifera*), lacuna was found adjacent to fibre cap of phloem in ground tissue. This result supports the study of Morris *et al.* (1996). Sclerenchymatous bundle sheath cells were found surrounding xylem in most species and surrounding vascular bundle in *D. anceps* (Section *Aporum*), *D. amoenum*, *D. chrysanthum*, *D. crepidatum*, *D. heterocarpum* (Section *Dendrobium*), *D. longicornu* (Section *Formosae*), *D. fuscescens* (Section *Sarcopodium*), *D. denudans*, *D. eriiflorum*, *D. porphyrochilum* (Section *Stachyobium*).

Stegmata with rough-surfaced spherical silica bodies was found indistinct in most species; along outer margin of phloem fibre cap in *D. fugax* (Section *Crinifera*), *D. amoenum*, *D. aphyllum*, *D. bicameratum*, *D. densiflorum*, *D. polyanthum*, *D. transparens* (Section *Dendrobium*), *D. formosum*, *D. longicornu* (Section *Formosae*), *D. amplum*, *D. rotundatum* (Section *Sarcopodium*); absent in *D. moniliforme* (Section *Dendrobium*), *D. eriiflorum* and *D. monticola* (Section *Stachyobium*). This result supports the hypothesis of Moller & Rasmussen (1984) in possessing stegmata with spherical silica bodies in all *Dendrobiinae*.

Thus the present study revealed that the anatomical characters of leaves and stem with stegmata were found taxonomically significant in delimiting the species of *Dendrobium*.

4.3. Micromorphology

4.3.1. Introduction

Besides gross morphological variations such as habit, stem, leaf, inflorescence and flower, there are number of micromorphological characters like stomata and stegmata on leaf epidermal surfaces within *Dendrobium* which had been widely used in taxonomic and phylogenetic studies as they can provide valuable information (Patel, 1979; Stace, 1980; Davis, 1997). These characters can be used in solving the taxonomic problems existing within *Dendrobium*. Variation in micromorphological characters can be used as a tool in delimiting taxa at the species level.

Stomata complex

Micromorphological study on leaf epidermal surface had been widely used in taxonomic and phylogenetic studies. Some of the notable work on stomatal patterns in some angiosperms have been done by Stebbins and Khush (1961), Inamder (1968), Withner *et al.* (1974), Kaushik (1983), Rao and Khasim (1987) and Croxdale (2000).

In Orchidaceae several micromorphological studies on stomatal types based on their structures have been done by (Rosso 1966, Williams 1975, Singh 1981, Kaushik 1983 and Khasim and Rao 1990). Singh and Singh (1974) studied the organization of stomatal complex in some Orchidaceae and concluded that the presence of tetracytic stomata was considered significant in evolutionary relationships of the family. Kaushik (1983) and Rasmussen (1987) studied the ecological significance of dermal characters. Mohana and Khasim (1987) studied anatomy of some members of Coelogyninae and concluded that the evolution of stomatal types has progressed from anomocytic to diacytic to cyclocytic to paracytic. The absorbing trichomes are abundant in the epiphytes and absent in the terrestrials. Du puy and Cribb (1988) found the stomatal shape variation in the genus *Cymbidium*. Isaiah *et al.* (1990) studied the vegetative anatomy of two species of *Eria*. Khasim and Rao (1990) studied anatomy in relation to taxonomy in some members of Epidendrodoideae and found the differences among the species based on the stomatal features, presence or absence of trichomes and fibrous bodies. Vij *et al.* (1991) studied the epidermal features of Indian orchids for taxonomic and ecological implications. Yukawa *et al.* (1992) reported the existence of two types of stomatal shape in the genus *Dendrobium* and its systematic significance. Arditti (1992) suggested that the shape of subsidiary

cells had been used to distinguish the stomatal complex of Orchidaceae into several types. Rosinski (1992) recognized two types of stomata within *Dendrochilum*. Morris *et al.* (1995) studied the vegetative anatomy and systematics of subtribe Dendrobiinae. Stern (1997) studied the vegetative anatomy including leaf anatomy of subtribe Orchidinae and Habernariinae. Carlsward *et al.* (1997) studied the comparative leaf anatomy and systematics in *Dendrobium*, sections *Aporum* and *Rhizobium* (Orchidaceae). Stern and Judd (1999, 2000, 2002) studied the comparative anatomy and systematics of Catasetinae, Cymbidieae, tribe Vanillae excluding *Vanilla*. Stern *et al.* (2003) studied the systematics and comparative anatomy of Maxillarieae. Sonowal and Baruah (2010) studied foliar epidermis of twenty orchid species from Northeast India with emphasis to their taxonomy. Abraham *et al.* (2016) studied the stomatal structures in the epiphytic orchids and reported that low value of stomatal index is an adaptation of orchid plants to survive in different climatic conditions.

In concerning about Himalayan species, Shakya (1999) studied on revision of genus *Oberonia* of the Himalayas and observed the variations in size of stomata, arrangement of subsidiary cells and surface sculpturing of epidermal cells on the leaf surface. Eight different types of stomatal complex had been recorded according to the arrangement of subsidiary cells among the 12 species of the genus *Oberonia*. Bajracharya (2003) studied the leaf epidermis of genus *Eria*. He classified the stomatal complex on the basis of variation in size of stomata, arrangement of subsidiary cells and surface sculpturing of epidermal cells and nature of stoma and recorded 7 distinct stomatal complexes. Bajracharya (2003) observed seven types of stomata within the Himalayan genus *Eria*. Dangol (2006) studied the anatomical structures of subtribe Coelogyninae.

Stegmata

Stegmata or silica cell in orchids was reported and illustrated by Link (1849) for the first time but described them as projections from the sclerenchyma. The stegmata are restricted to the monocotyledon families Orchidaceae, Palmae, Maranthaceae, Musaceae, and with some doubt Juncaceae and not found in dicotyledons (Kohl, 1889). He distinguished two main kinds of stegmata in orchids one with conical bodies and other with spherical bodies. Stegmata with conical bodies are widespread within the family and those with spherical bodies are found in vandoid orchids and

Dendrobium. Although the distribution of stegmata in orchids seems to be of systematic value and phylogenetic interest, little attention has been paid to them since then. Moller & Rasmussen (1984) studied the distribution of stegmata in 130 species representing 105 genera in Orchidales. They reported that the stegmata bearing silica bodies occur in longitudinal files lining fibre bundles and vascular bundle sheaths of rhizomes, stems and especially in the leaves and rarely in roots. Dressler (1993) reported that in most orchids the silica cells are roughly conical in shape but they are spherical and rather lumpy in the Vandae, Eriinae, Podochilinae and Dendrobiinae. Carlsward *et al.* (1997) reported that stegmata containing rough-surfaced spherical bodies are found associated with phloic sclerenchyma of the larger bundles of *Dendrobium leonis*, *D. anceps*, *D. brevimentum*, *D. aloifolium*, *D. distichum*, *D. indivisum*, *D. mannii*, *D. rosellum* and *D. nathaniele* and they are absent along vascular bundle sclerenchyma in *D. acinaciforme*. Bajracharya (2003) studied the stegmata on leaf surface of 28 species of *Eria*. He reported that the study of stegmata reveal valuable characters that had been used in delimiting the taxa *Eria* at species level.

4.3.2. Materials and Methods

The plant materials were collected from West, Central and Eastn Nepal on the basis of those regions mentioned in the herbaria and also from the available literature. The collected plant specimens from the field visits were identified by tallying with protologues, type specimens and previously authenticated literatures. The micromorphological (stomata and stegmata) studies were done on the collected specimens.

Stomata complex

Stomatal study was done on the species collected from various localities of Nepal Himalaya. For the study of epidermis of leaves, the method described by Carpenter (2005; with some modification) was followed. The mature leaf was selected from the plant specimen. The selected leaf was taken out and immersed in potassium hydroxide solution (5%) overnight, rinsed with de-ionized water and again immersed in fresh solution of potassium hydroxide solution for few hours, however the time of immersion of the leaves in the potassium hydroxide varied with the material. The leaf was then washed with water and treated with glacial acetic acid for few minutes (2-5

minutes). The epidermal layer (both adaxial and abaxial) of the leaf was peeled by fine forceps. The peeled epidermal layer was then treated with Sodium hypochlorite (4%) until the tissue got discolored. The time for the discoloration of the tissue varied from half an hour to 3 hours depending upon the peeled material. It was then washed with water for several times. The material was stained in saffranin (1%) and excess stain was washed by water, mounted on glycerin so as to prepare the temporary slides. The temporary slides were sealed with nail polish for later use. The leaf epidermis was observed under light microscope. Various micro-morphological features such as no. and shape of epidermal cells, no. and type of stomata, length and width of stomata and size of stomatal pore were studied. The size of stomata and stomatal pore of each specimen were measured by using the standardized ocular micrometer scale. The microscopic photography was carried out.

The stomatal distribution on the both surfaces were observed and noted. The stomatal index and stomatal frequency in the microscopic field (10×40X) in five readings were recorded and mean value was calculated. The size of stomata and stomatal pore were measured by using the standardized ocular micrometer. The ocular micrometer was calibrated with stage micrometer to get exact measurement of stomata. The area of the stomata was the product of length and width of guard cells. Besides, the no. and shape of epidermal cells and cell wall nature were also recorded. The terminologies used for stomatal complex types were followed those of Patel (1979). The data were stored in the tabulated form. Stomatal index and stomatal frequencies were calculated using the formula given by Salisbury (1928).

$SI = S / E + S \times 100$, Where,

SI = Stomata Index, E = Average number of epidermal cells per unit area or microscopic field, S = Average number of stomata in microscopic field.

$SF = S/A \text{ per mm}^2$, Where,

SF= Stomata frequency, A= Area of microscopic field.

$A = \pi r^2$, Where,

$\pi = 3.14$, r = radius of the microscopic field

In microscopic field of 40 x 10 magnification, 1 ocular division = 0.003 mm

Divisions in the diameter of circle of ocular micrometer = 96

Diameter of circle = 0.003 x 96 = 0.288 mm

Radius of circle = 0.288/2 = 0.144 mm

$$A = 3.14 \times (0.144)^2 = 0.065 \text{ mm}^2$$

Stegmata

Stegmata were studied on the leaf surfaces of specimen by peeling the epidermal layer with fine forceps. The peeled material was stained in saffranin (1%) and excess stain was washed by water, mounted on glycerin so as to prepare the temporary slides. The temporary slides were sealed with nail polish for later use. The leaf epidermis was observed under light microscope. The microscopic photography was carried out.

4.3.3. Result

4.3.3.1. Stomata complex

Section I. *Aporum*

Dendrobium anceps

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are rectangular to polygonal in shape. Epidermal cells are thick-walled parenchymatous with anticlinal wall varying from straight-sided to curvilinear. Stomata are elliptic and eupara two-monocyclic with hexa-monocyclic type. Subsidiary cells are distinctly differentiated from epidermal cells. Subsidiary cells are polygonal in shape and irregular in size (Plate 31 A). Stomatal size is 29.97 μm (l) x 25.30 μm (w), stomatal pore size is 13.32 μm (l) x 6.66 μm (w), stomatal index is 3.75 and stomatal frequency is 46.15 mm^2 (Table 10).

Section II. *Crinifera*

Dendrobium fugax

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are rectangular, square, pentagonal, hexagonal to polygonal in shape and irregular in size. Epidermal cells are made up of sclerenchymatous cells with anticlinal walls varying from straight-sided to curvilinear. Stomata are circular-shaped and eupara two-monocyclic type. Stoma is surrounded by four subsidiary cells. Subsidiary cells are distinctly differentiated from epidermal cells. Subsidiary cells are polygonal in shape and irregular in size (Plate 31 B). Stomatal size is 29.97 μm (l) x 29.97 μm (w), stomatal pore size is 13.32 x 13.32 μm , stomatal index is 10.17 and stomatal frequency is 184.61 mm^2 (Table 10).

Section III. *Dendrobium*

Dendrobium amoenum

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are made up of parenchyma with anticlinal walls varying from straight-sided to curvilinear. Epidermal cells are rectangular to polygonal in shape. Stomata are elliptical and b-tetra-monocyclic type. Stomata are surrounded by four subsidiary cells. Subsidiary cells are not differentiated from epidermal cells being polygonal in shape and irregular in size (Plate 31 C). Stomatal size is 29.97 μm (l) x 23.31 μm (w), stomatal pore size is 13.32 μm (l) x 4.99 μm (w), stomatal index is 5.81 and stomatal frequency is 76.92 mm^2 (Table 10).

Dendrobium aphyllum

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are rectangular to polygonal in shape. Epidermal cells are thin-walled parenchymatous with anticlinal wall varying from straight-sided to curvilinear and the angles are rounded. Stomata are elliptic and a-tetra-monocyclic type. Subsidiary cells are undifferentiated from epidermal cells. Subsidiary cells are polygonal in shape and polar subsidiary cells are perpendicular with the longitudinal axis of the stomata (Plate 31 D). Stomatal size is 33.30 μm (l) x 23.31 μm (w), stomatal pore size is 16.65 μm (l) x 9.99 μm (w), stomatal index is 7.31 and stomatal frequency is 46.15 mm^2 (Table 10).

Dendrobium bicameratum

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are squarish, pentagonal, hexagonal to polygonal in shape and irregular in size. Epidermal cells are thick-walled parenchymatous with anticlinal wall varying from straight-sided to curvilinear. Stomata are elliptic and a-tetra-monocyclic type. Stomata are surrounded by four subsidiary cells. Subsidiary cells are distinctly differentiated from epidermal cells. Subsidiary cells are polygonal in shape and irregular in size (Plate 31 E). Stomatal size is 33.30 μm (l) x 29.97 μm (w), stomatal pore size is 23.31 μm (l) x 9.99 μm (w), stomatal index is 7.04 and stomatal frequency is 76.92 mm^2 (Table 10).

Dendrobium chrysanthum

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are squarish, pentagonal, and hexagonal to polygonal in shape. The epidermal cells are thin-walled parenchymatous with anticlinal wall varying from straight-sided to curvilinear. Stomata are more or less circular shaped and a-tetra-monocyclic type and possess four subsidiary cells. Subsidiary cells are not differentiated from epidermal cells (Plate 31 F). Stomatal size is 33.30 μm (l) x 23.31 μm (w), stomatal pore size is 16.65 μm (l) x 6.66 μm (w), stomatal index is 5.68 and stomatal frequency is 76.92 mm^2 (Table 10).

Dendrobium crepidatum

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are thin-walled, squarish, pentagonal, hexagonal to polygonal parenchymatous with anticlinal wall varying from straight-sided to curvilinear. Stomata are elliptic and b-tetra-monocyclic type and possess four subsidiary cells. Subsidiary cells are not differentiated from epidermal cells and irregular in size (Plate 31 G). Stomatal size is 32.63 μm (l) x 26.64 μm (w), stomatal pore size is 15.32 μm (l) x 7.32 μm (w), stomatal index is 13.04 and stomatal frequency is 130.77 mm^2 (Table 10).

Dendrobium denneanum

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are irregular, squarish, pentagonal and hexagonal to polygonal sclerenchymatous cells with anticlinal wall varying from straight-sided to curvilinear. Stomata are circular-shaped and a-tetra-monocyclic type. Stomata are surrounded by four subsidiary cells. Subsidiary cells are differentiated from epidermal cells. Subsidiary cells are polygonal in shape and irregular in size (Plate 31 H). Stomatal size is 26.64 μm (l) x 26.64 μm (w), stomatal pore size is 16.65 μm (l) x 9.99 μm (w), stomatal index is 7.34 and stomatal frequency is 123.07 mm^2 (Table 10).

Dendrobium densiflorum

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are squarish, pentagonal, hexagonal to polygonal in shape and irregular in size. Epidermal cells are

sclerenchymatous with anticlinal wall varying from straight-sided to curvilinear. Stomata are elliptic shaped and a-tetra-monocyclic type. Stomata are surrounded by four subsidiary cells. Subsidiary cells are distinctly differentiated from epidermal cells. Subsidiary cells are polygonal in shape and irregular in size (Plate 31 I). Stomatal size is 33.30 μm (l) x 26.64 μm (w), stomatal pore size is 26.64 μm (l) x 13.32 μm (w), stomatal index is 6.76 and stomatal frequency is 76.92 mm^2 (Table 10).

Dendrobium fimbriatum

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are rectangular to polygonal in shape and irregular in size. Epidermal cells are thick-walled and made up of sclerenchymatous cells with anticlinal wall varying from straight-sided to curvilinear. Stomata are circular-shaped and a-tetra-monocyclic type with two parallel cells and two polar cells. Subsidiary cells are differentiated from epidermal cells. Subsidiary cells are polygonal and irregular in shape (Plate 31 J). Stomatal size is 33.30 μm (l) x 34.60 μm (w), stomatal pore size is 16.65 μm (l) x 9.99 μm (w), stomatal index is 10.38 and stomatal frequency is 123.07 mm^2 (Table 10).

Dendrobium gibsonii

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are rectangular, squarish to polygonal in shape. Epidermal cells are thick-walled parenchymatous with anticlinal wall varying from straight-sided to curvilinear. Stomata are elliptic-shaped and a-tetra-monocyclic type. Subsidiary cells are undifferentiated from epidermal cells. Subsidiary cells are polygonal and irregular in shape. The polar subsidiary cells are perpendicular with the longitudinal axis of the stomata (Plate 31 K). Stomatal size is 33.30 μm (l) x 24.98 μm (w), stomatal pore size is 19.98 μm (l) x 6.66 μm (w), stomatal index is 8.33 and stomatal frequency is 76.92 mm^2 (Table 10).

Dendrobium heterocarpum

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are rectangular to polygonal in shape. Epidermal cells are thick-walled parenchymatous with anticlinal wall varying from straight-sided to curvilinear and the angles are rounded. Stomata are circular-shaped and a-tetra-monocyclic type. Subsidiary cells are undifferentiated

from epidermal cells. Subsidiary cells are polygonal and irregular in shape. The polar subsidiary cells are perpendicular with the longitudinal axis of the stomata (Plate 31 L). Stomatal size is 38.30 μm (l) x 33.30 μm (w), stomatal pore size is 16.65 μm (l) x 10.00 μm (w), stomatal index is 13.04 and stomatal frequency is 92.30 mm^2 (Table 10).

Dendrobium moniliforme

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are rectangular to polygonal in shape. Epidermal cells are thick-walled parenchymatous with anticlinal wall varying from straight-sided to curvilinear and the angles are rounded. Stomata are circular and a-tetra-monocyclic type. Subsidiary cells are undifferentiated from epidermal cells. Subsidiary cells are polygonal and irregular in shape. The polar subsidiary cells are perpendicular with the longitudinal axis of the stomata (Plate 31 M). Stomatal size is 38.30 μm (l) x 34.00 μm (w), stomatal pore size is 16.65 μm (l) x 6.66 μm (w), stomatal index is 12.50 and stomatal frequency is 138.50 mm^2 (Table 10).

Dendrobium moschatum

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are rectangular to polygonal in shape and irregular in size. Epidermal cells are thick-walled parenchymatous with anticlinal wall varying from straight-sided to curvilinear. Stomata are circular-shaped and a-tetra-monocyclic type. Stoma is surrounded by four subsidiary cells. Subsidiary cells are distinctly differentiated from epidermal cells. Subsidiary cells are polygonal in shape and irregular in size (Plate 31 N). Stomatal size is 27.97 μm (l) x 26.64 μm (w), stomatal pore size is 16.65 μm (l) x 9.99 μm (w), stomatal index is 5.00 and stomatal frequency is 76.92 mm^2 (Table 10).

Dendrobium nobile

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are rectangular to polygonal in shape. The epidermal cells are thin-walled parenchymatous with anticlinal wall varying from straight-sided to curvilinear. Stomata are elliptic and c-tetra-monocyclic type. Stoma possesses four subsidiary cells. Subsidiary cells are not

differentiated from epidermal cells (Plate 31 O). Stomatal size is 44.95 μm (l) x 39.96 μm (w), stomatal pore size is 27.30 μm (l) x 17.98 μm (w), stomatal index is 15.79 and stomatal frequency is 92.31 mm^2 (Table 10). The cuticular projections are observed around the stomatal apparatus.

Dendrobium polyanthum

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are rectangular to polygonal in shape. The epidermal cells are thin-walled parenchymatous with anticlinal wall varying from straight-sided to curvilinear. Stomata are elliptic and b-tetra-monocyclic type and possess four subsidiary cells. Subsidiary cells are not differentiated from epidermal cells (Plate 31 P). Stomatal size is 32.63 μm (l) x 26.64 μm (w), stomatal pore size is 16.65 μm (l) x 4.99 μm (w), stomatal index is 7.94 and stomatal frequency is 76.92 mm^2 (Table 10).

Dendrobium transparens

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are rectangular to polygonal in shape. The epidermal cells are thin-walled parenchymatous with anticlinal wall varying from straight-sided to curvilinear. Stomata are elliptic-shaped and b-tetra-monocyclic type with four or five subsidiary cells. Subsidiary cells are polygonal in shape and irregular in size. Subsidiary cells are not differentiated from epidermal cells (Plate 31 Q). Stomatal size is 33.30 μm (l) x 27.31 μm (w), stomatal pore size is 17.98 μm (l) x 6.66 μm (w), stomatal index is 10.71 and stomatal frequency is 138.46 mm^2 (Table 10).

Section IV. *Formosae*

Dendrobium formosum

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are rectangular to polygonal in shape and irregular in size. Epidermal cells are thick-walled and made up of sclerenchymatous cells with anticlinal wall varying from straight-sided to curvilinear and the angles are rounded. Stomata are circular-shaped and c-tetra-monocyclic type with two parallel cells and two polar cells. Polar cells are similar to ordinary epidermal cells. Subsidiary cells are polygonal and irregular in shape (Plate

31 R). Stomatal size is 45.96 μm (l) x 41.96 μm (w), stomatal pore size is 24.64 μm (l) x 6.66 μm (w), stomatal index is 12.50 and stomatal frequency is 76.92 mm^2 (Table 10).

Dendrobium longicornu

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are rectangular to polygonal in shape. The epidermal cells are thick-walled parenchymatous with anticlinal wall varying from straight-sided to curvilinear. Stomata are elliptic and a-tetra-monocyclic type and possess four subsidiary cells. Subsidiary cells are not differentiated from epidermal cells (Plate 31 S). Stomatal size is 29.97 μm (l) x 23.31 μm (w), stomatal pore size is 13.32 μm (l) x 4.99 μm (w), stomatal index is 10.53 and stomatal frequency is 123.07 mm^2 (Table 10).

Section V. *Sarcopodium*

Dendrobium amplum

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are square, pentagonal, hexagonal to polygonal in shape and irregular in size. Epidermal cells are made up of sclerenchymatous cells with anticlinal walls varying from straight-sided to curvilinear. Stomata are sub-orbicular shaped and b-tetra-monocyclic type. Stoma is surrounded by four subsidiary cells. Subsidiary cells are distinctly differentiated from epidermal cells. Subsidiary cells are polygonal in shape and irregular in size (Plate 31 T). Stomatal size is 33.30 μm (l) x 29.97 μm (w), stomatal pore size is 16.65 μm (l) x 6.66 μm (w), stomatal index is 6.03 and stomatal frequency is 108.00 mm^2 (Table 10).

Dendrobium fuscens

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are square, pentagonal, hexagonal to polygonal in shape and irregular in size. Epidermal cells are made up of sclerenchymatous cells with anticlinal walls varying from straight-sided to curvilinear. Stomata are circular-shaped and a-tetra-monocyclic type. Stoma is surrounded by four subsidiary cells. Subsidiary cells are distinctly differentiated from epidermal cells. Subsidiary cells have no distinct partition walls. Subsidiary cells are polygonal in shape and irregular in size (Plate 31 U). Stomatal size is 23.3 μm (l) x

23.31 μm (w), stomatal pore size is 13.32 μm (l) x 6.66 μm (w), stomatal index is 5.37 and stomatal frequency is 76.92 mm^2 (Table 10).

Dendrobium rotundatum

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are square, pentagonal, hexagonal to polygonal in shape and irregular in size. Epidermal cells are made up of sclerenchymatous cells with anticlinal walls varying from straight-sided to curvilinear. Stomata are sub-orbicular shaped and a-tetra-monocyclic type. Stoma is surrounded by four subsidiary cells. Subsidiary cells are distinctly differentiated from epidermal cells. Subsidiary cells are polygonal in shape and irregular in size (Plate 31 V). Stomatal size is 26.64 μm (l) x 23.31 μm (w), stomatal pore size is 13.32 μm (l) x 6.66 μm (w), stomatal index is 8.33 and stomatal frequency is 92.00 mm^2 (Table 10).

Section VI. *Stachyobium*

Dendrobium denudans

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are squarish, pentagonal, hexagonal to polygonal in shape and irregular in size. Epidermal cells are thick-walled parenchymatous cells with anticlinal wall varying from straight-sided to curvilinear. Stomata are elliptic-shaped and a-tetra-monocyclic type. Stomata are surrounded by four and five subsidiary cells. Subsidiary cells are not differentiated from epidermal cells. Subsidiary cells are polygonal in shape and irregular in size (Plate 31 W). Stomatal size is 39.96 μm (l) x 26.64 μm (w), stomatal pore size is 26.64 μm (l) x 9.99 μm (w), stomatal index is 10.71 and stomatal frequency is 92.30 mm^2 (Table 10).

Dendrobium eriiflorum

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are rectangular to polygonal in shape. Epidermal cells are thin-walled parenchymatous with anticlinal wall varying from straight-sided to curvilinear and the angles are rounded. Stomata are elliptic and c-tetra-monocyclic type. Subsidiary cells are undifferentiated from epidermal cells. Subsidiary cells are polygonal in shape and irregular in size (Plate 31 X). Stomatal size is 38.62 μm (l) x 25.97 μm (w), stomatal pore size is 20.64 μm (l) x

10.65 μm (w), stomatal index is 10.66 and stomatal frequency is 123.07 mm^2 (Table 10).

Dendrobium monticola

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are rectangular to polygonal in shape and irregular in size. Epidermal cells are thick-walled parenchymatous with anticlinal wall varying from straight-sided to curvilinear. Stomata are elliptic-shaped and a-tetra-monocyclic type. Stoma is surrounded by four subsidiary cells. Subsidiary cells are not differentiated from epidermal cells. Subsidiary cells are polygonal in shape and irregular in size (Plate 31 Y). Stomatal size is 39.96 μm (l) x 26.64 μm (w), stomatal pore size is 23.31 μm (l) x 9.99 μm (w), stomatal index is 10.83 and stomatal frequency is 200 mm^2 (Table 10).

Dendrobium porphyrochilum

Leaf Epidermis in Surface View

Stomata are present on abaxial surface only. Epidermal cells are rectangular, square to polygonal in shape. The epidermal cells are thick-walled parenchymatous with anticlinal wall varying from straight-sided to curvilinear. Stomata are elliptic and a-tetra-monocyclic type and possess four to five subsidiary cells. Subsidiary cells are not differentiated from epidermal cells (Plate 31 Z). Stomatal size is 36.63 μm (l) x 19.98 μm (w), stomatal pore size is 13.32 μm (l) x 3.33 μm (w), stomatal index is 7.14 and stomatal frequency is 76.92 mm^2 (Table 10).

Plate 31. Stomata of *Dendrobium* species showing stoma (s), subsidiary cell (sc), epidermal cell (ec).

A. *D. anceps*

B. *D. fugax*

C. *D. amoenum*

D. *D. aphyllum*

E. *D. bicameratum*

F. *D. chrysanthum*

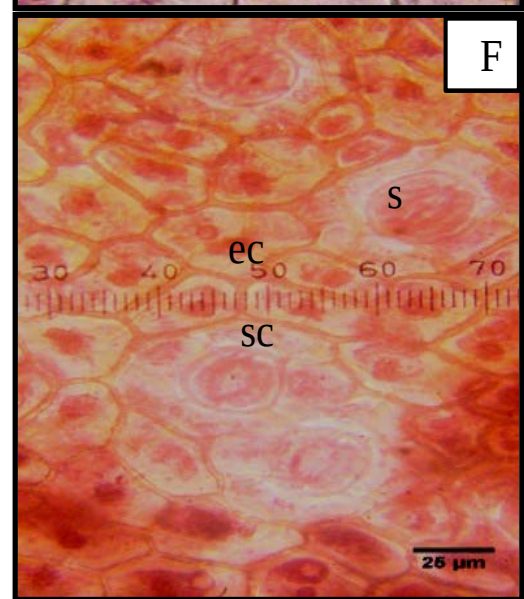
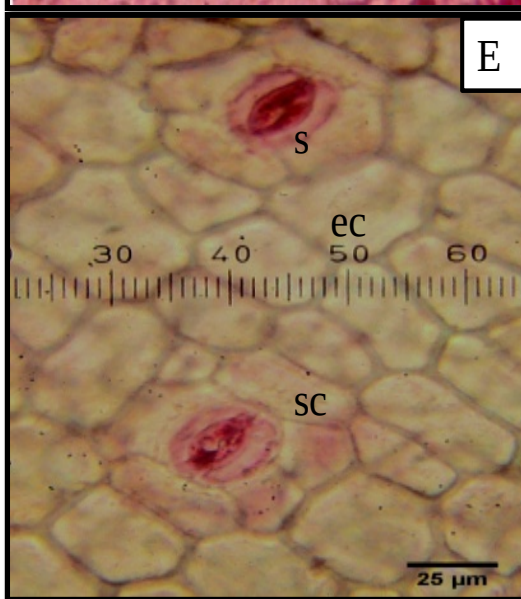
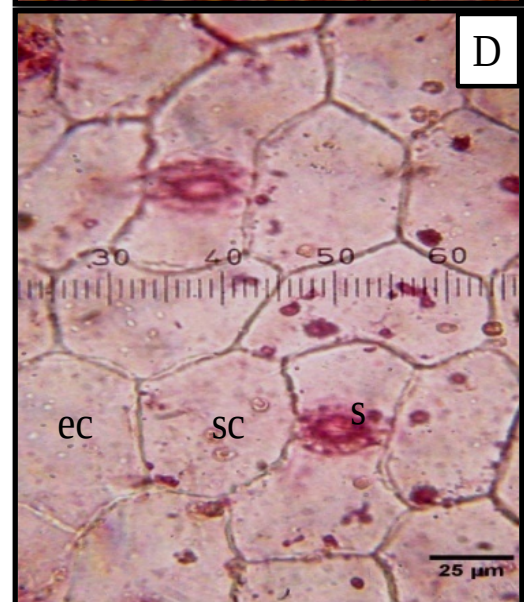
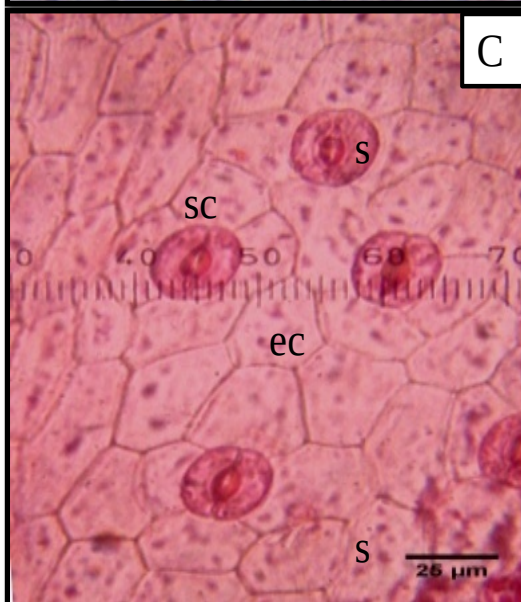
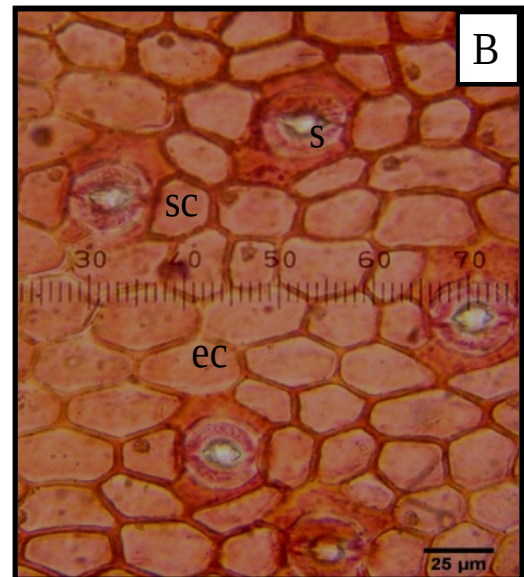
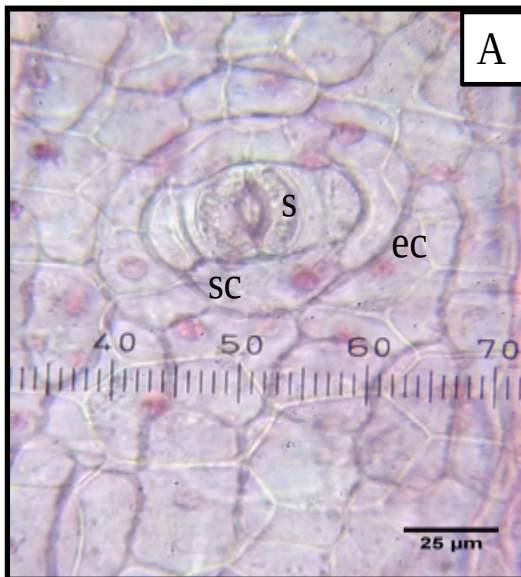


Plate 31. (contd.)

G. *D. crepidatum*

H. *D. denneanum*

I. *D. densiflorum*

J. *D. fimbriatum*

K. *D. gibsonii*

L. *D. heterocarpum*

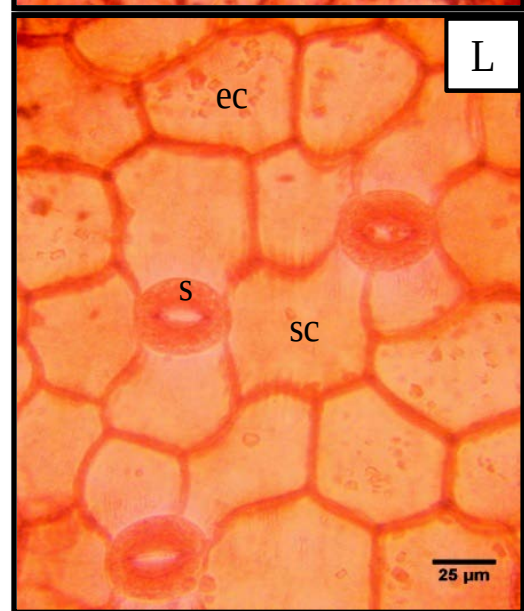
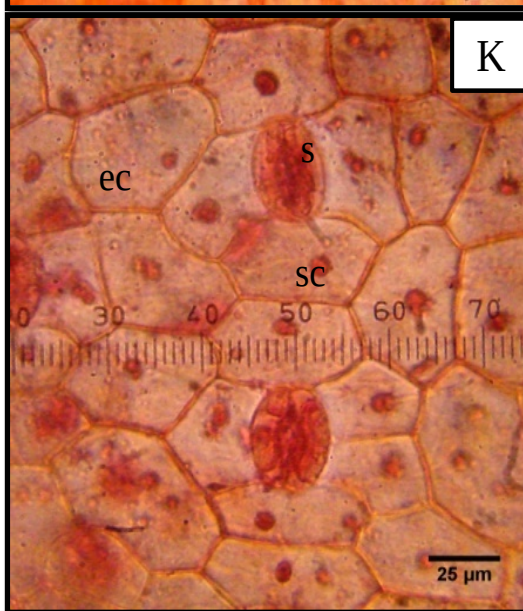
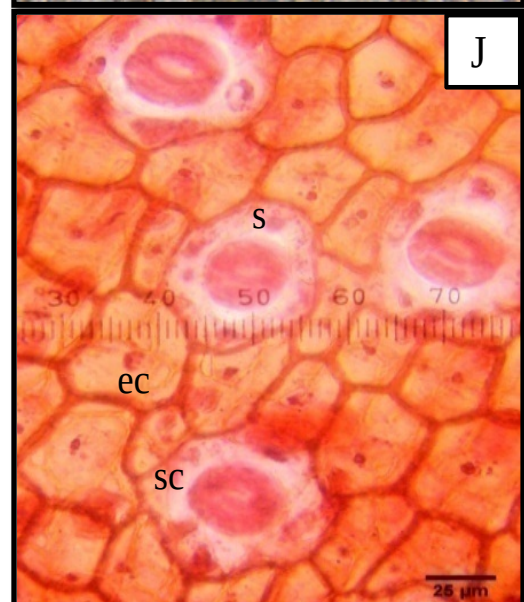
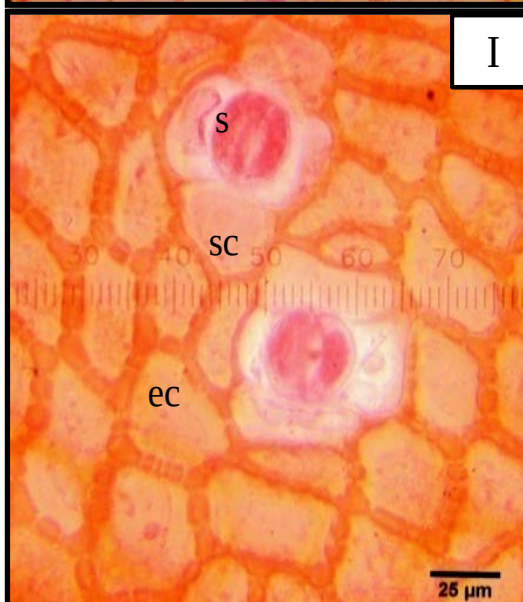
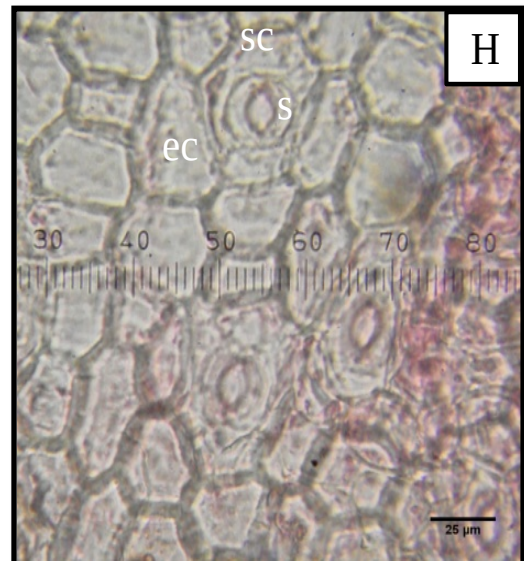
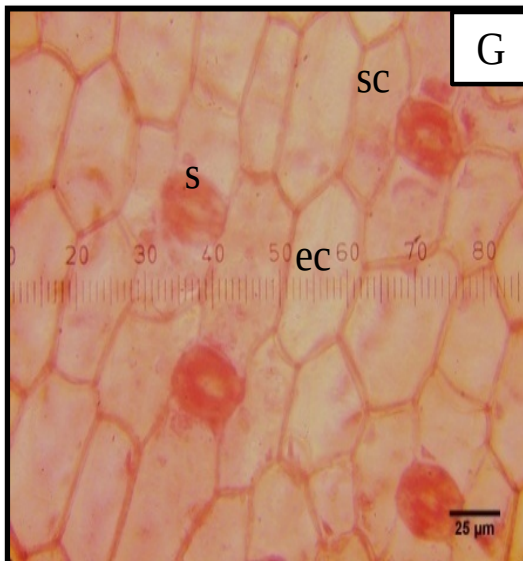


Plate 31. (Contd.)

M. *D. moniliforme*

N. *D. moschatum*

O. *D. nobile*

P. *D. polyanthum*

Q. *D. transparens*

R. *D. formosum*

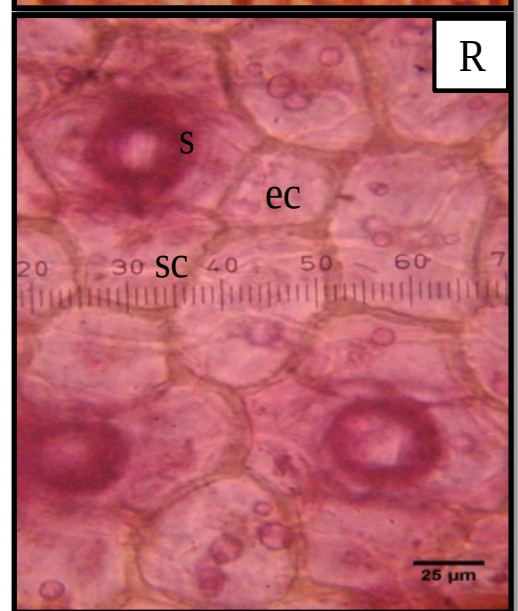
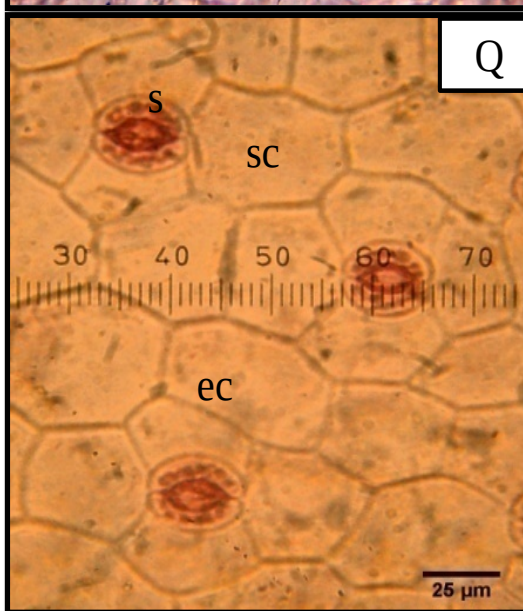
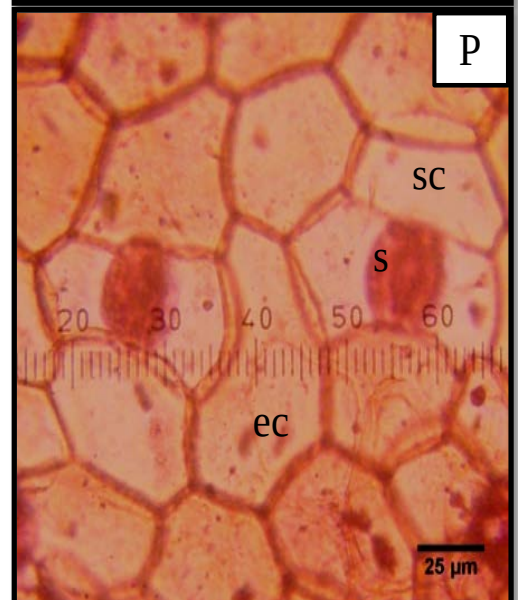
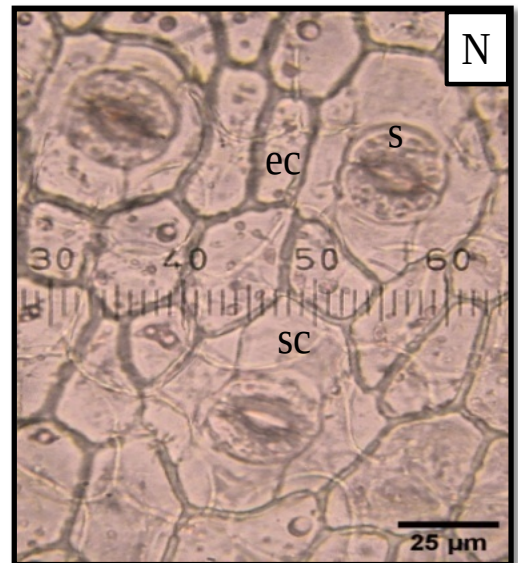
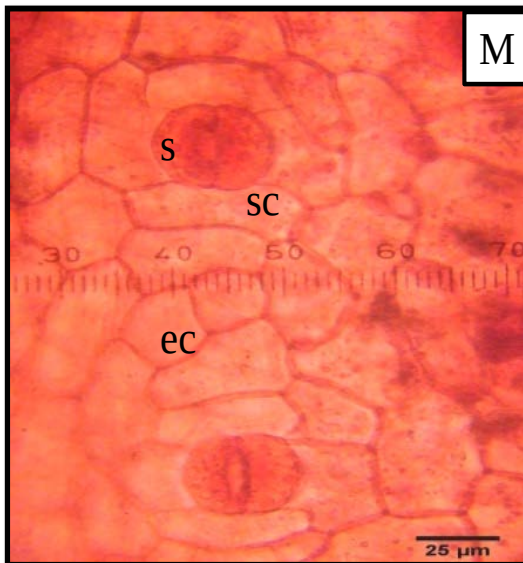


Plate 31 (Contd.)

S. *D. longicornu*

T. *D. amplum*

U. *D. fuscescens*

V. *D. rotundatum*

W. *D. denudans*

X. *D. eriiflorum*

Y. *D. monticola*

Z. *D. porphyrochilum*

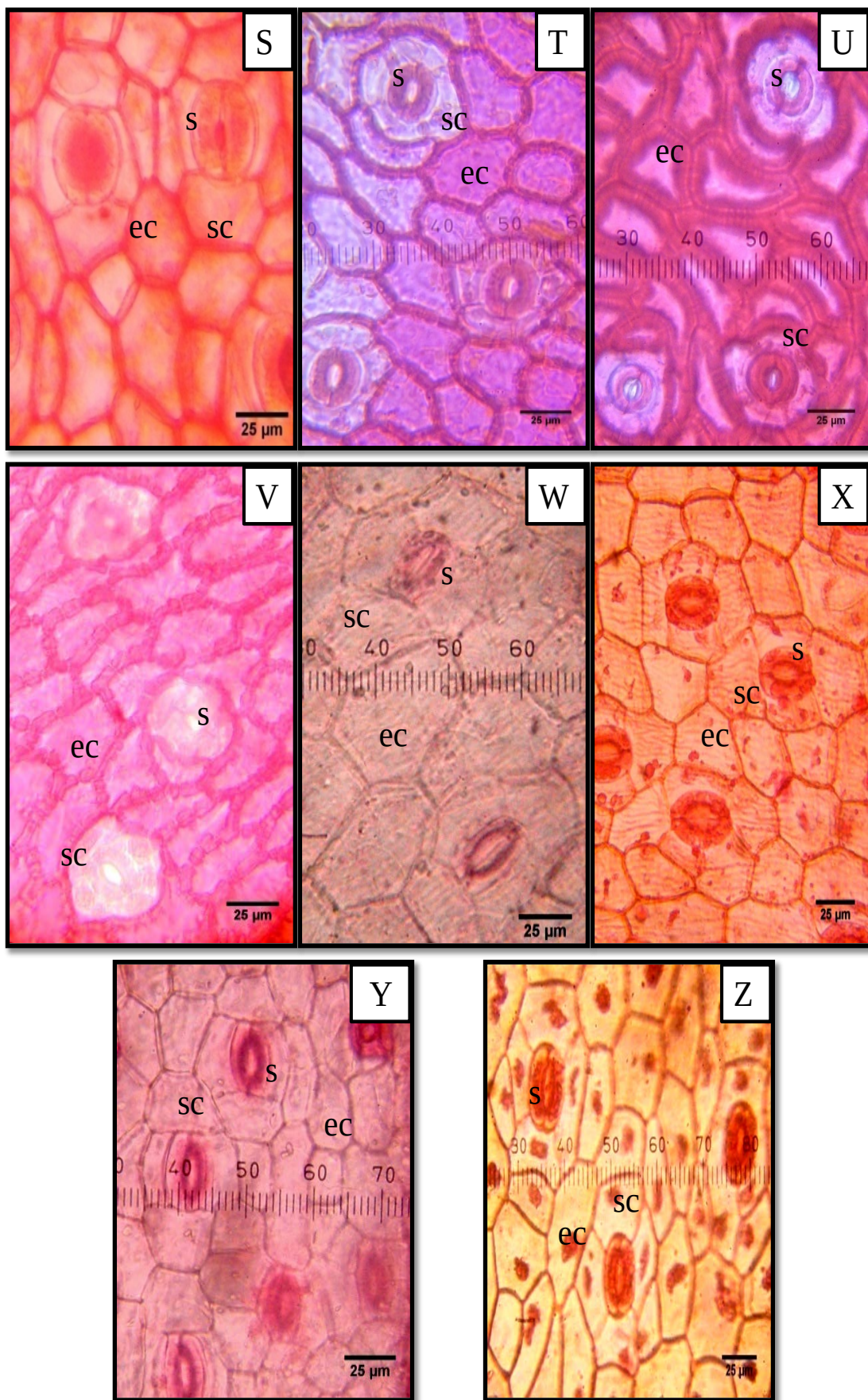


Table 10. Stomatal and Stegmatal characters in *Dendrobium*

S. N.	Taxa	Stomatal size with guard cells (l x w) μm	Stomatal pore size (l x w) μm	Stomatal Frequency mm^2	Stomatal Index %	Shape of Stomata	Type of Stomata	Shape of Epidermal cells	Type of Epidermal cells	Stegmata
1	<i>Dendrobium amoenum</i> Wallich ex Lindley	29.97 x 23.31	13.32 x 4.99	76.92	5.81	Elliptic	b-tetramonocyclic	Rect. to poly.	Paren.	Spherical
2	<i>D. amplum</i> Lindley	33.30 x 29.97	16.65 x 6.66	107.69	6.03	Suborbicular	b-tetramonocyclic	Rect. to poly.	Scleren.	Spherical
3	<i>D. anceps</i> Swartz	29.97 x 25.30	13.32 x 6.66	46.15	3.75	Elliptic	eupara twi + hexamonocyclic	Rect. to poly.	Paren.	Indistinct
4	<i>D. aphyllum</i> (Roxburgh) C.E.C. Fischer	33.30 x 23.31	16.65 x 9.99	46.15	7.31	Elliptic	a-tetramonocyclic	Rect. to poly.	Paren.	Spherical
5	<i>D. bicameratum</i> Lindley	33.30 x 29.97	23.31 x 9.99	76.92	7.04	Elliptic	a-tetramonocyclic	Squa. to poly.	Paren.	Indistinct
6	<i>D. chrysanthum</i> Wallich ex Lindley	33.30 x 23.31	16.65 x 6.66	76.92	5.68	Circular	a-tetramonocyclic	Squa. to poly.	Paren.	Spherical
7	<i>D. crepidatum</i> Lindley & Paxton	32.63 x 26.64	15.32 x 7.32	130.77	13.04	Elliptic	b-tetramonocyclic	Squa. to poly.	Paren.	Spherical
8	<i>D. denneanum</i> Kerr	26.64 x 26.64	16.65 x 9.99	123.07	7.34	Circular	a-tetramonocyclic	Squa. to poly.	Scleren.	Spherical
9	<i>D. densiflorum</i> Wallich	33.30 x 26.64	26.64 x 13.32	76.92	6.76	Elliptic	a-tetramonocyclic	Squa. to poly.	Scleren.	N.P
10	<i>D. denudans</i> D. Don	39.96 x 26.64	26.64 x 9.99	92.3	10.71	Elliptic	a-tetramonocyclic	Squa. to poly.	Paren.	Indistinct

							c			
11	<i>D. eriiflorum</i> Griffith	38.62 x 25.97	20.64 x 10.65	123.0 7	10.66	Ellipt ic	c-tetra- monocycli c	Rect. to poly.	Paren.	Indisti nct
12	<i>D. fimbriatum</i> Hooker	33.30 x 34.60	16.65 x 9.99	123.0 7	10.38	Circu lar	a-tetra- monocycli c	Rect. to poly.	Sclere n.	Spheri cal
13	<i>D. formosum</i> Roxburgh ex Lindley	45.96 x 41.96	24.64 x 6.66	76.92	12.5	Circu lar	c-tetra- monocycli c	Rect. to poly.	Sclere n.	N.P
14	<i>D. fugax</i> Reichenbach	29.97 x 29.97	13.32 x 13.32	184.6 1	10.17	Circu lar	eupara twi- monocycli c	Squa. to poly.	Sclere n.	Indisti nct
15	<i>D. fuscescens</i> Griffith	23.31 x 23.31	13.32 x 6.66	76.92	5.37	Circu lar	a-tetra- monocycli c	Squa. to poly.	Sclere n.	Spheri cal
16	<i>D. gibsonii</i> Paxton	33.30 x 24.98	19.98 x 6.66	76.92	8.33	Ellipt ic	a-tetra- monocycli c	Rect. to poly.	Paren.	Spheri cal
17	<i>D. heterocarpum</i> Wallich ex Lindley	38.30 x 33.30	16.65 x 10.00	92.3	13.04	Circu lar	a-tetra- monocycli c	Rect. to poly.	Paren.	Spheri cal
18	<i>D. longicornu</i> Lindley	29.97 x 23.31	13.32 x 4.99	123.0 7	10.53	Ellipt ic	a-tetra- monocycli c	Rect. to poly.	Paren.	N.P
19	<i>D. moniliforme</i> (L.) Swartz	38.30 x 34.00	16.65 x 6.66	138.5	12.5	Circu lar	a-tetra- monocycli c	Rect. to poly.	Paren.	Indisti nct
20	<i>D. monticola</i> Hunt & Summerhayes	39.96 x 26.64	23.31 x 9.99	200	10.83	Ellipt ic	a-tetra- monocycli c	Rect. to poly.	Paren.	Indisti nct
21	<i>D. moschatum</i> (Buchanan- Hamilton) Swartz	27.97 x 26.64	16.65 x 9.99	76.92	5	Circu lar	a-tetra- monocycli c	Rect. to poly.	Paren.	Spheri cal
22	<i>D. nobile</i> Lindley	44.95 x 39.96	27.30 x 17.98	92.31	15.79	Ellipt ic	c-tetra- monocycli c	Rect. to poly.	Paren.	Spheri cal
23	<i>D. polyanthum</i>	32.63 x	16.65 x	76.92	7.94	Ellipt	b-tetra- monocycli	Rect. to	Paren.	N.P

	Wallich ex Lindley	26.64	4.99			ic	c	poly.		
24	<i>D. porphyrochilum</i> Lindley	36.63 x 19.98	13.32 x 3.33	76.92	7.14	Ellipt ic	a-tetra- monocycli c	Squa. to poly.	Paren.	Spheri cal
25	<i>D. rotundatum</i> (Lindley) Hooker	26.64 x 23.31	13.32 x 6.66	92.3	8.33	Sub- orbic ular	c-tetra- monocycli c	Rect. to poly.	Sclere n.	Indisti nct
26	<i>D. transparens</i> Wallich ex Lindley	33.30 x 27.31	17.98 x 6.66	138.4 6	10.71	Ellipt ic	b-tetra- monocycli c	Rect. to poly.	Paren.	Spheri cal

Abbreviations used: N.P = Not present; Rect. = Rectangular; poly. = Polygonal; Squa. = Square; Paren = Parenchyma; Scleren. = Sclerenchyma.

The stomatal complex of 26 species of *Dendrobium* had examined with light microscope. The shape and type of epidermal cells on the abaxial surface of leaves, stomatal size with guard cells, stomatal pore size, stomatal frequency, stomatal index, shape of stomata, type of stomata were found to be variable in different species of *Dendrobium*.

The species of *Dendrobium* were found hypostamic leaf surfaces (i.e., stomata occurring on the abaxial surface only).

The epidermal cells on abaxial surface are rectangular to polygonal, squarish to polygonal and regular to irregular in shape. In most of species like *D. anceps* (Section *Aporum*), *D. amoenum*, *D. aphyllum*, *D. fimbriatum*, *D. gibsonii*, *D. heterocarpum*, *D. moniliforme*, *D. moschatum*, *D. nobile*, *D. polyanthum*, *D. transparens* (Section *Dendrobium*), *D. formosum*, *D. longicornu* (Section *Formosae*), *D. amplum* *D. rotundatum* (Section *Sarcopodium*), *D. eriiflorum*, *D. monticola* (Section *Stachyobium*), the epidermal cells were found to be rectangular to polygonal where as in remaining species, the epidermal cells were found to be squarish, pentagonal, hexagonal to polygonal. The epidermal cells were mostly parenchymatous (thin-walled or thick-walled) but sclerenchymatous in species like *D. fugax* (Section *Crinifera*), *D. denneanum*, *D. densiflorum*, *D. fimbriatum* (Section *Dendrobium*), *D. formosum* (Section *Formosae*), *D. amplum* *D. fuscescens*, *D. rotundatum* (Section *Sarcopodium*).

The stomata were found mostly tetracytic type (a, b and c-tetra-monocyclic). In most species a-tetra-monocyclic stomatal type was found whereas b-tetra-monocyclic type was found in *D. amoenum*, *D. crepidatum*, *D. polyanthum*, *D. transparens* (Section *Dendrobium*), *D. amplum* (Section *Sarcopodium*), and c-tetra-monocyclic type was found in *D. nobile* (Section *Dendrobium*), *D. formosum* (Section *Formosae*), *D. eriiflorum* (Section *Stachyobium*) and *D. rotundatum* (Section *Sarcopodium*). Eupara twi-monocyclic with hexa-monocyclic was found in *D. anceps* (Section *Aporum*) and eupara twi-monocyclic was found in *D. fugax* (Section *Crinifera*).

Shape of stomata in *Dendrobium* varied from elliptical, circular to suborbicular. Elliptic type of stomata had found more in number than circular and suborbicular

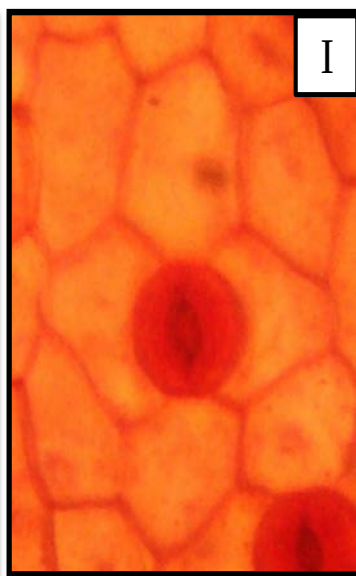
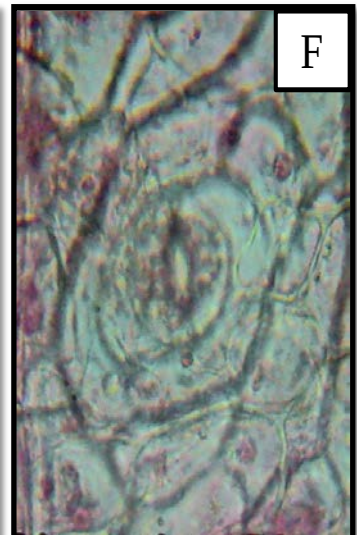
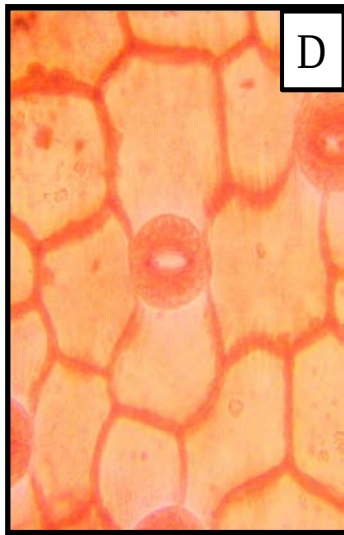
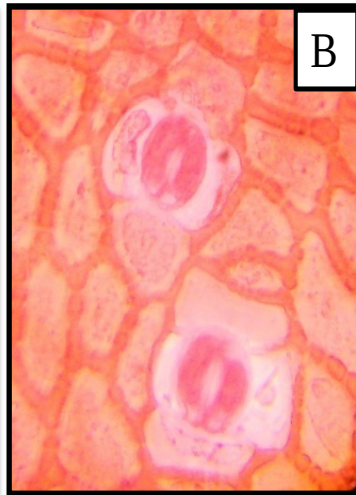
type. The most species had elliptical type stomata whereas the species like *D. fugax* (Section *Crinifera*), *D. chrysanthum*, *D. denneanum*, *D. fimbriatum*, *D. heterocarpum*, *D. moniliforme*, *D. moschatum* (Section *Dendrobium*), *D. formosum* (Section *Formosae*), *D. fuscescens* (Section *Sarcopodium*) had circular type. The suborbicular stomata were found in *D. amplum*, *D. rotundatum* (Section *Sarcopodium*).

The largest stoma was found in *D. formosum* with the area of $1928.48 \mu\text{m}^2$ and the smallest in *D. fuscescens* with the area of $543.35 \mu\text{m}^2$. The stomatal pore size was found smallest in *D. porphyrochilum* with $44.35 \mu\text{m}^2$ and the largest size with $490.85 \mu\text{m}^2$ was found in *D. nobile*. The stomatal frequency varied from $46.15\text{mm}^2 - 200.00 \text{mm}^2$. The highest stomatal frequency was found in *D. monticola* with 200.00mm^2 and the lowest in *D. anceps* and *D. aphyllum* with 46.15mm^2 . The stomatal index was found highest in *D. nobile* with 15.79 % and the lowest in *D. anceps* with 3.75 %.

In the present study, different types of stomata were found in different species of *Dendrobium* such as epidermal cells sclerenchymatous with circular stoma in *D. formosum* (Plate 32 A), elliptical stoma in *D. densiflorum* (Plate 32 B), suborbicular stoma in *D. amplum* (Plate 32 C); epidermal cells parenchymatous with circular stoma in *D. heterocarpum* (Plate 32 D), elliptical stoma in *D. gibsonii* (Plate 32 E); euparati + hexamonocyclic types of stomata in *D. anceps* (Plate 32 F); a-tetramonocyclic stomata in *D. porphyrochilum* (Plate 32 G), b-tetramonocyclic stomata in *D. amoenum* (Plate 32 H), c-tetramonocyclic stomata in *D. nobile* (Plate 32 I).

Plate 32. Different types of stomata in *Dendrobium* species

- A. Epidermal cells sclerenchymatous with circular stoma (*D. formosum*)
- B. Epidermal cells sclerenchymatous with elliptical stoma (*D. densiflorum*)
- C. Epidermal cells sclerenchymatous with suborbicular stoma (*D. amplum*)
- D. Epidermal cells parenchymatous with circular stoma (*D. heterocarpum*)
- E. Epidermal cells parenchymatous with elliptical stoma (*D. gibsonii*)
- F. Eupara twi+ hexa monocyclic stomata (*D. anceps*)
- G. a-tetramonocyclic stomata (*D. porphyrochilum*)
- H. b-tetramonocyclic stomata (*D. amoenum*)
- I. c-tetramonocyclic stomata (*D. nobile*)



From the present study, stomatal characters like shape of epidermal cells, types of stomata, stomatal density and stomatal index were found to be taxonomically significant and the stomatal distribution on the leaf surface seemed to be less significant as all species of *Dendrobium* were found to be hypostamic. Based on these characters, key has been prepared to delimit the species of *Dendrobium*.

Keys for the identification of spp. of *Dendrobium*

1a. Epidermal cells sclerenchymatous -----	2
1b. Epidermal cells parenchymatous -----	9
2a. Stomatal index < 10 -----	3
2b. Stomatal index > 10 -----	6
3a. Stomatal frequency < 100 -----	4
3b. Stomatal frequency > 100 -----	5
4a. a-tetra-monocyclic with circular stomata -----	<i>D. fuscescens</i>
4b. c-tetra-monocyclic with suborbicular stomata -----	<i>D. rotundatum</i>
5a. a-tetra-monocyclic with circular stomata -----	<i>D. denneanum</i>
5b. b-tetra-monocyclic with suborbicular stomata -----	<i>D. amplum</i>
6a. Stomatal frequency > 100 -----	7
6b. Stomatal frequency < 100 -----	8
7a. eupara twi-monocyclic with circular stomata -----	<i>D. fugax</i>
7b. a-tetra-monocyclic with circular stomata -----	<i>D. fimbriatum</i>
8a. a-tetra-monocyclic with elliptic stomata -----	<i>D. densiflorum</i>
8b. c-tetra-monocyclic with circular stomata-----	<i>D. formosum</i>
9a. Circular stomata-----	10
9b. Elliptic stomata -----	13
10a. Stomatal length <33 -----	<i>D. chrysanthum</i>
10b. Stomatal length > 33-----	11
11a. Stomatal index < 7 -----	<i>D. moschatum</i>
11b. Stomatal index >7 -----	12
12a. Stomatal frequency 80-120 -----	<i>D. heterocarpum</i>
12b. Stomatal frequency >120-----	<i>D. moniliforme</i>
13a. a, b, c-tetra-monocyclic stomata -----	14
13b. eupara-twi-monocyclic+hexa-monocyclic stomata -----	<i>D. anceps</i>
14a. a-tetra-monocyclic stomata with stomata index 7-10 -----	15

14b. b,c-tetra-monocyclic stomata-----	21
15a. Stomata length < 33 -----	<i>D. longicornu</i>
15b. Stomatal length > 33 -----	16
16a. Stomata width > 28 -----	<i>D. bicameratum</i>
16b. Stomata width < 28 -----	17
17a. Stomatal pore length < 16 -----	<i>D. porphyrochilum</i>
17b. Stomatal pore length > 16 -----	18
18a. Stomatal pore width < 7 -----	<i>D. gibsonii</i>
18b. Stomatal pore width > 7 -----	19
19a. Stomatal frequency < 80 -----	<i>D. aphyllum</i>
19b. Stomatal frequency > 80-----	20
20a. Stomata frequency 80-120 -----	<i>D. denudans</i>
20b. Stomata frequency > 120 -----	<i>D. monticola</i>
21a. b-tetra-monocyclic with stomata index 7 to > 10-----	22
21b. c- tetra-monocyclic with stomata index 10-----	25
22a. Stomata width < 26 -----	<i>D. amoenum</i>
22b. Stomata width > 26 -----	23
23a. Stomatal frequency < 80 -----	<i>D. polyanthum</i>
23b. Stomatal frequency > 80 -----	24
24a. Stomata length < 33 -----	<i>D. crepidatum</i>
24b. Stomata length > 33 -----	<i>D. transparens</i>
25a. Stomata width < 28 -----	<i>D. eriiflorum</i>
25b. Stomata width > 28 -----	<i>D. nobile.</i>

4.3.3.2. Stegmata

Stegmata on leaf surface of 26 species of *Dendrobium* had examined with light microscope. Stegmata occurred as longitudinal files of silica cells lining fibre bundles or vascular bundle sheaths. Silica bodies contained in stegmata are of 2 kinds, spherical and conical. Stegmata containing rough surfaced spherical silica bodies had recorded in *Dendrobium* species.

The stegmata was found indistinct in Section *Aporum* (*D. anceps*) (Plate 33 C) and in Section *Crinifera* (*D. fugax*) (Plate 33 L) (Table 10). In Section *Dendrobium*, the stegmata was found with rough-surfaced spherical silica bodies in *D. amoenum* (Plate 33 A), *D. aphyllum* (Plate 33 D), *D. chrysanthum* (Plate 33 F), *D. crepidatum* (Plate

33 G), *D. denneanum* (Plate 33 H), *D. fimbriatum* (Plate 33 K), *D. gibsonii* (Plate 33 N), *D. heterocarpum* (Plate 33 O), *D. moschatum* (Plate 33 R), *D. nobile* (Plate 33 S), *D. transparens* (Plate 33 V); indistinct in *D. bicameratum* (Plate 33 E), *D. moniliforme*; (Plate 33 P) absent in *D. densiflorum* and *D. polyanthum* (Table 10). In Section *Formosae*, stigmata was absent in *D. formosum* and *D. longicornu* (Table 10). In Section *Sarcopodium*, stigmata with rough-surfaced spherical silica bodies was found in *D. amplum* (Plate 33 B), *D. fuscescens* (Plate 33 M) and *D. rotundatum* (Plate 33 U) (Table 10). In Section *Stachyobium*, stigmata with rough-surfaced spherical silica bodies was found in *D. porphyrochilum* (Plate 33 T), and indistinct in *D. denudans* (Plate 33 I), *D. eriiflorum* (Plate 33 J) and *D. monticola*. (Plate 33 Q) (Table 10).

In the present study, stigmata on leaf epidermal cells containing rough surfaced spherical silica bodies was found in all species of *Dendrobium* except *D. densiflorum*, *D. formosum*, *D. longicornu* and *D. polyanthum*.

On the basis of stigmata containing silica bodies, *Dendrobium* can be classified as follows:

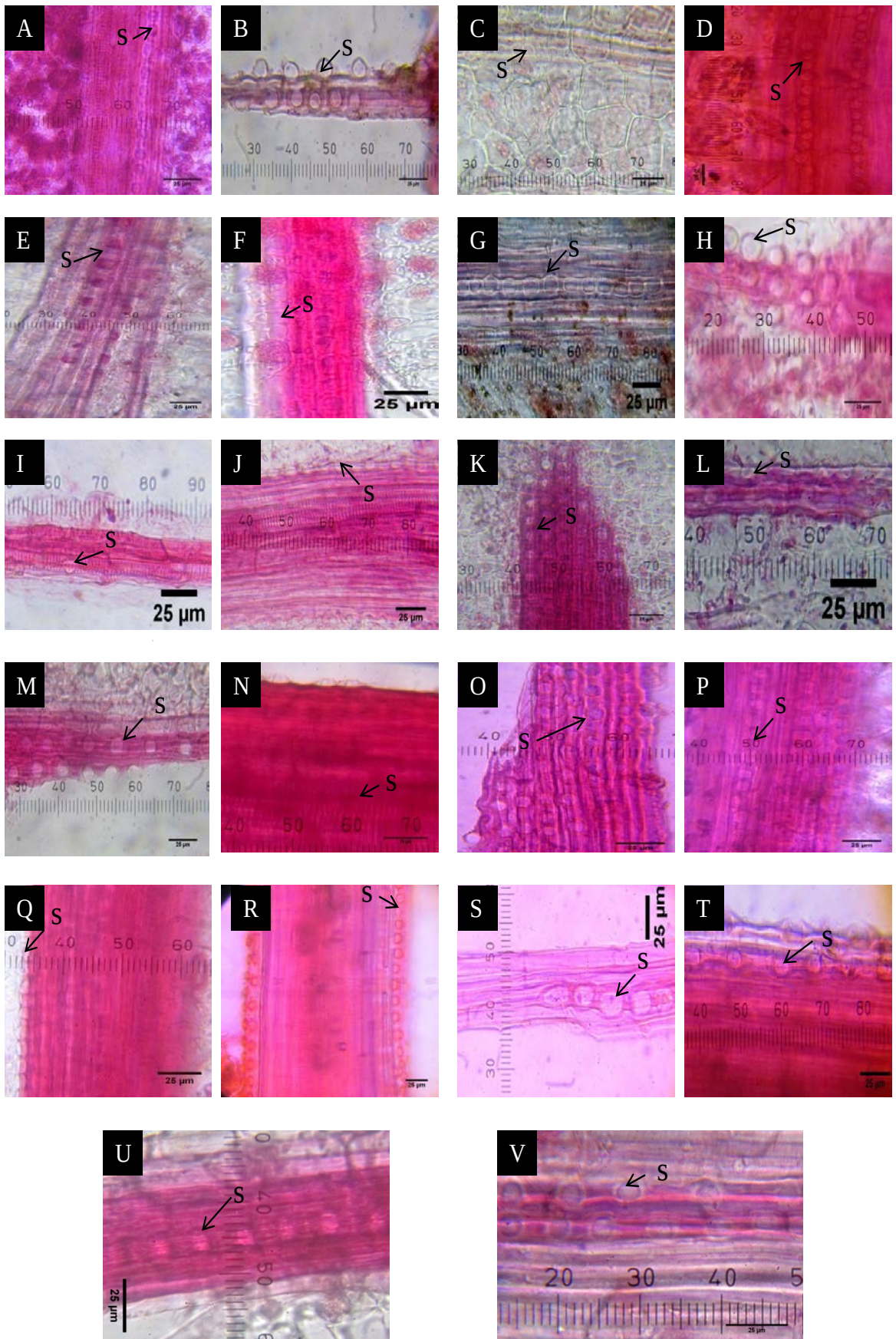
Key for the identification of spp. of *Dendrobium*

- 1a. Stigmata present ----- 2
- 1b. Stigmata absent ----- *D. densiflorum*, *D. formosum*, *D. longicornu*, *D. polyanthum*
- 2a. Silica bodies spherical shaped ----- *D. amoenum*, *D. amplum*, *D. aphyllum*,
D. chrysanthum, *D. crepidatum*, *D. denneanum*, *D. fimbriatum*, *D. fuscescens*, *D. gibsonii*, *D. heterocarpum*, *D. moschatum*, *D. nobile*, *D. porphyrochilum*, *D. transparens*
- 2b. Silica bodies not distinct ----- *D. anceps*, *D. bicameratum*, *D. denudans*,
D. eriiflorum, *D. fugax*, *D. moniliforme*, *D. monticola*, *D. rotundatum*.

Plate 33. Stegmata in Leaf surface of *Dendrobium* species (A-V).

A. *D. amoenum*; B. *D. amplum*; C. *D. anceps*; D. *D. aphyllum*; E. *D. bicameratum*; F. *D. chrysanthum*; G. *D. crepidatum*; H. *D. denneanum*; I. *D. denudans*; J. *D. eriiflorum*; K. *D. fimbriatum*; L. *D. fugax*; M. *D. fuscescens*; N. *D. gibsonii*; O. *D. heterocarpum*; P. *D. moniliiforme*; Q. *D. monticola*; R. *D. moschatum*; S. *D. nobile*; T. *D. porphyrochilum*; U. *D. rotundatum*; V. *D. transparens*.

Leaf surface showing stegmata (s).



4.3.4. Discussion

The micromorphological studies on stomata and stegmata revealed that they were taxonomically significant in delimiting the species of *Dendrobium*.

Stomata complex

The distribution of stomata on leaf surface was found to be less significant in delimiting the species of *Dendrobium* as the stomata of all species of *Dendrobium* showed hypostomatic in distribution, restricted to abaxial surface of leaf. Similarly the hypostomatic distribution was found in other groups of Orchidaceae (Avadhani *et al.* 1982). The hypostomatic condition is predominant in order to adjust with the epiphytic habitat and to conserve the water. Stomata were found only on the abaxial surface (hypostomatic) as these plants are adapted to aerial habitats to minimize water loss through stomata (Stebbins & Khush 1961).

The epidermal cells on the abaxial surface varied from rectangular, squarish, pentagonal, hexagonal to polygonal, irregular with thick or thin walled parenchymatous cells and some species with sclerenchymatous cells. Species like *D. anceps*, *D. longicornu*, *D. polyanthum*, *D. porphyrochilum*, *D. denudans* and *D. transparens* which form distinct cluster were characterized by presence of parenchymatous leaf epidermal cells while others were having parenchymatous and sclerenchymatous cells.

The shape of stomata varied from elliptical, circular to suborbicular. In *Dendrobium* most species had elliptical stomata and few species with circular stomata whereas in *D. amplum* and *D. rotundatum* sub-orbicular stomata were present. The distinct cluster formed by *D. anceps*, *D. longicornu*, *D. polyanthum*, *D. porphyrochilum*, *D. denudans* and *D. transparens* were characterized by elliptic stomata. Various modifications of stomatal shape such as elliptical, circular, transversely elliptical and angular are known to exist within Orchidaceae (Rasmussen 1987). Two types of stomatal shape (Stoma I and Stoma II) were reported in *Dendrobium* (Yukawa *et al.*, 1992). In the present study, the presence of two types of stomatal shape i.e. elliptical and circular is supported by the result of (Yukawa *et al.*, 1992; Pradhan and Bajracharya, 2016-2018). In addition suborbicular stomata were found in *D. amplum* and *D. rotundatum*.

In the present study, tetracytic type (a-tetra-monocyclic, b-tetra-monocyclic and c-tetra-monocyclic) was found in most species of *Dendrobium* (Pradhan and Bajracharya, 2016-2018). In some species like *D. anceps* eupara twi-monocyclic with hexa-monocyclic and in *D. fugax* eupara twi-monocyclic type were found. The stomata possessed four to five subsidiary cells. Species like *D. moniliforme*, *D. eriiflorum*, *D. monticola*, *D. bicameratum*, *D. amoenum*, *D. aphyllum* and *D. heterocarpum* forming cluster group and cluster formed by *D. amplum*, *D. fuscescens*, *D. rotundatum* were characterized by tetracytic (a-tetra-monocyclic, b-tetra-monocyclic and c-tetra-monocyclic) stomata. Tetracytic type of stomata had been reported in many monocotyledons (Metcalf, 1961). Mostly three types of stomata paracytic, tetracytic and anomocytic were reported in mostly in monocots (Cheadle, 1953; Stebbins & Khush, 1961). Patel (1979) distinguished five types of stomata i.e. tetracytic (a-tetra-monocyclic, b-tetra-monocyclic and c-tetra-monocyclic), twicytic, perihaplocytic, anisocytic and hexacytic and each type with four to six subsidiary cells. In the stomatal type the monocyclic means the guard cells of the stomata are surrounded by a single cycle of subsidiary cells (Patel, 1979). Paracytic stomata are also reported in *Ephemerantha* of tribe Epidendreae (Kaushik, 1983). Anisocytic stomata are observed in *D. amplum* according to Rasmussen (1987) but it was not observed in our study.

The size of stomata showed a wide variation ranging from $543.35 \mu\text{m}^2$ (*D. fuscescens*) to $1928.48 \mu\text{m}^2$ (*D. formosum*). The stomatal pore size varied from $44.35 \mu\text{m}^2$ (*D. porphyrochilum*) to $490.85 \mu\text{m}^2$ (*D. nobile*). In *D. nobile*, the cuticular projections were observed around the stomatal apparatus. This result supports the study of Ramesh *et al.* (2020). The stomatal frequency ranged from 46.15mm^2 (*D. anceps* and *D. aphyllum*) to 200.00mm^2 (*D. monticola*). The reduced stomatal frequency was distinctly related with the extent of leaf succulence and more the succulence lesser the frequency of stomata (Goh *et al.*, 1977). The stomatal index ranged from 3.75% (*D. anceps*) to 15.79% (*D. nobile*). Similar variation in stomatal index was reported in orchid species (Saadu *et al.*, 2009). The variation in stomatal index could be on account of variation in sunlight intensity (Santosh *et al.* 2015). A direct correlation between light intensity and stomatal index was observed in orchids (Rasmussen 1987).

The present study revealed that the shape of epidermal cells, shape, size and type of stomata, stomatal density and stomatal index were found to be taxonomically significant in delimiting species of *Dendrobium*.

Stegmata

Stegmata on the epidermal layers of leaves showed that they were taxonomically significant and they can be used as parameters for delimiting the species of *Dendrobium*. Stegmata was found in all species of *Dendrobium* but lacking in *D. formosum*, *D. densiflorum*, *D. longicornu* and *D. polyanthum*. Moller & Rasmussen (1984) reported that presence of conical silica bodies are the most common condition in the Epidendroideae but spherical silica bodies are found in the subtribes Eriinae, Dendrobiinae and Podochilinae. According to Moller & Rasmussen (1984) there was no difference between conical and spherical silica bodies. This is due to fact that the spherical bodies are found only in epiphytic orchids and conical bodies are found in both terrestrial and epiphytic orchids. The lack of stegmata in orchids may either make up an autapomorphy for these sequences compared with presence of silica bodies or represent an intermediate state between the conical and spherical silica bodies. Presence of stegmata in Dendrobiinae was supported by the result of Dressler (1993). Stegmata containing rough surfaced spherical bodies present in *D. anceps* was found similar to the result of Carlsward *et al* (1997).

4.4. Cluster analysis

4.4.1. Introduction

Subtribe Dendrobiinae (Orchidaceae) is a significant group belonging to tribe Malaxideae and subfamily Epidendroideae (Chase *et al.* 2015). *Dendrobium* belongs to subtribe Dendrobiinae, is one of the second largest genera in the family Orchidaceae. The taxonomy of genus *Dendrobium* is considered to be one of the most complicated problems in Orchidaceae nowadays, due to large number of species, wide distribution range and significant morphological variations within and among species. Based on morphological characters, various generic delimitations and infrageneric classification have been proposed after the establishment of *Dendrobium* by Swartz (1799) time to time. Schlechter (1912) presents an infrageneric classification of *Dendrobium* which was followed by most subsequent authors with few modifications proposing a natural infrageneric classification at section level. Recently based on molecular methods, various classification had been proposed for *Dendrobium* and related genera (Wood, 2006). The result of phylogenetic analysis shed new light on the taxonomy of *Dendrobium*.

To identify the phylogenetic relationships within the subtribe Dendrobiinae many taxonomists had carried out a number of cladistic analyses.

For phylogenetic analysis, cladistic is accepted as the best method available as it provides specific and assessable hypothesis of organism relationships. Cladistic is a method of hypothesizing relationships among organisms and in other words a method of reconstructing evolutionary trees. According to Stuessy (1990), cladistic can be defined as the concepts and methods for determination of branching of evolution. The original methods used in cladistic analysis are derived from the work of Henning (1966) who referred to cladistics as phylogenetic systematics.

Hedberg (1995) demonstrated that cladistics, as currently practiced in taxonomic botany, is no less subjective than traditional evolutionary systematic, although nowadays it generally attempts to avoid idiosyncratic reactions by delegating the combination of facts and assumptions and the construction of phylogenetic trees to standard computer programs.

Yukawa *et al.* (1993) studied the phylogenetic implications of chloroplast DNA restriction site variations in 15 species in 12 sections of subtribe Dendrobiinae. The results exhibited that subtribe Bulbophyllinae is an early branching lineage and *Pseuderia* and *Eria* are nested outside Dendrobiinae in tribe Podochileae. Subtribe Dendrobiinae comprises three major clades: *Epigeneium*; an Asian clade containing sections *Callista*, *Dendrobium*, *Pedilonum*, *Distichophyllum*, *Formosae*, *Phalaenanthe*, *Aporum*; and an Australian clade containing sections *Rhizobium*, *Latouria*, *Spatulata*, *Grastidium*, *Cadetia*, *Diplocaulobium* and *Flickingeria*.

Yukawa *et al.* (1996) performed the phylogenetic analysis using 2 chloroplast DNA data sets derived from variation of the ribulose-biphosphate carboxylase gene (*rbcL*) and restriction sites to examine relationship among 13 taxa in subtribe Dendrobiinae. The data set combining *rbcL* and restriction sites mutations provided the following insights: (1) *Pseuderia* belongs with tribe Podochileae rather than tribe Dendrobieae. (2) Subtribe Dendrobiinae is monophyletic if *Pseuderia* is excluded. (3). Excluding *Pseuderia* Dendrobiinae comprises 3 major clades: Clade 1 (*Dendrobium* sections *Spatulata*, *Cadetia*, *Diplocaulobium* and *Flickingeria*); Clade 2 (*Dendrobium* sections *Dendrobium* and *Callista*); and Clade 3 (*Epigeneium*). In this analysis *Dendrobium* is shown to be para/polyphyletic.

Morris *et al.* (1996) performed the study of Vegetative anatomy and systematics of subtribe Dendrobiinae (Orchidaceae). Based on anatomical data, they indicate that *Dendrobium* is non-monophyletic. They suggested that a more detailed understanding of the phylogeny of Dendrobiinae will require cladistical analyses employing characters from morphology, micromorphology, anatomy and DNA.

Clements (2003) performed the phylogenetic analysis in the Dendrobiinae (Orchidaceae), with emphasis on *Dendrobium* section *Pedilonum*. The cladistic analysis revealed that Dendrobiinae is polyphyletic with *Epigeneium* forming an independent clade; *Dendrobium* section *Oxystophyllum* is deeply embedded within one of the outgroups, subtribe Eriinae: Podochileae; and the remaining taxa isolated into two major groups, viz the Asian and Australasianclades.

Xiang *et al.* (2013) analyzed the phylogenetic study of *Dendrobium* and its relatives from mainland Asia (109 species) based on plastid and nuclear sequences. The result

indicated that mainland Asia *Dendrobium* is divided into eight clades (with two unplaced species) that form polytomies along the spine of the cladogram. Both *Dendrobium* and *Epigeneium* are well supported as monophyletic, whereas section *Dendrobium*, section *Densiflora*, section *Breviflores*, section *Holochrysa* are paraphyletic/polyphyletic. The study revealed that it is preferable to use a broad generic concept of *Dendrobium* and to proceed an improved infrageneric classification at sectional level together with both morphology and current molecular findings.

Takamiya (2014) performed the phylogenetic analysis of 210 taxa of *Dendrobium* based on DNA sequences of internal transcribed spacer (ITS) regions of 18S-26S nuclear ribosomal DNA and the maturase-coding gene (*matK*) located in an intron of the plastid gene *trnK* using maximum parsimony and Bayesian methods. This study revealed 13 distinct clades in the group comprising section *Dendrobium* and its allied groups. It was found that many of the morphological characters that have been believed to reflect phylogenetic relationships are, in fact, the result of convergence. Many of the sections that have been recognized up to this point were found not to be monophyletic, so recircumscription of sections is required.

In the genus *Dendrobium*, many molecular analyses have been performed from time to time in different countries, but in the context to Nepal Himalaya, it has not been performed till now. In the present study, the cluster analysis was carried out based on gross morphological, micro-morphological and anatomical characters with the aim of investigating interrelationships among the species of *Dendrobium* present in Nepal Himalaya. In this study, the result of the cluster analysis would be useful to make the basic hypothesis for finding the phylogenetic relationships.

Cluster analysis is a statistical method for classifying several objects into some groups (clusters) according to similarities between them. It is a special form of hierarchical clustering for inferring the history of evolution as a dendrogram. The cluster analysis does not reflect the evolutionary relatedness but this analysis has shown to be useful in evaluating and refining the existing classification.

Moudi and Go (2017) performed the cluster and cladistic analysis of *Dendrobium*, based on morphological data, to construct a phylogenetic tree and to find the

relationship of the species among four sections (*Aporum*, *Crumenata*, *Strongyle* and *Bolbidium*). Their result from both methods demonstrated that the four sections form a monophyletic group and it is best to recognize only one section *Aporum* instead of four sections.

Ramesh *et al.* (2020) carried out the cluster analysis of *Bulbophyllum* and *Dendrobium* based on the morpho-anatomical characters with special reference to ecological adaptations and phylogenetic implications. They discussed the sectional delimitation and phylogenetic interrelationships based on anatomical data.

4.4.2. Materials and Methods

4.4.2.1. Taxon sampling

The present study included 26 species of *Dendrobium* present in Nepal Himalaya. Out of 1500 spp. of *Dendrobium*, only 29 species of *Dendrobium* are distributed in Nepal Himalaya. In this study, only 26 spp. of *Dendrobium* were analysed and 3 spp. were excluded from this study because the specimens could not be collected from field and other sources. The species of *Dendrobium* viz. *D. anceps* (Section *Aporum*); *D. fugax* (Section *Crinifera*); *D. amoenum*, *D. aphyllum*, *D. bicameratum*, *D. chrysanthum*, *D. crepidatum*, *D. denneanum*, *D. densiflorum*, *D. fimbriatum*, *D. gibsonii*, *D. heterocarpum*, *D. moniliforme*, *D. moschatum*, *D. nobile*, *D. polyanthum*, *D. transparens* (Section *Dendrobium*); *D. formosum*, *D. longicornu* (Section *Formosae*); *D. amplum*, *D. fuscescens*, *D. rotundatum* (Section *Sarcopodium*); *D. denudans*, *D. eriiflorum*, *D. monticola*, *D. porphyrochilum* (Section *Stachyobium*) were analyzed. Within few spp. of *Dendrobium*, they showed high gross morphological, micromorphological and anatomical variations.

4.4.2.2. Gross morphological, micromorphological and anatomical analysis

In the present study, the character and character states based on collected live specimens and herbarium specimens were described to carry out the cluster analysis. Altogether 104 characters were considered to perform the cluster analysis.

4.4.2.2.1. Gross morphological characters

Habit: The habit of different species of *Dendrobium* varied from erect to pendulous, epiphyte or lithophytes herbs.

Root and Rhizome: Roots are present in most species but rhizomes are found in some species. In rhizome, roots are developed from node.

Stem/Pseudobulb: The height of the plants was found varied in different species. The minimum height of the plant was taken for the cluster analysis. The stem may be erect or pendulous. In some species, the distinct pseudobulbs were found. The shape of pseudobulb was found varied in the different species. The stem may be hairy or glabrous.

Leaves and leaf sheaths: Leaves of *Dendrobium* showed variation in orientation, shape and size. The phyllotaxy of leaf may be unifoliate, bifoliate or distichous. The leaves were arranged distichously along the stem or one to many leaves at apex of pseudobulb. The number of leaves varied from one to four at the apex of pseudobulb in some species. The size of leaves varied from 2.5 to 20.0 cm in length and 0.5 to 5.0 cm in width. The leaves may be membranous, coriaceous, fleshy or subleathery. Leaf sheaths may be glabrous or covered with blackish hairs.

Inflorescence: Inflorescence may be erect or pendulous. The inflorescence may be axillary, lateral, terminal or subterminal raceme. Length of peduncle and rachis varied across different species.

Flower: The number of flowers in inflorescence may be one to eight or more than eight. The flowers varied in shape, size and colour. The size of flower varied from 0.8 to 10.0 cm across the different species. The length of pedicel with ovary varied in different species. The colour of flower also varied across the different species.

Floral bract: The floral bract varied in shape and size in different species. The shape of floral bract varied across different species. The size of floral bract varied from 0.2 to 2.0 cm in length. The number of veins in floral bract varied from one to seven across different species. The variations were found in apex of floral bract of different species.

Sepal: Dorsal sepal varied in shape and size in different species. The shape of dorsal sepal varied across different species. The size of dorsal sepal varied from 0.5-4.7 cm in length and 0.15-1.6 cm in width in different species. The apex of dorsal sepal varied from obtuse, acute, subacute to acuminate across different species. The number of veins of dorsal sepal may be 3 to 10 in different species.

Lateral sepal varied in shape and size in different species. The shape of lateral sepal varied across different species. The size of lateral sepal varied from 0.7-5.5 cm in length and 0.2-1.6 cm in width in different species. The apex of lateral sepal varied from acute, obtuse, acuminate, subacute to obtusely acute across different species. The number of veins of lateral sepal may be 3 to 10 in different species.

Petal: Petal varied in shape and size in different species. The shape of petal varied across different species. The size of petal varied from 0.4-5.0 cm in length and 0.1-3.3 cm in width in different species. The apex of petal varied from acute, obtuse, acuminate, rounded, subacute, emarginate to cuspidate different species. The number of veins of lateral sepal may be 3 to 7 in different species.

Lip: The lip characters were considered as most distinguishing characters for delimitation of species. The lip may be simple or trilobed. The size of lip varied from 0.40-6.00 cm in length and 0.25-3.50 cm in width in different species. The lip varied in apex and margin in different species. There were variations in nature of ornamentation on disc.

4.4.2.2.2. Micromorphological characters

Besides gross morphological variations, the micromorphological variations were considered for the cluster analysis.

Stomata : Variations were found in shape, size and type of stomata in different species of *Dendrobium*. Leaf epidermal cell may be parenchymatous or sclerenchymatous. Shape of stomata varied from elliptic, circular to sub-orbicular. Stomata were tetracytic type with four or six subsidiary cells. Stomatal type may be a, b or c-tetramonocyclic, eupara-tetramonocyclic and hexa-monocyclic. There were variations in size of stomata and stomatal pore, stomatal frequency and stomatal index.

Stegmata: Stegmata was found present, absent or indistinct in different species of *Dendrobium*.

4.4.2.2.3. Anatomical characters

Besides gross morphological variations and micromorphological variations, anatomical variations were considered for the cluster analysis.

Leaf anatomy: In leaf anatomy, variations were found in thickness of cuticle, size of adaxial and abaxial epidermal cells, position and layer of hypodermis within different species of *Dendrobium*. There were variations in type of mesophyll layer, shape and size of mid vascular bundle, position of fibre bundle on midrib vascular bundle.

Variations were also found in size of xylem fibre cap and phloem fibre cap and size of xylem and phloem on vascular bundle.

Stem anatomy: Variations were found in stem anatomy within different species of *Dendrobium*. Epidermal cells showed variations in shape and size. There were variations in shape and layers of hypodermal cells, shape, size and number of vascular bundles. Size of xylem fibre cap, phloem fibre cap and size of xylem and phloem on vascular bundle were varied among different species. Stegmata and raphide bundles were found either present or absent.

4.4.2.2.4. Data Matrix

Altogether 104 variable characters (gross morphological, micromorphological and anatomical characters) were scored as multistate characters. The multistate characters were coded as 0-9. The complete data matrix of characters and character states are presented in Table 11. The data matrix of different species is presented in Table 12.

4.4.2.2.5. Data analysis

The cluster analysis was performed on the gross morphological, micromorphological and anatomical data with Pvcust (Suzuki and Shimodaira, 2011), an R package (R version 3.1.0, 2014). Pvcust is an add-on package for a statistical software R to assess the uncertainty in hierarchical cluster analysis. Pvcust can be used easily for general statistical problems, to perform the bootstrap analysis of clustering, which has been popular in phylogenetic analysis. Pvcust is an implementation of bootstrap analysis on a statistical software R for hierarchical clustering with *p*-values. It is a special form of hierarchical clustering for inferring the history of evolution as a dendrogram. Pvcust calculates probability values (*p*-values) for each cluster during bootstrap resampling techniques. In pvcust, two types of *p*-values are available: Approximately Unbiased (AU) *p*-value and Bootstrap Probability (BP) *p*-value. Multiple bootstrap resampling is used for the calculation of AU *p*-value which has superiority in bias over BP *p*-value calculated by normal bootstrap resampling.

Thousands of bootstrap samples are generated by randomly sampling elements of the data and bootstrap replicates of the dendrogram are obtained by repeatedly applying the cluster analysis to them (Efron, 1979; Felsenstein, 1985). The bootstrap probability (BP) value of a cluster is the frequency that it appears in the bootstrap replicates. The multiscale bootstrap resampling was developed for calculating approximately unbiased (AU) probability values (Efron *et al.*, 1996; Shimodaira, 2002, 2004).

R-pvclust analysis was performed on the gross morphological, micromorphological and anatomical data with 10000 bootstrapping to get the stronger cluster supported by data. The average cluster analysis with correlation distance was used to analyze the data set.

The importance of the gross-morphological, micromorphological and anatomical characters was analyzed to obtain the probable significant characters for identifying the significant clusters.

Table 11. Characters and character states used in Cluster analysis of *Dendrobium*

S.N.	Character	Character states
0	Habit form	(0) epiphyte; (1) epiphyte + lithophyte
1	Minimum plant height, cm	(0) < 15; (1) 15 - 24; (2) > 24
2	Stem habit	(0) erect; (1) pendulous
3	Stem surface	(0) hairy; (1) glabrous
4	Pseudobulb	(0) absent; (1) fusiform; (2) cylindric-ovoid; (3) cylindrical; (4) ovoid; (5) ellipsoid; (6) elongate; (7) conical-ovoid
5	Rhizome	(0) absent; (1) present
6	Leaf position/Stem or Pseudobulb	(0) throughout stem; (1) at apex
7	Leaf texture	(0) membranous; (1) coriaceous; (2) subleathery; (3) fleshy
8	Maximum length of leaf, cm	(0) < 9; (1) 9 - 13; (2) > 13
9	Maximum width of leaf, cm	(0) < 2; (1) 2-3; (2) > 3
10	Leaf no./ Stem, pseudobulb	(0) 1; (1) 2; (2) 3- 4; (3) > 4
11	Leaf phyllotaxy	(0) bifoliate; (1) unifoliate; (2) distichous
12	Inflorescence	(0) erect; (1) pendulous
13	Inflorescence orientation	(0) lateral; (1) axillary; (2) terminal; (3) subterminal; (4) terminal or axillary; (5) terminal or lateral; (6) subterminal or lateral
14	Length of peduncle, cm	(0) < 0.5; (1) 0.5 - 2.0; (2) 2.0
15	Maximum length of rachis	(0) absent; (1) ≤ 8.0 cm; (2) > 8 cm
16	Highest no. of flowers/Inflorescence	(0) < 4; (1) 4 - 8; (2) > 8
17	Floral bract shape	(0) ovate-lanceolate; (1) ovate; (2) ovate-oblong; (3) oblong; (4) lanceolate; (5) ovate-triangular; (6) triangular; (7) oblong-lanceolate
18	Floral bract apex	(0) acute; (1) obtuse; (2) acuminate; (3) subacute
19	No. of veins in floral bract	(0) 1; (1) 3; (2) 5; (3) 7
20	Length of floral bract, cm	(0) < 0.5 ; (1) 0.5 - 0.9; (2) > 0.9
21	Length of pedicel with ovary, cm	(0) < 1.0; (1) 1.0 - 3.0; (2) > 3.0
22	Flower size (across), cm	(0) < 2.5; (1) 2.5 - 4.0; (2) > 4.0
23	No. of veins in dorsal sepal	(0) 3; (1) 5; (2) 7; (3) 10
24	Dorsal sepal shape	(0) lanceolate; (1) oblong-lanceolate; (2) ovate-oblong; (3) oblong; (4) elliptic-oblong; (5) ovate-lanceolate; (6) elliptic; (7) ovate; (8) linear-lanceolate
25	Dorsal sepal length, cm	(0) < 1.5; (1) 1.5 - 2.5; (2) > 2.5
26	Dorsal sepal width, cm	(0) < 0.5; (1) 0.5 - 1.0; (2) > 1.0
27	Apex of dorsal sepal	(0) obtuse; (1) acute; (2) subacute; (3) acuminate
28	No. of veins in lateral sepal	(0) 3; (1) 5; (2) 7; (3) 10
29	Lateral sepal shape	(0) ovate-lanceolate; (1) oblong-elliptic; (2) ovate-triangular; (3) ovate-lanceolate; (4) falcate; (5) subfalcate; (6) lanceolate; (7) oblong; (8) ovate (9) Triangular
30	Lateral sepal length, cm	(0) < 1.5; (1) 1.5 - 2.5; (2) > 2.5
31	Lateral sepal width, cm	(0) < 0.5 (1) 0.5 - 1.0; (2) > 1.0
32	Apex of lateral sepal	(0) acute; (1) obtuse; (2) acuminate; (3) subacute; (4) obtusely acute

33	Petal shape	(0) linear-lanceolate; (1) oblong-lanceolate; (2) ovate-lanceolate; (3) ovate-orbicular; (4) ovate-triangular; (5) oblong-elliptic; (6) oblong; (7) elliptic; (8) ovate; (9) Obovate
34	No. of veins in petal	(0) 3; (1) 5; (2) 7
35	Petal length, cm	(0) < 1.4; (1) 1.4 - 2.5; (2) > 2.5
36	Petal width, cm	(0) < 0.5; (1) 0.5 - 1.2; (2) > 1.2
37	Apex of Petal	(0) acute; (1) obtuse; (2) acuminate; (4) rounded; (5) subacute; (6) emarginate; (7) cuspidate
38	Lip	(0) simple; (1) trilobed
39	Lip length, cm	(0) < 1.5 ; (1) 1.5-2.5 ; (2) > 2.5
40	Lip width, cm	(0) < 1.0; (1) 1.0-2.0; (2) > 2.0
41	Lip margin	(0) entire; (1) undulate; (2) crenulate; (3) fimbriate; (4) denticulate; (5) lacerate; (6) crisped; (7) cucullate,entire; (8) cucullate, fimbriate; (9) Serrate-crisped
42	Lip apex	(0) acute; (1) obtuse; (2) bilobed; (3) rounded; (4) emarginate; (5) truncate; (6) mucronate; (7) subtruncate; (8) subacute (9) Retuse
43	Nature of ornamentation on disc	(0) absent; (1) ridges; (2) lamellae; (3) keels; (4) callus; (5) claw; (6) sub-villous; (7) papillary hairs; (8) central veins (9) Shallow depression
44	Stomatal shape	(0) elliptic; (1) circular; (2) sub-orbicular
45	Stomatal type	(0) a-tetra-monocyclic; (1) b-tetramonocyclic; (2) c-tetra-monocyclic; (3) eupara-twimonocyclic; (4) eupara-twi-monocyclic + hexa-monocyclic
46	Stomata length, μm	(0) < 33; (1) 33 - 37; (2) > 37
47	Stomata width, μm	(0) < 26; (1) 26 - 28; (2) > 28
48	Stomatal pore length, μm	(0) < 16; (1) 16 - 18; (2) > 18
49	Stomatal pore width, μm	(0) < 7; (1) 7 – 9.99; (2) > 9.99
50	Stomatal frequency, mm^2	(0) < 80; (1) 80-120; (2) > 120
51	Stomatal index, %	(0) < 7; (1) 7 - 10; (2) > 10
52	Leaf epidermal cell type	(0) parenchyma; (1) sclerenchyma
53	Stegmata	(0) absent; (1) present; (2) indistinct
54	Cuticle layer of leaf	(0) thick; (1) thin
55	Adaxial leaf epidermal cell width (largest), μm	(0) < 46; (1) 46 - 67; (2) > 67
56	Adaxial leaf epidermal cell length (largest), μm	(0) < 28; (1) 28 - 40; (2) > 40
57	Abaxial leaf epidermal cell width (largest), μm	(0) < 28; (1) 28 - 42; (2) > 42
58	Abaxial leaf epidermal cell length (largest), μm	(0) < 18; (1) 18 - 24; (2) > 24
59	Leaf hypodermis position	(0) absent; (1) adaxial; (2) abaxial
60	Leaf hypodermal layer	(0) absent; (1) 1
61	Mesophyll layer type	(0) homogenous; (1) heterogenous
62	Homogenous mesophyll layers	(0) absent; (1) ≤ 7 ; (3) 8 - 10
63	Heterogenous mesophyll spongy layers	(0) absent; (1) 7; (2) 8
64	Water storage cells in mesophyll	(0) absent; (1) present
65	Calcium oxalate crystals in mesophyll	(0) absent; (1) present
66	Midrib vascular bundle shape	(0) oval; (1) flask-shaped; (2) conical; (3) oblong; (4) circular

67	Midrib vascular bundle length, μm	(0) <140; (1) 140 - 200; (2) > 200
68	Midrib vascular bundle width, μm	(0) < 120; (1) 120 - 170; (2) > 170
69	Fibre bundle	(0) absent; (1) present
70	Major vascular bundle at leaf pole	(0) absent; (1) present
71	Fibre cap on midrib bundle	(0) absent; (1) present
72	Xylem fibre cap layers in midrib bundle	(0) absent; (1) < 4; (2) 4 - 6; (3) > 6
73	Phloem fibre cap layers in midrib bundle	(0) absent; (1) < 4; (2) 4 - 5; (3) > 5
74	Xylem fibre cap length, μm	(0) absent; (1) < 30; (2) 30 - 50; (3) > 50
75	Xylem fibre cap width, μm	(0) absent; (1) < 125; (2) 125 - 150; (3) > 150
76	Phloem fibre cap length, μm	(0) absent; (1) < 28; (2) 28 - 37; (3) > 37
77	Phloem fibre cap width, μm	(0) absent; (1) < 130 (2) 130 - 175; (3) > 175
78	Xylem length (largest), μm	(0) < 19; (1) 19 - 25; (2) > 25
79	Xylem width (largest), μm	(0) < 10; (1) 10 - 17; (2) > 17
80	Phloem length (largest), μm	(0) < 6; (1) 6 - 9; (2) > 9
81	Phloem width (largest), μm	(0) < 4.0; (1) 4.0 - 6.5; (2) > 6.5
82	Stem epidermal cell shape	(0) rectangular to polygonal; (1) rectangular to square; (2) rectangular to angular; (3) rectangular; (4) barrel-shaped
83	Stem epidermal cell width (largest), μm	(0) < 18; (1) 18 - 25; (2) > 25
84	Stem epidermal cell length (largest), μm	(0) < 12; (1) 12 - 16; (2) > 16
85	Stem hypodermal layer	(0) absent; (1) 1; (2) 2 - 3; (3) 4 - 5
86	Stem hypodermal cell shape	(0) absent; (1) oblong-polygonal; (2) rectangular-polygonal; (3) polygonal; (4) oval-polygonal
87	Stem vascular bundle shape	(0) oval; (1) elongate
88	Stem vascular bundle no.	(0) 60; (1) 60 - 70; (2) > 70
89	Stem vascular bundle length (smallest), μm	(0) < 100; (1) 100 - 130; (2) > 130
90	Stem vascular bundle width (smallest), μm	(0) < 80; (1) 80 - 90; (2) > 90
91	Stem vascular bundle length (largest), μm	(0) < 190; (1) 190 - 230; (2) > 230
92	Stem vascular bundle width (largest), μm	(0) < 100; (1) 100 - 130; (2) > 130
93	Fibre cap in vascular bundle of stem	(0) absent; (1) present
94	Xylem fibre cap length (largest), μm	(0) absent; (1) ≤ 45 ; (2) > 45
95	Xylem fibre cap width (largest) μm ,	(0) absent; (1) ≤ 100 ; (2) > 100
96	Phloem fibre cap length (largest), μm	(0) absent; (1) < 30; (2) 30 - 37; (3) > 37
97	Phloem fibre cap width (largest), μm	(0) absent; (1) < 80; (2) 80 - 100; (3) > 100
98	Xylem length (largest), μm	(0) < 18; (1) 18 - 27; (2) > 27
99	Xylem width (largest), μm	(0) < 15; (1) 15 - 20 ; (2) > 20
100	Phloem length (largest), μm	(0) < 7; (1) 7 - 10; (2) > 10
101	Phloem width (largest), μm	(0) < 5; (1) 5 - 8; (2) > 8
102	Stegmata in vascular bundle of stem	(0) absent; (1) present
103	Raphide bundles in stem	(0) absent; (1) present

Table 12. Data matrix for Cluster analysis of *Dendrobium*

S. N.	Taxa <i>Dendrobium</i>	Characters and character states with codes																											
		0	1	2	3	4	5	6	7	8	9	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2
1	<i>D. amoenum</i>	1	1	1	1	0	0	0	0	1	0	3	2	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1
2	<i>D. amplum</i>	0	2	1	1	5	1	1	1	2	2	1	0	0	2	1	0	0	2	0	2	2	2	2	2	3	0	2	1
3	<i>D. anceps</i>	0	1	0	1	0	0	0	3	0	0	3	2	0	1	0	0	0	3	1	2	0	0	0	1	6	0	0	0
4	<i>D. aphyllum</i>	0	1	1	1	0	0	0	3	0	1	3	2	1	1	0	0	0	1	0	0	0	1	1	1	1	1	2	1
5	<i>D. bicameratum</i>	0	0	0	1	0	0	0	0	0	1	3	2	0	6	1	1	1	2	0	1	1	0	0	1	2	0	1	1
6	<i>D. chrysanthum</i>	0	2	1	1	0	0	0	0	2	2	3	2	1	0	0	0	1	5	0	0	0	2	2	2	6	1	2	2
7	<i>D. crepidatum</i>	0	0	1	1	0	0	0	2	1	0	3	2	1	0	0	0	0	1	0	0	0	2	1	1	1	0	1	1
8	<i>D. denneanum</i>	1	2	0	1	0	0	0	1	1	1	3	2	1	3	1	2	1	3	0	3	2	2	2	2	3	1	2	2
9	<i>D. densiflorum</i>	0	1	0	1	0	0	1	1	2	2	2	2	1	1	2	2	2	3	1	0	2	1	1	2	2	1	2	2
10	<i>D. denudans</i>	0	0	0	1	0	0	0	0	1	0	3	2	1	1	2	1	2	4	0	0	0	0	0	0	8	0	0	0
11	<i>D. eriiflorum</i>	1	0	0	1	0	0	0	0	0	0	3	2	1	4	2	2	2	0	2	0	0	0	0	1	0	0	0	0
12	<i>D. fimbriatum</i>	1	2	0	1	0	0	0	1	2	2	3	2	1	1	1	1	1	5	0	2	0	1	2	1	4	1	2	2
13	<i>D. formosum</i>	0	1	0	0	0	0	0	1	0	1	3	2	0	5	2	0	1	1	3	2	1	2	2	2	4	2	2	2
14	<i>D. fugax</i>	0	1	1	1	1	1	1	1	2	1	0	1	0	2	1	0	0	6	0	0	2	0	0	1	4	0	0	0
15	<i>D. fuscescens</i>	1	2	1	1	2	1	1	1	1	1	1	0	0	2	0	0	0	0	0	2	1	1	2	3	5	2	1	1
16	<i>D. gibsonii</i>	0	2	1	1	0	0	0	1	2	2	3	2	1	0	1	2	2	4	0	2	1	2	1	1	6	1	2	2
17	<i>D. heterocarpum</i>	0	1	0	1	0	0	0	1	1	1	3	2	0	1	0	0	0	1	1	1	1	1	1	2	1	1	2	1
18	<i>D. longicornu</i>	0	0	0	0	0	0	0	1	0	0	3	2	0	1	1	0	0	0	0	2	2	1	1	2	5	1	1	1
19	<i>D. moniliforme</i>	0	1	0	1	0	0	0	0	0	0	3	2	0	1	0	1	0	1	0	1	1	1	1	1	0	0	0	0
20	<i>D. monticola</i>	1	0	0	1	6	0	1	1	0	0	2	2	0	2	1	1	1	1	0	0	0	0	0	0	0	0	0	0
21	<i>D. moschatum</i>	0	2	0	1	0	0	0	1	2	2	3	2	1	0	2	2	2	4	1	2	2	2	2	2	3	2	2	2
22	<i>D. nobile</i>	0	2	0	1	0	0	0	1	1	1	3	2	0	0	1	0	1	2	1	2	1	2	2	2	1	2	1	1
23	<i>D. polyanthum</i>	0	0	1	1	0	0	0	0	1	1	3	2	1	0	0	0	0	1	1	0	1	1	2	1	0	1	1	1
24	<i>D. porphyrochilum</i>	0	0	0	1	3	0	1	0	0	0	2	2	1	2	2	1	2	4	2	0	0	0	0	0	0	0	0	0
25	<i>D. rotundatum</i>	0	2	1	1	4	1	1	1	2	1	1	0	0	2	1	0	0	1	0	2	2	1	1	2	5	2	0	0
26	<i>D. transparens</i>	0	1	0	1	0	0	0	0	1	1	3	2	0	1	0	0	2	4	0	2	2	2	2	1	1	0	2	0

S. N.	Taxa	Characters and character states with codes																										
		2 7	2 8	2 9	3 0	3 1	3 2	3 3	3 4	3 5	3 6	3 7	3 8	3 9	4 0	4 1	4 2	4 3	4 4	4 5	4 6	4 7	4 8	4 9	5 0	5 1	5 2	5 3
1	<i>D. amoenum</i>	0	1	6	2	1	0	8	1	2	1	1	1	2	1	1	1	6	0	1	0	0	0	0	0	0	0	1
2	<i>D. amplum</i>	3	3	4	2	1	2	0	1	2	0	0	1	2	1	0	6	2	2	1	1	2	1	0	1	0	1	1
3	<i>D. anceps</i>	2	1	4	0	0	1	7	1	0	0	1	1	0	0	2	2	9	0	4	0	0	0	0	0	0	0	2
4	<i>D. aphyllum</i>	2	1	0	2	1	3	5	1	2	1	1	0	2	2	3	3	7	0	0	1	0	1	1	0	1	0	1
5	<i>D. bicameratum</i>	2	1	9	0	1	0	7	1	0	1	1	1	0	0	0	5	4	0	0	1	2	2	1	0	1	0	2
6	<i>D. chrysanthum</i>	0	2	2	1	2	1	9	2	1	2	3	0	1	2	4	3	1	1	0	1	0	1	0	0	0	0	1
7	<i>D. crepidatum</i>	0	1	0	1	1	1	9	1	1	1	1	0	0	1	1	3	1	0	1	0	1	0	1	2	2	0	1
8	<i>D. denneanum</i>	3	1	5	1	1	2	8	0	1	1	1	0	1	1	3	9	5	1	0	0	1	1	1	2	1	1	1
9	<i>D. densiflorum</i>	0	2	1	1	2	4	3	2	1	2	1	0	1	2	5	9	5	0	0	1	1	2	2	0	0	1	0
10	<i>D. denudans</i>	3	1	4	0	0	2	0	0	0	0	2	1	0	0	9	0	1	0	0	2	1	2	1	1	2	0	2
11	<i>D. eriiflorum</i>	3	1	4	0	0	2	0	0	0	0	0	1	0	0	1	0	1	0	2	2	0	2	2	2	2	0	2
12	<i>D. fimbriatum</i>	0	1	3	1	2	1	5	1	1	2	1	0	2	2	3	3	5	1	0	1	2	1	1	2	2	1	1
13	<i>D. formosum</i>	2	2	5	2	2	0	9	2	2	2	6	1	2	2	1	9	1	1	2	2	2	2	0	0	2	1	0
14	<i>D. fugax</i>	2	1	1	0	0	3	6	0	0	0	4	1	0	0	6	5	2	1	3	0	2	0	2	2	2	1	2
15	<i>D. fuscescens</i>	3	3	3	2	2	2	0	1	2	0	0	1	1	1	4	6	2	1	0	0	0	0	0	0	0	1	1
16	<i>D. gibsonii</i>	0	1	7	1	1	1	7	1	1	2	5	0	1	1	3	4	7	0	0	1	0	2	0	0	1	0	1
17	<i>D. heterocarpum</i>	2	2	6	2	1	0	2	1	2	1	0	0	2	1	1	0	7	1	0	2	2	1	2	1	2	0	1
18	<i>D. longicornu</i>	3	2	6	2	2	2	0	0	1	1	0	1	2	2	3	1	1	0	0	0	0	0	0	2	2	0	0
19	<i>D. moniliforme</i>	1	1	5	1	1	0	2	1	1	1	0	1	1	0	0	0	4	1	0	2	2	1	0	2	2	0	2
20	<i>D. monticola</i>	3	1	4	0	0	0	0	0	0	0	2	1	0	0	1	0	2	0	0	2	1	2	1	2	2	0	2
21	<i>D. moschatum</i>	0	2	7	2	2	0	8	2	2	2	1	0	2	1	8	3	0	1	0	0	1	1	1	0	0	0	1
22	<i>D. nobile</i>	0	2	0	2	1	0	7	2	2	2	1	0	2	2	7	1	5	0	2	2	2	2	2	1	2	0	1
23	<i>D. polyanthum</i>	2	1	6	1	0	3	6	1	1	0	1	0	1	1	4	3	4	0	1	0	1	1	0	0	1	0	0
24	<i>D. porphyrochilum</i>	0	0	6	0	0	1	1	0	0	0	0	0	0	0	0	8	1	0	0	1	0	0	0	0	1	0	1
25	<i>D. rotundatum</i>	1	2	5	2	2	0	1	2	2	1	2	1	1	1	1	4	3	2	2	0	0	0	0	1	1	1	2
26	<i>D. transparens</i>	0	1	6	2	0	2	6	1	2	2	1	1	2	1	1	0	8	0	1	1	1	1	0	2	2	0	1

S. N.	Taxa	Characters and character states with codes																										
		5 4	5 5	5 6	5 7	5 8	5 9	6 0	6 1	6 2	6 3	6 4	6 5	6 6	6 7	6 8	6 9	7 0	7 1	7 2	7 3	7 4	7 5	7 6	7 7	7 8	7 9	8 0
1	<i>D. amoenum</i>	1	2	1	2	1	0	0	0	1	0	0	1	0	1	1	0	0	1	2	1	3	2	2	2	2	2	1
2	<i>D. amplum</i>	0	1	1	2	1	0	0	1	0	1	0	0	1	1	1	0	0	1	2	3	1	2	3	2	1	2	1
3	<i>D. anceps</i>	0	0	0	0	0	2	1	0	3	0	1	1	4	0	1	1	1	1	1	1	1	1	1	2	0	0	0
4	<i>D. aphyllum</i>	1	2	2	2	2	0	0	0	2	0	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1
5	<i>D. bicameratum</i>	0	1	1	1	0	0	0	0	2	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	1
6	<i>D. chrysanthum</i>	1	2	0	1	1	0	0	0	2	0	0	0	0	2	2	0	0	1	3	2	2	3	2	3	1	2	2
7	<i>D. crepidatum</i>	1	0	2	0	2	0	0	0	2	0	0	1	2	2	1	0	0	1	2	3	2	2	3	2	1	1	1
8	<i>D. denneanum</i>	0	0	0	0	0	0	0	0	2	0	0	1	2	2	2	0	0	1	2	2	2	3	2	3	1	1	1
9	<i>D. densiflorum</i>	0	0	0	0	1	1	1	0	3	0	0	1	2	2	2	0	0	1	3	3	3	3	3	3	2	1	2
10	<i>D. denudans</i>	1	0	0	1	0	0	0	0	1	0	0	1	3	0	0	0	0	1	1	1	0	1	1	1	1	0	1
11	<i>D. eriiflorum</i>	1	0	2	0	2	0	0	0	1	0	0	1	0	0	0	0	0	1	2	2	2	1	1	1	1	1	1
12	<i>D. fimbriatum</i>	1	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	1	2	2	2	1	2	1	1	1	1
13	<i>D. formosum</i>	1	2	2	2	2	0	0	0	2	0	0	1	0	2	2	0	0	1	3	2	3	3	2	3	2	2	2
14	<i>D. fugax</i>	0	0	0	0	0	0	0	0	3	0	0	1	1	2	1	0	0	1	3	3	3	3	2	3	2	1	2
15	<i>D. fuscescens</i>	0	0	0	1	1	0	0	1	0	1	0	0	1	2	1	0	0	1	2	3	3	1	3	3	1	1	2
16	<i>D. gibsonii</i>	1	1	1	1	0	0	0	0	2	0	0	1	0	2	2	0	0	1	2	2	3	3	3	3	2	2	2
17	<i>D. heterocarpum</i>	1	2	2	1	2	0	0	0	1	0	0	1	0	1	0	0	0	1	2	1	1	1	1	1	1	1	1
18	<i>D. longicornu</i>	1	1	2	2	2	0	0	0	2	0	0	1	4	1	1	0	0	1	2	2	2	3	2	1	1	1	1
19	<i>D. moniliforme</i>	0	1	2	0	1	0	0	0	2	0	0	1	0	0	1	0	0	1	1	2	1	1	1	2	0	0	0
20	<i>D. monticola</i>	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	1
21	<i>D. moschatum</i>	1	1	0	0	0	0	0	0	3	0	1	1	2	2	2	0	0	1	3	3	3	3	3	3	2	2	2
22	<i>D. nobile</i>	1	2	1	2	2	0	0	0	2	0	1	1	0	1	1	0	0	1	1	1	2	3	1	3	1	2	2
23	<i>D. polyanthum</i>	1	0	0	1	0	0	0	0	2	0	1	0	4	2	2	0	0	1	3	2	3	3	3	2	1	1	1
24	<i>D. porphyrochilum</i>	1	2	1	1	1	0	0	0	1	0	1	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	<i>D. rotundatum</i>	0	1	1	1	2	0	0	1	0	2	1	1	1	1	1	0	0	1	2	3	2	3	3	1	2	2	1
26	<i>D. transparens</i>	1	1	2	2	1	0	0	0	2	0	0	1	4	1	1	0	0	1	2	2	2	2	1	2	1	1	1

Taxa		Characters and character states with codes																						
S. N.	<i>Dendrobium</i>	8 1	8 2	8 3	8 4	8 5	8 6	8 7	8 8	8 9	9 0	9 1	9 2	9 3	9 4	9 5	9 6	9 7	9 8	9 9	1 0	1 0	1 0	1 0
1	<i>D. amoenum</i>	1	0	1	0	2	3	0	2	2	2	0	1	1	0	0	2	2	2	2	2	2	1	0
2	<i>D. amplum</i>	1	1	1	1	2	3	1	0	2	0	2	2	1	2	2	3	3	2	1	1	1	1	0
3	<i>D. anceps</i>	0	4	0	0	2	3	0	1	1	0	1	0	1	1	1	3	2	0	0	0	1	0	0
4	<i>D. aphyllum</i>	1	4	0	2	1	3	0	2	2	2	2	1	1	0	0	2	2	1	1	2	1	1	1
5	<i>D. bicameratum</i>	0	4	0	0	2	3	1	2	0	1	1	0	1	0	0	2	1	2	2	0	1	1	0
6	<i>D. chrysanthum</i>	2	4	1	1	2	4	1	1	1	1	2	2	1	0	0	2	2	2	2	1	1	0	1
7	<i>D. crepidatum</i>	1	0	2	0	1	1	0	0	1	1	1	0	1	0	0	1	1	1	1	1	2	0	0
8	<i>D. denneanum</i>	1	4	1	1	3	2	1	2	2	2	2	2	1	0	0	3	3	2	2	2	2	0	0
9	<i>D. densiflorum</i>	2	3	0	2	3	2	0	2	1	1	1	2	1	0	0	2	3	0	1	0	0	1	1
10	<i>D. denudans</i>	1	3	2	1	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0
11	<i>D. eriiflorum</i>	1	3	2	1	0	0	0	1	1	1	1	1	1	0	0	1	1	0	0	0	0	0	1
12	<i>D. fimbriatum</i>	1	4	0	0	3	2	0	1	2	2	1	2	1	0	0	3	3	2	0	2	2	0	0
13	<i>D. formosum</i>	2	0	2	2	2	3	0	1	2	2	2	2	1	0	0	3	3	2	0	2	2	1	0
14	<i>D. fugax</i>	2	4	1	2	2	3	1	2	1	1	1	2	1	0	0	2	2	1	1	0	1	1	0
15	<i>D. fuscescens</i>	2	1	2	2	2	3	0	2	0	1	2	1	1	2	2	1	1	1	1	1	1	0	0
16	<i>D. gibsonii</i>	2	2	0	1	2	3	0	0	1	2	2	2	1	0	0	3	2	2	1	2	2	0	1
17	<i>D. heterocarpum</i>	1	2	1	1	2	3	0	2	1	2	0	1	1	0	0	3	2	0	0	1	1	0	1
18	<i>D. longicornu</i>	2	0	1	1	2	3	1	1	0	1	0	1	1	0	0	3	2	1	1	2	2	1	1
19	<i>D. moniliforme</i>	0	0	1	1	2	3	1	0	2	2	2	2	1	0	0	1	1	1	1	2	2	0	1
20	<i>D. monticola</i>	1	3	2	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0
21	<i>D. moschatum</i>	2	4	0	2	2	3	0	2	2	2	0	2	1	1	1	2	3	0	0	0	0	0	1
22	<i>D. nobile</i>	2	0	2	1	2	3	0	2	1	1	1	2	1	0	0	2	2	1	1	0	1	0	0
23	<i>D. polyanthum</i>	1	0	2	2	1	3	1	0	0	0	2	2	1	0	0	2	3	2	2	2	2	1	1
24	<i>D. porphyrochilum</i>	0	0	2	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
25	<i>D. rotundatum</i>	1	1	2	2	2	3	0	2	0	1	0	1	1	0	0	3	2	1	1	2	2	1	1
26	<i>D. transparens</i>	1	1	1	2	2	3	1	0	0	0	0	0	1	0	0	1	1	0	0	1	1	1	1

4.4.2.3. Anatomical analysis

Besides gross morphological variations, micromorphological variations and anatomical variations, only anatomical variations were considered for the cluster analysis.

Altogether 60 variable anatomical characters (no. 44-103) as mentioned in Table 11. were scored as multistate characters. The multistate characters were coded as 0-9. The complete data matrix of characters and character states are presented in Table 11. The data matrix of different species is presented in Table 12.

The cluster analysis was performed on anatomical data with pvclust (Suzuki & Shimodaira, 2011), an R package (R version 3.1.0, 2014). The methods were similar as described in grossmorphological, micromorphological and anatomical analysis.

4.4.3. Result

4.4.3.1. Gross morphological, micromorphological and anatomical analysis

The gross morphological, micromorphological and anatomical data were analyzed to find the interrelationships among the species of genus *Dendrobium*. The analysis results in one dendrogram with AU *p*-value (printed in red colour by default) and BP *p*-value (printed in green colour by default). In the dendrogram, AU *p*-value above 95% was the significant clusters.

The dendrogram of cluster analysis of species of *Dendrobium* is presented in Fig. 60. The topology showed that the species of *Dendrobium* were divided into two major clusters: cluster A with AU *p*-value of 97% and BP *p*-value of 11% and cluster B with AU *p*-value of 96% and BP *p*-value of 3% with significant values.

Cluster A was further divided into two clusters: cluster C with single species *D. formosum* and cluster D with *D. moschatum*, *D. chrysanthum*, *D. fimbriatum*, *D. gibsonii*, *D. fugax*, *D. denneanum* and *D. densiflorum*. Cluster D was again divided into two clusters: cluster D1 with *D. moschatum*, *D. chrysanthum*, *D. fimbriatum* and *D. gibsonii* with AU *p*-value of 83% and BP *p*-value of 17% and cluster D2 with *D. fugax*, *D. denneanum* and *D. densiflorum* with AU *p*-value of 91% and BP *p*-value of 14%. Cluster D1 again divided into two clusters: cluster D1a with single species *D. moschatum* and cluster D1b with *D. chrysanthum*, *D. fimbriatum* and *D. gibsonii*. Cluster D1b again divided into two clusters: cluster D1bi with single species *D. chrysanthum* and cluster D1bii with *D. fimbriatum* and *D. gibsonii*. Cluster D2 again divided into two clusters: cluster D2a with single species *D. fugax* and cluster D2b

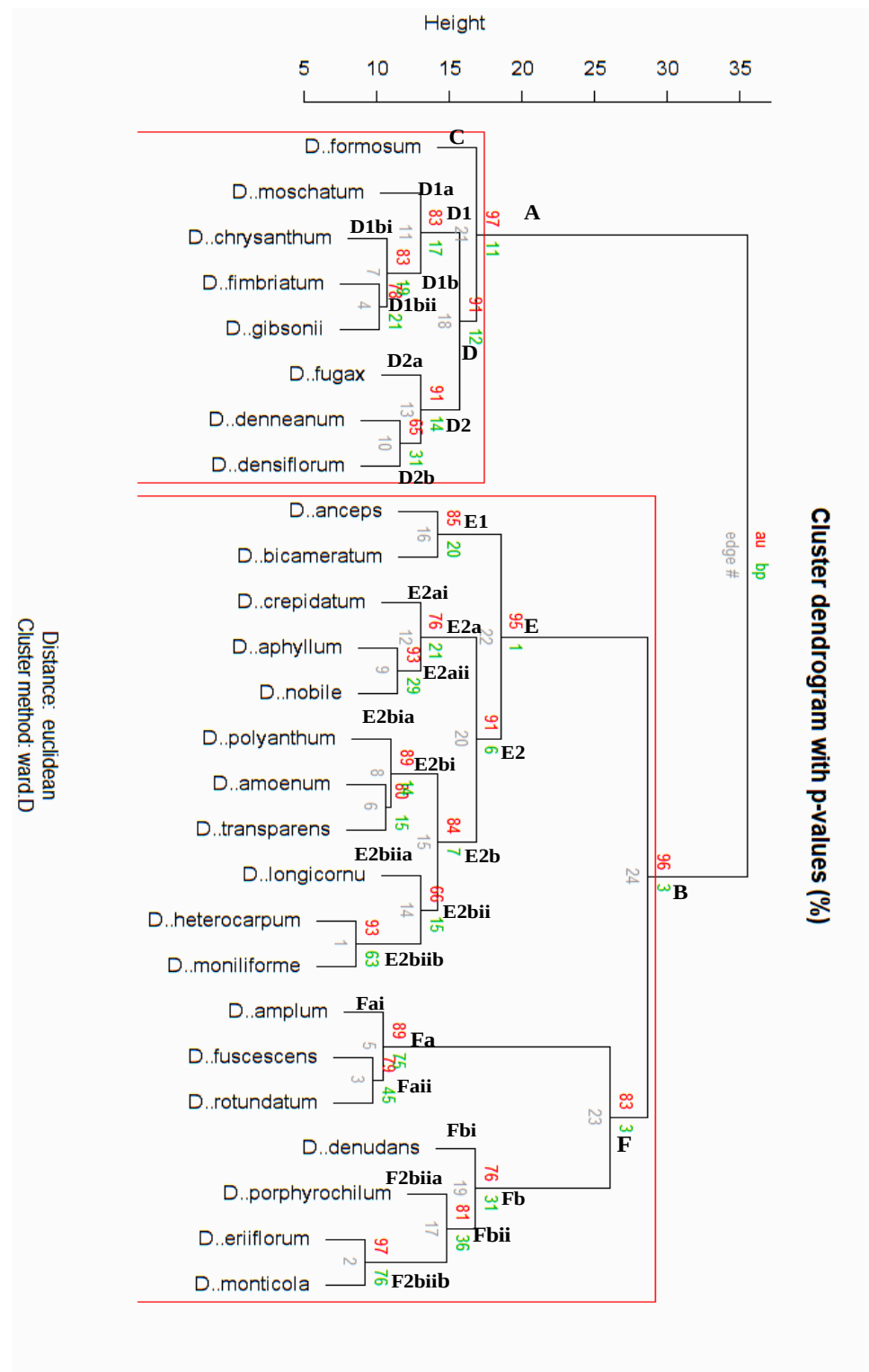


Fig. 60. Dendrogram constructed according to pvclust cluster analysis with AU/BP p -values in % and the bootstrapping of 10000. The AU/BP p -values are indicated below the branches. The AU p -value above 95% indicates the significant clusters.

with *D. denneanum* and *D. densiflorum*.

Cluster B was further divided into two clusters: cluster E with AU *p*-value of 95% and BP *p*-value of 1% and cluster F with AU *p*-value of 83% and BP *p*-value of 1%. Cluster E was again divided into two clusters: cluster E1 with *D. anceps*, *D. bicameratum* and cluster E2 with *D. crepidatum*, *D. aphyllum*, *D. nobile*, *D. polyanthum*, *D. amoenum*, *D. transparens*, *D. longicornu*, *D. heterocarpum*, *D. moniliforme*. Cluster E2 was further divided into two clusters: cluster E2a with *D. crepidatum*, *D. aphyllum* and *D. nobile* and cluster E2b with *D. polyanthum*, *D. amoenum*, *D. transparens*, *D. longicornu*, *D. heterocarpum* and *D. moniliforme*. Cluster E2a again divided into two clusters: cluster E2ai with *D. crepidatum* and cluster E2aii with *D. aphyllum* and *D. nobile*. Cluster E2b again divided into two clusters: cluster E2bi with *D. polyanthum*, *D. amoenum*, *D. transparens* and cluster E2bii with *D. longicornu*, *D. heterocarpum*, *D. moniliforme*. Cluster E2bi further divided into two clusters: cluster E2bia with *D. polyanthum* and cluster E2bib with *D. amoenum* and *D. transparens*. Cluster E2bii again divided into two clusters: cluster E2biia with *D. longicornu* and E2biib with *D. heterocarpum* and *D. moniliforme* with AU *p*-value of 93% and BP *p*-value of 63%. Cluster F was divided into two clusters: cluster F1 with *D. amplum*, *D. fuscescens*, *D. rotundatum* and cluster F2 with *D. denudans*, *D. porphyrochilum*, *D. eriiflorum*, *D. monticola*. Cluster F1 again divided into two clusters: cluster F1a with *D. amplum* and cluster F1b with *D. fuscescens*, *D. rotundatum*. Cluster F2 further divided into two clusters: cluster F2a with *D. denudans* and cluster F2b with *D. porphyrochilum*, *D. eriiflorum*, *D. monticola*. Cluster F2b again divided into two clusters: cluster F2bi with *D. porphyrochilum* and cluster F2bii with *D. eriiflorum*, *D. monticola* with AU *p*-value of 97% and BP *p*-value of 76% with significant values.

4.4.3.2. Anatomical analysis

The anatomical data were analyzed to find the interrelationship among the species of genus *Dendrobium*. The analysis results in one dendrogram with AU *p*-value (printed in red colour by default) and BP *p*-value (printed in green colour by default). In the dendrogram, AU *p*-value above 95% was the significant clusters.

The dendrogram of cluster analysis of species of *Dendrobium* is presented in Fig. 61. The topology showed that the species of *Dendrobium* were divided into two major

clusters: cluster A with AU *p*-value of 45% and BP *p*-value of 19% and cluster B with AU *p*-value of 49% and BP *p*-value of 18% with significant values.

Cluster A was further divided into two clusters: cluster C with a single species *D. anceps* and cluster D with *D. longicornu*, *D. polyanthum*, *D. porphyrochilum*, *D. denudans*, *D. transparens*. Cluster D was again divided into two clusters: cluster D1 with *D. longicornu*, *D. polyanthum* with AU *p*-value of 60% and BP *p*-value of 24% and cluster D2 with *D. porphyrochilum*, *D. denudans*, *D. transparens* with AU *p*-value of 68% and BP *p*-value of 24%. Cluster D2 was again divided into two clusters: cluster D2a with single species *D. porphyrochilum* (section *Stachyobium*) and cluster D2b with *D. denudans*, *D. transparens*.

Cluster B was further divided into two clusters: cluster E with AU *p*-value of 66% and BP *p*-value of 3% and cluster F with AU *p*-value of 69% and BP *p*-value of 1%. Cluster E was again divided into two clusters: cluster E1 with *D. moniliforme*, *D. eriiflorum*, *D. monticola* and cluster E2 with *D. bicameratum*, *D. amoenum*, *D. aphyllum*, *D. heterocarpum*. Cluster E1 was again divided into two clusters: cluster E1a with a single species *D. moniliforme* and cluster E1b with *D. eriiflorum*, *D. monticola*. Cluster E2 was again divided into two clusters: cluster E2a with a single species *D. bicameratum* and cluster E2b with *D. amoenum*, *D. aphyllum*, *D. heterocarpum*. Cluster E2b again divided into two clusters: cluster E2bi with *D. amoenum* and cluster E2bii with *D. aphyllum*, *D. heterocarpum*. Cluster F was divided into two clusters: cluster F1 with *D. rotundatum*, *D. amplum*, *D. fuscescens* with AU *p*-value of 98% and BP *p*-value of 64% with significant values and cluster F2 with *D. fugax*, *D. formosum*, *D. nobile*, *D. densiflorum*, *D. moschatum*, *D. chrysanthum*, *D. gibsonii*, *D. crepidatum*, *D. denneanum*, *D. fimbriatum* with AU *p*-value of 87% and BP *p*-value of 1%. Cluster F1 again divided into two clusters: cluster F1a with *D. rotundatum* and cluster F1b with *D. amplum* and *D. fuscescens*. Cluster F2 further divided into two clusters: cluster F2a with *D. fugax*, *D. formosum*, *D. nobile* with AU *p*-value of 94% and BP *p*-value of 35% with significant values and cluster F2b with *D. densiflorum*, *D. moschatum*, *D. chrysanthum*, *D. gibsonii*, *D. crepidatum*, *D. denneanum*, *D. fimbriatum* with AU *p*-value of 96% and BP *p*-value of 0% with significant values. Cluster F2a again divided into two clusters: cluster F2ai with *D. fugax* and cluster F2aii with *D. formosum*, *D. nobile* with AU *p*-value of 92% and BP *p*-value of 54% with significant values. Cluster F2b again divided into two

clusters: cluster F2bi with *D. densiflorum*, *D. moschatum* with AU *p*-value of 98% and BP *p*-value of 85% with significant values and cluster F2bii with *D. chrysanthum*, *D. gibsonii*, *D. crepidatum*, *D. denneanum*, *D. fimbriatum* with AU *p*-value of 81% and BP *p*-value of 0% with significant values. Cluster F2bii again divided into two clusters: cluster F2biii with *D. chrysanthum*, *D. gibsonii* with AU *p*-value of 94% and BP *p*-value of 77% with significant values and cluster F2biv with *D. crepidatum*, *D. denneanum*, *D. fimbriatum* with AU *p*-value of 83% and BP *p*-value of 8% with significant values. Cluster F2biv again divided into two clusters: cluster F2bv with *D. crepidatum* and cluster F2bvi with *D. denneanum*, *D. fimbriatum*.

4.4.4. Discussion

4.4.4.1. Gross morphological, micromorphological and anatomical analysis

The cluster analysis based on gross morphological, micromorphological and anatomical characters revealed two major significant clusters: cluster A formed by *D. formosum*, *D. moschatum*, *D. chrysanthum*, *D. fimbriatum*, *D. gibsonii*, *D. fugax*, *D. denneanum*, *D. densiflorum* with AU *p*-value of 97% and BP *p*-value of 11%; and cluster B formed by other remaining species with AU *p*-value of 96% and BP *p*-value of 3%.

In cluster A, the species had coriaceous leaves except in *D. chrysanthum* having membranous leaves, 5 to 7 dorsal sepal veins, dorsal sepal width less than 0.5 or more than 0.9 cm, elliptic to circular stomatal shape, less than 80 or more than 120 mm² stomatal frequency, no leaf hypodermis but adaxial hypodermis in *D. densiflorum*, homogenous mesophyll layers, no fibre bundle and major vascular bundle at leaf pole, less than 125 or more than 150 µm xylem fibre cap width, two to five stem hypodermal layers, stem vascular bundle width more than 130 µm, stem xylem fibre cap length absent or less than 45 µm.

In cluster B, the species had membranous, coriaceous, subleathery to fleshy leaves, 3 to 10 dorsal sepal veins, dorsal sepal width less than 0.5 to 0.9 cm, elliptic, circular to suborbicula stomatal shape, less than 80 to more than 120 mm² stomatal frequency, no leaf hypodermis but abaxial hypodermis in *D. anceps*, homogenous or heterogenous mesophyll layers, fibre bundle and major vascular bundle at leaf pole in *D. anceps*, xylem fibre cap width absent, less than 125 to more than 150 µm, absent or absent or one to three stem hypodermal layers, stem vascular bundle width less

than 100 to more than 130 μm , stem xylem fibre cap length absent, less than or more than 45 μm .

Cluster C of cluster A with *D. formosum* differed from cluster D with *D. moschatum*, *D. chrysanthum*, *D. fimbriatum*, *D. gibsonii*, *D. fugax*, *D. denneanum*, *D. densiflorum* in having hairy stem, terminal or lateral inflorescence, ovate floral bract, cuspidate petal apex, undulate lip margin, c-tetra-monocyclic stomata, adaxial epidermal cell length more than 40 μm , rectangular to polygonal stem epidermal cell. *D. formosum* though in Section *Formosae* was closely related to *D. moschatum* of Section *Dendrobium* as both species *D. formosum* and *D. moschatum* had distichous and coriaceous leaves, lip length of more than 2.5 cm, circular stomata, thin cuticle layer of leaf, two to three stem hypodermal layers.

In cluster D1 of cluster D with *D. moschatum*, *D. chrysanthum*, *D. fimbriatum*, *D. gibsonii* differed from cluster D2 with *D. fugax*, *D. denneanum*, *D. densiflorum* in having plant height more than 24 cm, leaves throughout stem, pendulous inflorescence, simple lip, a-tetra-monocyclic stomata, thin cuticle layer of leaf and no stegmata on stem vascular bundle. In cluster D1, cluster D1a formed by *D. moschatum* differed from cluster D1b with *D. chrysanthum*, *D. fimbriatum*, *D. gibsonii* in having obtuse floral bract apex, oblong dorsal sepal, ovate petal, cucullate and fimbriate lip margin, no ornamentation on disc, stomata length less than 33 μm , conical midrib vascular bundle, more than 70 numbers of stem vascular bundles. Cluster D1bi of cluster D1b with a single species *D. chrysanthum* differed from cluster D1bii with *D. fimbriatum* and *D. gibsonii*. in having membranous leaf, one veined floral bract, denticulate lip margin, ridges on disc, oval to polygonal stem hypodermal cell and elongate stem vascular bundle. In cluster D1bii, *D. fimbriatum* and *D. gibsonii* (Section *Dendrobium*) were nested together as they had similar characters like coriaceous and distichous leaves, pendulous inflorescence, acute floral bract apex, simple lip, fimbriate lip margin, a-tetra-monocyclic stomata, thin cuticle, homogenous mesophyll, oval midrib vascular bundle, 4 to 6 xylem fibre cap layers in midrib bundle, oval stem vascular bundle, no xylem fibre cap but they differed from each other by plant habit, inflorescence orientation, lip apex, stomata shape, leaf epidermal cell type and stem epidermal cell shape. Moudi and Go (2017) performed the cluster analysis based on morphological characters like plant size; pseudobulb; stem habit; leaf thickness and shape; number of leaves on shoot; inflorescence

position; number, size, colour and longevity of flower; lip type, apex, surface and ornaments. In their study, *D. fimbriatum*, *D. crepidatum*, *D. gibsonii*, *D. nobile*, *D. heterocarpum* (Section *Dendrobium*) were found in one cluster and Section *Aporum* in another cluster. In Section *Dendrobium* *D. nobile* and *D. gibsonii* were found nested together but in the present study *D. fimbriatum* and *D. gibsonii* were found nested together as the present study was based on gross morphological, micromorphological and anatomical characters.

Cluster D2a of cluster D2 with a single species *D. fugax* differed from cluster D2b with *D. denneanum* and *D. densiflorum* in having fusiform pseudobulb, presence of rhizome, one leaf per pseudobulb, trilobed lip, eupara-twi-monocyclic stomata, flask shaped midrib vascular bundle of leaf. *D. fugax* of section *Crinifera* was found closely related to *D. denneanum* of section *Dendrobium*. Though *D. fugax* came under section *Crinifera*, it was found close to *D. denneanum* along with *D. densiflorum* of section *Dendrobium*. This was because both species *D. fugax* and *D. denneanum* had coriaceous leaf, glabrous stem, circular stomata, thick cuticle layer of leaf, presence of fibre cap on midrib bundle of leaf and elongate stem vascular bundle. In previous classification, this species *D. fugax* came under *Flickingeria* but in update classification, *Flickingeria* was merged into *Dendrobium* s.l. based on the molecular data (Schuiteman & Adams, 2014). The inclusion of *Flickingeria* into *Dendrobium* s.l. was seemed correct as *D. fugax* showed close relationship with other species of *Dendrobium*. This cluster analysis result revealed that the analysis based on gross morphological, micromorphological and anatomical characters correlate with the result of molecular data. In cluster D2b, *D. denneanum* and *D. densiflorum* were nested together as they had erect stem, coriaceous leaves, pendulous inflorescence, simple lip, retuse lip apex, claw on lip, sclerenchymatous leaf epidermal cells, homogenous mesophyll, conical midrib vascular bundle, 4 to 5 stem hypodermal layers, no xylem fibre cap. *D. denneanum* differed from *D. densiflorum* in having leaves throughout stem, subterminal inflorescence, ovate shaped petal, fimbriate lip margin, circular stomata, absence of leaf hypodermal layer, barrel shaped stem epidermal cell and elongate stem vascular bundle.

Cluster E of cluster B with *D. anceps*, *D. bicameratum*, *D. crepidatum*, *D. aphyllum*, *D. nobile*, *D. polyanthum*, *D. amoenum*, *D. transparens*, *D. longicornu*, *D. heterocarpum*, *D. moniliforme* differed from cluster F with *D. amplum*, *D. fuscescens*,

D. rotundatum, *D. denudans*, *D. porphyrochilum*, *D. eriiflorum*, *D. monticola* in having leaves throughout stem, no pseudobulb, distichous leaves, parenchymatous leaf epidermal cell, fibre cap on midrib bundle, homogenous mesophyll layers, stem xylem fibre cap absent or less than 45 µm. In cluster E1 of cluster E, *D. anceps* (Section *Aporum*) was found close to *D. bicameratum* (Section *Dendrobium*) as they have distichous leaves, erect and glabrous stem, small flower, small and trilobed lip, elliptic stomata, thick cuticle layer, homogenous mesophyll layer, fibre cap on midrib bundle, barrel shaped stem epidermal cell. *D. anceps* differed from *D. bicameratum* in having eupara-twi-monocyclic+hexa-monocyclic stomata, one abaxial leaf hypodermis, water storage cells in mesophyll, circular midrib vascular bundle, fibre bundle, major vascular bundle at leaf pole, oval stem vascular bundle. This result did not support the findings of Moudi and Go (2017). In the present study, Section *Aporum* was found close to Section *Dendrobium* whereas in the cluster analysis of Moudi and Go (2017) Section *Aporum* and Section *Dendrobium* were found in different clusters.

Cluster E2a of cluster E2 with *D. crepidatum*, *D. aphyllum*, *D. nobile* differed from cluster E2b with *D. polyanthum*, *D. amoenum*, *D. transparens*, *D. longicornu*, *D. heterocarpum*, *D. moniliforme* in having oblong-lanceolate dorsal sepal, obtuse petal apex, simple lip, elliptic stomata, 8 to 10 homogenous mesophyll layers, oval stem vascular bundle. Cluster E2ai of cluster E2a with *D. crepidatum* differed from cluster E2aii with *D. aphyllum* and *D. nobile* in having plant height up to 14 cm, subleathery leaf, lip with undulate margin, ridges on disc, b-tetra-monocyclic stomata, conical midrib vascular bundle, 4 to 6 xylem fibre cap layers in leaf, oblong-polygonal stem hypodermal cell. In cluster E2aii, *D. aphyllum* was closely related to *D. nobile* as both species have distichous leaves, simple lip, elliptic stomata, parenchymatous leaf epidermal cell, thin cuticle layer of leaf, homogenous mesophyll layer, polygonal stem hypodermal cell, oval stem vascular bundle. Cluster E2bi of cluster E2b with *D. polyanthum*, *D. amoenum*, *D. transparens* differed from cluster E2bii with *D. longicornu*, *D. heterocarpum*, *D. moniliforme* in having membranous leaves, 5 lateral sepal veins, obtuse petal apex, b-tetra-monocyclic stomata, thin cuticle layer of leaf, stem epidermal cell less than 12 or more than 16 µm long. In cluster E2bi, cluster E2bia with a single species *D. polyanthum* differed from cluster E2bib with *D. amoenum* and *D. transparens* by lateral inflorescence, large flower, lip simple with

denticulate margin, large midrib vascular bundle, xylem fibre cap layers more than 6 in midrib bundle, one stem hypodermal layer. In cluster E2bib, *D. amoenum* and *D. transparens* nested together as they were similar in having membranous leaves, axillary inflorescence, acute floral bract apex, lanceolate lateral shape, trilobed lip, elliptic stomata, thin cuticle, homogenous mesophyll, 4 to 6 xylem fibre cap layers in leaf, 2 to 3 polygonal stem hypodermal cells, stigmata, *D. amoenum* differed from *D. transparens* in having epiphytic with lithophytic habit, pendulous stem, obtuse lip apex, sub-villous on disc of lip, 7 mesophyll homogenous layers, oval midrib vascular bundle, rectangular to polygonal stem epidermal cell. In cluster E2bii, cluster E2biia with *D. longicornu* differed from E2biib with *D. heterocarpum* and *D. moniliforme* in having hairy stem, ovate-lanceolate dorsal sepal, lip with obtuse apex, fimbriate margin and ridges on disc, elliptic stomata, absence of stigmata, circular midrib vascular bundle of leaf and stem vascular bundle number 68. Though in Section Formosae *D. longicornu* was found close related to *D. heterocarpum* along with *D. moniliforme* of section *Dendrobium* as they had epiphytic habit, distichous leaves, erect and axillary inflorescence, a-tetra-monocyclic stomata, stomatal index more than 10.0%, parenchymatous epidermal cell, no leaf hypodermis, homogenous mesophyll layers of leaf, two to three polygonal stem hypodermal layers and raphide bundles in stem. In cluster E2biib, *D. heterocarpum* differed from *D. moniliforme* in having coriaceous leaf, obtuse floral bract apex, simple lip with undulate margin, papillary hairs on disc, stigmata, thin cuticle, 7 homogenous mesophyll layers of leaf, rectangular to angular stem epidermal cells and oval vascular bundle of stem.

In cluster F, cluster F1 with *D. amplum*, *D. fuscescens* and *D. rotundatum* had pendulous stem, pseudobulb, rhizome, bifoliate large leaves at apex, no rachis, lip large with mucronate to emarginated apex, circular or suborbicular stomata, thick cuticle, sclerenchymatous epidermal cells and heterogenous mesophyll layers, flask shaped midrib vascular bundle, two to five polygonal stem hypodermal cells whereas cluster F2 with *D. denudans*, *D. porphyrochilum*, *D. eriiflorum* and *D. monticola* had erect stem, pseudobulb or not, no rhizome, distichous small leaves throughout stem or at apex, rachis, lip small with acute apex, elliptic stomata, thin cuticle, parenchymatous epidermal cells and homogenous mesophyll layers, oval or oblong midrib vascular bundle, no stem hypodermal layer. In cluster F1, cluster F1a with *D. amplum* differed from cluster F1b with *D. fuscescens* and *D. rotundatum* in having

epiphytic habit, ellipsoid pseudobulb, entire lip margin, b-tetra-monocyclic stomata, elongate stem vascular bundle. In cluster F1b, *D. fuscescens* and *D. rotundatum* nested together as they had pendulous stem, rhizome, bifoliate coriaceous leaves at apex of pseudobulb, trilobed lip, thick leaf cuticle, parenchymatous leaf epidermal cell, one hypodermal layer, heterogenous mesophyll layer, flask shaped midrib vascular bundle, oval stem vascular bundle. *D. fuscescens* differed from *D. rotundatum* in having epiphytic with lithophytic habit, cylindric-ovoid pseudobulb, circular a-tetra-monocyclic stomata, 7 heterogenous mesophyll spongy layers, no stem xylem fibre cap. In cluster F1, *D. amplum*, *D. fuscescens* and *D. rotundatum* (Section *Sarcopodium*) formed a distinct insignificant cluster with AU p-value of 89% and BP p-value of 75%. These three species were closely interrelated as they had glabrous and pendulous stem, pseudobulb, rhizome, bifoliate coriaceous leaves at apex of pseudobulb, axillary inflorescence, trilobed lip, thick cuticle of leaf, heterogenous mesophyll layers of leaf, fibre cap on vascular bundle of stem. These three species came under genus *Epigeneium* in previous classification but now it was merged into genus *Dendrobium* s.l. on the basis of molecular data (Schuiteman & Adams, 2014). The merging of genus *Epigeneium* into genus *Dendrobium* s.l. seemed to be correct as they formed a distinct cluster within genus *Dendrobium* s.l. This indicated that the present result of cluster analysis based on morphological, micromorphological and anatomical characters correlated with molecular data.

Cluster F2a of cluster F2 with *D. denudans* differed from cluster F2b with *D. porphyrochilum*, *D. eriiflorum* and *D. monticola* in having epiphytic habit, axillary inflorescence, linear-lanceolate dorsal sepal, serrate-crisped lip margin, 19.98 µm long adaxial epidermal cell and 16.65 µm long abaxial epidermal cell of leaf. In cluster F2b, cluster F2bi with *D. porphyrochilum* differed from cluster F2bii with *D. eriiflorum* and *D. monticola* in having epiphytic habit, cylindrical pseudobulb, simple lip with entire margin and subacute apex, oblong midrib vascular bundle of leaf, rectangular to polygonal epidermal cell and no fibre cap on stem vascular bundle. Cluster F2bii with *D. eriiflorum* and *D. monticola* formed a significant cluster with AU p-value of 97% and BP p-value of 76%. There were close interrelationships between *D. eriiflorum* and *D. monticola* as they had epiphytic with lithophytic habit, distichous leaves, simple lip with undulate margin and acute apex, elliptic stomata, thin cuticle, parenchymatous epidermal cell, no hypodermal layer, seven homogenous

mesophyll layers and oval midrib vascular bundle, rectangular stem epidermal cell and no stem hypodermal layer. *D. eriiflorum* differed from *D. monticola* in having c-tetra-monocyclic stomata, calcium oxalate crystals in leaf and oval stem vascular bundles. As *D. eriiflorum* and *D. monticola* were closely interrelated, with further research on these species, these two species may be merged into a single species.

4.4.4.2. Anatomical analysis

The cluster analysis based on anatomical with micromorphological characters revealed two main insignificant clusters: cluster A formed by *D. anceps*, *D. longicornu*, *D. polyanthum*, *D. denudans*, *D. transparens* with AU *p*-value of 45% and BP *p*-value of 19% and cluster B formed by remaining species with AU *p*-value of 49% and BP *p*-value of 18%.

In cluster A, the species had elliptic, a-tetra-monocyclic, b-tetra-monocyclic to eupara-twi-monocyclic+hexa-monocyclic stomata, parenchymatous leaf epidermal cells, abaxial leaf hypodermis, homogenous mesophyll, oblong to circular midrib vascular bundle, fibre bundle or not, fibre cap or not on midrib vascular bundle, major vascular bundle at leaf pole, 1 to 3 stem hypodermal layers.

In cluster B, the species had circular to suborbicular, a-tetra-monocyclic, b-tetra-monocyclic, c-tetra-monocyclic to eupara-twi-monocyclic typed stomata, parenchymatous or sclerenchymatous leaf epidermal cells, adaxial leaf hypodermis, homogenous and heterogenous mesophylls, oval, flask-shaped to conical midrib vascular bundle, no fibre bundle and major vascular bundle at leaf pole, fibre cap on midrib vascular bundle, 1 to 5 stem hypodermal layers.

In cluster A, a separate cluster C was formed by single species *D. anceps* (Section *Aporum*) as it is differed from cluster D by eupara-twi-monocyclic+hexa-monocyclic stomata, thick cuticle, one layered abaxial leaf hypodermis, major vascular bundle at leaf pole and fibre bundle. In cluster D1 of cluster D, *D. longicornu* (Section *Formosae*) was found close to *D. polyanthum* (Section *Dendrobium*) as they had elliptic stomata, parenchymatous leaf epidermal cell, thick cuticle, circular midrib vascular bundle, rectangular to polygonal stem epidermal cell, polygonal stem hypodermal cell and elongate stem vascular bundle. Cluster D2a of cluster D with *D. porphyrochilum* (Section *Stachyobium*) differed from cluster D2b with *D. denudans* (Section *Stachyobium*) and *D. transparens* (Section *Dendrobium*) in having a-tetra-monocyclic stomata, water storage cells in mesophyll, no fibre cap on midrib bundle

of leaf and stem vascular bundle. In cluster D2b, *D. denudans* was found close to *D. transparens* as both species had elliptic stomata, parenchymatous leaf epidermal cell, thin cuticle, no leaf hypodermis, homogenous mesophyll layers, stem vascular bundle numbers up to 60.

In cluster B, cluster E differed from cluster F in having elliptic or circular stomata, parenchymatous leaf epidermis, no leaf hypodermis, oval midrib vascular bundle, stem hypodermal layers absent or 1 to 3, no xylem fibre cap in stem. In cluster E1a of cluster E with *D. moniliforme* (Section *Dendrobium*) was found separated from cluster E1b in having circular shaped a-tetra-monocyclic stomata, thick cuticle, polygonal stem hypodermal layers. In cluster E1b, *D. eriiflorum* (Section *Stachyobium*) was found close to *D. monticola* (Section *Stachyobium*) because both species had elliptic stomata, parenchymatous leaf epidermal cell, thin cuticle, no leaf hypodermis, rectangular stem epidermal cell and no stem hypodermis. In cluster E2a, *D. bicameratum* (Section *Dendrobium*) differed from cluster E2b in having stomatal pore more than 28 μm , thick cuticle of leaf and elongate stem vascular bundle. In cluster E2bi, *D. amoenum* (Section *Dendrobium*) differed from cluster E2bii in having b-tetra-monocyclic stomata, rectangular to polygonal stem epidermal cell and larger xylem in stem vascular bundle. In E2bii, *D. aphyllum* (Section *Dendrobium*) was found close to *D. heterocarpum* (Section *Dendrobium*) as both species had a-tetra-monocyclic stomata, thin cuticle, parenchymatous leaf epidermal cell, stegmata, no leaf hypodermis, oval midrib vascular bundle, polygonal stem hypodermal cell, oval stem vascular bundle and raphide bundles in stem.

In cluster F, cluster F1 with *D. rotundatum*, *D. amplum* and *D. fuscescens* (Section *Sarcopodium*) form a significant cluster with AU *p*-value of 98% and BP *p*-value of 64% with significant values. *D. rotundatum* of cluster F1a differed from cluster F1b in having suborbicular c-tetra-monocyclic stomata, water storage cell and calcium oxalate crystals in mesophyll, no xylem fibre cap in stem vascular bundle and raphide bundles in stem. *D. amplum* and *D. fuscescens* of cluster F1b were placed closely as both species had thick cuticle, sclerenchymatous leaf epidermal cell, stegmata, no leaf hypodermis, heterogenous mesophyll layers, flask-shaped midrib vascular bundle, two to three polygonal stem hypodermal layers. As *D. amplum*, *D. fuscescens* and *D. rotundatum* were found closely related, with further researches on these species, may reveal the reshuffling of the species. *D. amplum*, *D. fuscescens* and *D. rotundatum*

(Section *Sarcopodium*) came under *Epigeneium* in previous classification but now it was merged into *Dendrobium* s.l. on the basis of molecular data (Schuiteman & Adams, 2014). The merging of *Epigeneium* into *Dendrobium* s.l. was seemed to be good as they formed a distinct significant cluster within *Dendrobium* s.l. This indicated that the present result of cluster analysis based on anatomical characters correlated with molecular data.

In cluster F2, *D. fugax* (Section *Crinifera*) of cluster F2ai differed from cluster F2aii in having eupara-twi-monocyclic stomata, thick cuticle, more than ten homogenous mesophyll layers, flask-shaped midrib vascular bundle, barrel-shaped stem epidermal cell and elongate stem vascular bundle. *D. fugax* of Section *Crinifera* came under *Flickingeria* in previous classification, but in update classification, *Flickingeria* was merged into *Dendrobium* s.l. based on the molecular data (Schuiteman & Adams, 2014). The inclusion of *Flickingeria* into *Dendrobium* s.l. was seemed correct as *D. fugax* showed close relationship with other species of *Dendrobium*. This cluster analysis result revealed that the analysis result based on anatomical characters with micromorphological characters correlate with molecular data.

In cluster F2aii, *D. formosum* (Section *Formosae*) was found close to *D. nobile* (Section *Dendrobium*) as both species had c-tetra-monocyclic stomata, eight to ten homogenous mesophyll layers, calcium oxalate crystals in mesophyll, oval midrib vascular bundle, rectangular to polygonal stem epidermal cell, two to three layers of polygonal stem hypodermis, oval stem vascular bundle. In cluster F2b, cluster F2bi formed a significant cluster with *D. densiflorum* and *D. moschatum* (Section *Dendrobium*) with AU *p*-value of 98% and BP *p*-value of 85% with significant values. *D. densiflorum* was found close to *D. moschatum* as both species had a-tetra-monocyclic stomata, more than ten homogenous mesophyll layers, conical midrib vascular bundle, oval stem vascular bundle and raphide bundles in stem. As *D. densiflorum* and *D. moschatum* were closely interrelated, these two species may be merged into a single species with further research. This result did not support the result of Ramesh *et al.* (2020). Ramesh *et al.* (2020) performed the cluster analysis of some *Dendrobium* species based on anatomical characters like size of adaxial epidermal cells in leaf, no. of subsidiary cells in stoma and no. of phloem cap layers in leaf. In their result, the dendrogram revealed two clusters: cluster I with *D. densiflorum*, *D. moschatum*, *D. anceps*, *D. bicameratum* and cluster II with *D. nobile*.

In cluster I, *D. moschatum* and *D. anceps* were nested together whereas in present study *D. moschatum* and *D. densiflorum* were nested together and *D. anceps* formed separate cluster. Differences in the result may be due to numbers of characters used in cluster analysis.

In cluster F2biii, *D. chrysanthum* (Section *Dendrobium*) was found close to *D. gibsonii* (Section *Dendrobium*) as both species had a-tetra-monocyclic stomata, thin cuticle, parenchymatous leaf epidermal cell, no leaf hypodermis, eight to ten homogenous mesophyll layers, oval midrib vascular bundle, two to three stem hypodermal layers, no xylem fibre cap in stem vascular bundle and raphide bundles in stem. Cluster F2bv of cluster F2biv with *D. crepidatum* (Section *Dendrobium*) differed from cluster F2bvi with *D. denneanum* and *D. fimbriatum* in having elliptic shaped b-tetra-monocyclic stomata, parenchymatous leaf epidermal cell, phloem fibre cap layers more than 5 in midrib bundle, rectangular to polygonal stem epidermal cell, one stem hypodermal layer. In cluster F2bvi, *D. denneanum* was found close to *D. fimbriatum* as both species had circular shaped a-tetra-monocyclic stomata, sclerenchymatous leaf epidermal cell, no leaf hypodermis, barrel-shaped stem epidermal cell, four to five layers of rectangular to polygonal stem hypodermis and no xylem fibre cap in stem vascular bundle.

CHAPTER 5.

5. CONCLUSION AND RECOMMENDATIONS

Subtribe Dendrobiinae is a significant group in subfamily Epidendroideae which has been regarded as the largest, most diverse and challenging subfamily to classify and interpret phylogenetically (Dressler 1981, Cameron *et al.* 1999). Subtribe Dendrobiinae has already been the focus of broad taxonomic and phylogenetic studies based on analysis (Brieger, 1981). *Dendrobium* Sw., the most prominent member of subtribe Dendrobiinae with approximately 1500 species worldwide, ranges from Sri Lanka throughout tropical Asia and Pacific region north towards Japan, east towards Tahiti and south to New Zealand while it is absent in Africa and the Americas (Schuiteman & Adams, 2014). Because of huge genus with large number of species and wide range of morphological variations corresponding to its wide area of distribution, *Dendrobium* is considered to present one of the most intricate taxonomic problems in family Orchidaceae. In the present study, out of 1500 species worldwide, only 29 species of *Dendrobium* viz. *D. amoenum*, *D. amplum*, *D. anceps*, *D. aphyllum*, *D. bicameratum*, *D. chrysanthum*, *D. chryseum*, *D. crepidatum*, *D. darjeelingense*, *D. denneanum*, *D. densiflorum*, *D. denudans*, *D. eriiflorum*, *D. fimbriatum*, *D. formosum*, *D. fugax*, *D. fuscescens*, *D. gibsonii*, *D. heterocarpum*, *D. longicornu*, *D. moniliforme*, *D. monticola*, *D. moschatum*, *D. nobile*, *D. plicatile*, *D. polyanthum*, *D. porphyrochilum*, *D. rotundatum* and *D. transparens* from Nepal Himalaya were studied. The taxonomic significance of gross morphological, micromorphological and anatomical characters was analyzed and interrelationships among the species of *Dendrobium* were evaluated.

1. Gross Morphological study

The *Dendrobium* was studied through literature reviews, field observations, examinations of living specimens and voucher specimens deposited at different herbaria like KATH, TUCH, K, BM, E, TI and P. The variations in gross morphological characters within species of *Dendrobium* were analyzed and their taxonomic significance was evaluated.

The morphological study of the species of *Dendrobium* revealed that the characters like height of plant, leaf texture, leaf phyllotaxy, inflorescence orientation, rachis,

flower size, lip type and nature of ornamentation on disc were taxonomically important for delimiting the different species of the genus.

2. Anatomical study

Anatomical studies of the different parts of the plant body such as leaves and stems or pseudobulbs were carried out on 26 species of *Dendrobium* out of 29 species. Remaining 3 species (*D. darjeelingense* Pradhan, *D. chryseum* Rolfe and *D. plicatile* Lindley) were excluded from anatomical study because these species could not be collected from field or other sources. The anatomical characters of leaves and stem were found taxonomically significant in understanding the affinity and interrelationships among the species of *Dendrobium*.

a. Transverse section of leaf

T.S. leaf of *Dendrobium* showed that the characters like cuticle layer, hypodermal layer, mesophyll layer, stigmata and water storage cells were found taxonomically significant in delimiting the species of *Dendrobium*. Among the species, *D. anceps* of section *Aporum* was mainly characterized by presence of fibre bundle and major vascular bundle at leaf pole and these characters were absent in remaining species. *D. amplum*, *D. fuscescens* and *D. rotundatum* of Section *Sarcopodium* were characterized by presence of heterogenous mesophyll and remaining species by homogenous mesophyll. *D. fugax* of Section *Crinifera* was characterized by thin cuticle, no leaf hypodermis and fibre caps on midrib vascular bundle. In Section *Formosae*, *D. formosum* and *D. longicornu* were characterized by thin cuticle, absence of leaf hypodermis, absence of stigmata and water storage cells in mesophyll. *D. denudans*, *D. eriiflorum*, *D. monticola* and *D. porphyrochilum* of Section *Stachyobium* were characterized by presence of thin cuticle, stigmata, absence of leaf hypodermis and water storage cell in mesophyll. The remaining 15 species were present in Section *Dendrobium*. In Section *Dendrobium*, *D. densiflorum* was characterized by thick cuticle, leaf hypodermis, absence of stigmata and water storage cells in mesophyll. *D. bicameratum*, *D. denneanum* and *D. moniliforme* were characterized by thick cuticle, absence of leaf hypodermis, water storage cells in mesophyll and presence of stigmata. In *D. aphyllum*, *D. moschatum* and *D. nobile*, there were presence of thin cuticle, stigmata, water storage cells in mesophyll and no leaf hypodermis. *D. polyanthum* was characterized by thin cuticle, water storage cells

in mesophyll, absence of leaf hypodermis and stigmata. Remaining species like *D. amoenum*, *D. chrysanthum*, *D. crepidatum*, *D. fimbriatum*, *D. gibsonii*, *D. heterocarpum* and *D. transparens* were characterized by thin cuticle, stigmata, absence of leaf hypodermis and water storage cells in mesophyll.

b. Transverse section of stem/pseudobulb

In *Dendrobium*, the transverse section of stem or pseudobulb showed that the characters like the epidermal cells, hypodermal layers, shape and size of vascular bundles, stigmata and water storage cells of stem were found taxonomically significant in delimiting the species of *Dendrobium*. The species of *Dendrobium* viz. *D. anceps*, *D. fugax*, *D. aphyllum*, *D. bicameratum*, *D. chrysanthum*, *D. denneanum*, *D. fimbriatum* and *D. moschatum* were characterized by presence of barrel-shaped epidermal cells and remaining species by presence of rectangular-shaped epidermal cells. In Section *Stachyobium*, *D. denudans*, *D. eriiflorum*, *D. monticola* and *D. porphyrochilum* were characterized by absence of hypodermal layers. In Section *Sarcopodium*, *D. amplum*, *D. fuscescens* and *D. rotundatum* were characterized by presence of rectangular epidermal cells, hypodermal layer and pleated water storage cells. *D. anceps* in Section *Aporum* was characterized by presence of hypodermal layers, oval vascular bundle, unpleated water storage cells and absence of stigmata. In Section *Crinifera*, *D. fugax* was characterized by presence of hypodermal layers, elongate vascular bundle, stigmata and pleated water storage cells. In Section *Formosae*, *D. formosum* and *D. longicornu* were characterized by presence of hypodermal layers, stigmata and pleated water storage cells. In section *Dendrobium*, *D. aphyllum*, *D. bicameratum*, *D. chrysanthum*, *D. denneanum*, *D. fimbriatum* and *D. moschatum* were characterized by presence of barrel-shaped epidermal cells and remaining species by rectangular-shaped epidermal cells. The species with barrel-shaped epidermal cells like *D. chrysanthum* and *D. denneanum* were characterized by elongate vascular bundle, pleated water storage cells and absence of stigmata. *D. fimbriatum* and *D. moschatum* were characterized by oval vascular bundle, unpleated water storage cells, absence of stigmata. *D. aphyllum* and *D. bicameratum*, they had stigmata and pleated water storage cells but *D. aphyllum* had oval vascular bundle and *D. bicameratum* had elongate vascular bundle. The species with rectangular epidermal cells viz. *D. crepidatum*, *D. gibsonii*, *D. heterocarpum* and *D. nobile* were characterized by oval vascular bundle and absence of stigmata but in *D. crepidatum*

and *D. nobile* there was absence of unpleated water storage cells and pleated water storage cells were present in *D. gibsonii* and *D. heterocarpum*. The species *D. amoenum* and *D. densiflorum* were characterized by presence of oval vascular bundle and stegmata but differences in that *D. amoenum* had pleated water storage cells and *D. densiflorum* had unpleated water storage cells. *D. moniliforme* and *D. transparens* were characterized by elongate vascular bundle and pleated water storage cells but they differed in that *D. moniliforme* had no stegmata and *D. transparens* had stegmata. *D. polyanthum* was characterized by elongate vascular bundle, stegmata and unpleated water storage cells.

3. Micromorphological study

Besides the gross morphological characters, the micromorphological characters like stomata and stegmata were examined and their taxonomic significance was evaluated.

a. Stomata

Leaf surface of 26 species out of 29 species of *Dendrobium* were examined. In the present study, three species were excluded due to unavailability of living specimens. The stomata showed wide variations in the type of epidermal cells, type and shape of stomata. The type of epidermal cells, type and shape of stomata were found to be taxonomically significant in delimiting the species of *Dendrobium*. Based on the type of epidermal cells, the species like *D. amplum*, *D. denneanum*, *D. densiflorum*, *D. fimbriatum*, *D. formosum*, *D. fugax*, *D. fuscescens* and *D. rotundatum* were characterized by sclerenchymatous epidermal cells and remaining species were characterized by parenchymatous epidermal cells. The type and shape of stomata were also found to be taxonomically significant in delimiting the species of *Dendrobium*. The species with sclerenchymatous epidermal cells like *D. densiflorum* was characterized by the presence of a-tetra-monocyclic with elliptic stomata; *D. denneanum*, *D. fuscescens* and *D. fimbriatum* by a-tetra-monocyclic with circular stomata; *D. amplum* by b-tetra-monocyclic with suborbicular stomata; *D. formosum* by c-tetra-monocyclic with circular stomata; *D. rotundatum* by c-tetra-monocyclic with suborbicular stomata and *D. fugax* by eupara twi-monocyclic with circular stomata. In species with parenchymatous epidermal cells, *D. aphyllum*, *D. bicameratum*, *D. denudans*, *D. gibsonii*, *D. longicornu*, *D. monticola* and *D. porphyrochilum* were characterized by a-tetra-monocyclic with elliptic stomata; *D.*

chrysanthum, *D. heterocarpum*, *D. moniliforme* and *D. moschatum* by a-tetra-monocyclic with circular stomata; *D. amoenum*, *D. crepidatum*, *D. polyanthum* and *D. transparens* by b-tetra-monocyclic with elliptic stomata; *D. eriiflorum* and *D. nobile* by c-tetra-monocyclic stomata with elliptic stomata and *D. anceps* by eupara twi-monocyclic+hexa monocyclic with elliptic stomata.

b. Stegmata

Stegmata on leaf surface of 26 species of *Dendrobium* was examined. In the present study, stegmata on leaf epidermal cells containing rough surfaced spherical silica bodies was found in *D. amoenum*, *D. amplum*, *D. aphyllum*, *D. chrysanthum*, *D. crepidatum*, *D. denneanum*, *D. fimbriatum*, *D. fuscescens*, *D. gibsonii*, *D. heterocarpum*, *D. moschatum*, *D. nobile*, *D. porphyrochilum* and *D. transparens*. Stegmata was found not distinct in *D. anceps*, *D. bicameratum*, *D. denudans*, *D. eriiflorum*, *D. fugax*, *D. moniliforme*, *D. monticola*, *D. rotundatum*. Stegmata was lacking in *D. densiflorum*, *D. formosum*, *D. longicornu*, *D. polyanthum*.

In conclusion, the study of stomatal complexes and stegmata on the leaf surface and anatomical studies of leaf and stem of *Dendrobium* of Nepal Himalaya were found to be taxonomically significant for the understanding of infraspecific relationships within species of *Dendrobium*.

4. Cluster analysis

4.1. Gross morphological, micromorphological and anatomical analysis

Based on the results of gross morphological, micromorphological and anatomical studies, the cluster analysis was carried out in species of *Dendrobium* to find out the interrelationships among the species of *Dendrobium*. Altogether 104 morphological, micromorphological and anatomical characters were considered for cluster analysis.

The cluster dendrogram based on data analysis of *Dendrobium* revealed two main clusters: a cluster with *D. formosum*, *D. moschatum*, *D. chrysanthum*, *D. fimbriatum*, *D. gibsonii*, *D. fugax*, *D. denneanum*, *D. densiflorum* and another cluster with remaining species. The other remaining species formed two distinct clusters: a cluster with *D. anceps*, *D. bicameratum*, *D. crepidatum*, *D. aphyllum*, *D. nobile*, *D. polyanthum*, *D. amoenum*, *D. transparens*, *D. longicornu*, *D. heterocarpum*, *D. moniliforme* and another cluster with *D. amplum*, *D. fuscescens*, *D. rotundatum*, *D. denudans*, *D. porphyrochilum*, *D. eriiflorum*, *D. monticloa*. The species like *D.*

eriiflorum and *D. monticola* formed an important significant cluster with AU *p*-value of 97% and BP *p*-value of 76% values. This cluster showed that *D. eriiflorum* and *D. monticola* were closely related. As *D. eriiflorum* and *D. monticola* were closely interrelated, with further research, these two species may be merged into a single species.

According to update classification (Schuiteman & Adams, 2014), Genus *Epigeneium* and genus *Flickingeria* were merged into genus *Dendrobium* s.l.. With the result of cluster analysis, it was seemed that the placing of *Epigeneium* and *Flickingeria* into *Dendrobium* was acceptable as the species of *Epigeneium* and *Flickingeria* were found closely related to species of *Dendrobium*. This result revealed that morphological, micromorphological and anatomical characters are correlated with the result of molecular data.

4.2. Anatomical analysis

Based on anatomical with micromorphological characters, the cluster analysis was carried out in species of *Dendrobium* to find out the interrelationships among the species of *Dendrobium*. Out of 104 characters, 60 anatomical characters with micromorphological characters were considered for cluster analysis.

The cluster dendrogram obtained from data analysis of *Dendrobium* revealed two main clusters: a cluster with *D. anceps*, *D. longicornu*, *D. polyanthum*, *D. porphyrochilum*, *D. denudans*, *D. transparens* and another cluster with remaining species. The species like *D. rotundatum*, *D. amplum*, *D. fuscescens* formed an important cluster with significant AU *p*-value of 98% and BP *p*-value of 64% values revealing their close relationships. With further research, these three species may be merged into one species. Similarly, *D. densiflorum* and *D. moschatum* were also found closely related with high significant AU *p*-value of 98% and BP *p*-value of 85% values.

The present study represents the first attempt to bring the cluster analysis of *Dendrobium* of Nepal Himalaya based on gross morphological, micromorphological and anatomical characters.

The cluster analysis based on gross morphological, micromorphological, anatomical characters and anatomical with micromorphological characters showed different

results. In comparison between two cluster dendrograms, the cluster dendrogram resulted from gross morphological, micromorphological and anatomical characters was seemed to be more appropriate as it showed clusters with high significant values than the cluster dendrogram resulted from anatomical characters. The cluster dendrogram obtained from gross morphological, micromorphological, anatomical characters revealed two main significant clusters: a cluster with AU p -value of 97% and BP p -value of 11% and another cluster with AU p -value of 96% and BP p -value of 3% whereas the cluster dendrogram obtained from anatomical characters revealed two main insignificant clusters: a cluster with AU p -value of 45% and BP p -value of 19% and another cluster with AU p -value of 49% and BP p -value of 18%. With this result, it can be concluded that the result of cluster analysis based on gross morphological, micromorphological and anatomical characters was found more appropriate than the result obtained from anatomical with micromorphological characters.

From the result of cluster analysis, it was quite evident that gross morphological characters along with micromorphological and anatomical characters rather than the anatomical characters could be used as additional parameters in solving taxonomic problems.

Family Orchidaceae comes under CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) Appendix II. Though Orchidaceae comes under CITES group many *Dendrobium* species with high ornamental and medicinal values are extracted day by day in large amount and export them to other countries. Many orchid species are becoming threatened due to fast urbanization and industrialization. There should be forwarding step for conserving the threatened and endangered species of orchids and to make people aware about the importance of orchids aesthetically as well as medicinally that can reduce over exploitation of species from the wild habitat. So there should be strict control measure for preventing illegal collection in large amount and export them to other countries.

The present taxonomic study of *Dendrobium* species was based on gross morphological, micromorphological and anatomical characters. A more detailed study of *Dendrobium* could not be carried out because of unavailability of modern equipment like Scanning Electron Microscope (SEM), Transmission Electron

Microscope and DNA sequences. Therefore further research utilizing these modern techniques is recommended. However the result obtained from the present study will provide the working hypothesis for further study. With further studies into the genus *Dendrobium* of Nepal Himalaya, a new classification as well as the phylogeny of the species of *Dendrobium* could be deduced. Therefore it is recommended that additional researches should be needed to fully resolve the relationships between several species of *Dendrobium* of Nepal Himalaya.

Limitation of the study:

Due to unavailability of the modern equipment like Scanning Electron Microscope (SEM), Transmission Electron Microscope (TEM) and DNA sequences, a detailed study of the species could not be carried out.

CHAPTER 6.

6. SUMMARY

Subtribe Dendrobiinae Lindl. belongs to tribe Malaxideae of family Orchidaceae (Chase *et al.*, 2015). Family Orchidaceae constitutes one of the largest, most diverse and distinctive families of flowering plants comprising ca. 29,199 species (Govaerts *et al.*, 2017). The family Orchidaceae is widely distributed in the tropical and subtropical regions of the world. Subtribe Dendrobiinae has already been the focus of broad taxonomic and phylogenetic studies based on analysis (Brieger, 1981). With update classification, subtribe Dendrobiinae comprises 2 genera *Dendrobium* with ca. 1500 species and *Bulbophyllum* with ca. 2000 species (Schuitman, 2017). The present study was confined to *Dendrobium* s.l. of subtribe Dendrobiinae of Nepal Himalaya and *Bulbophyllum* was excluded as it was not placed in subtribe Dendrobiinae in earlier classifications and due to unavailability of time.

Dendrobium is considered to present one of the most intricate taxonomic problems in family Orchidaceae because of huge genus with large number of species and wide range of morphological variations corresponding to its wide area of distribution. To solve the existing taxonomic problems, the morphological, micromorphological and anatomical study could be carried out on *Dendrobium*. Dressler (1993) pointed out that anatomical work on the Orchidaceae is needed as it has been rather spotty and may well be one of the best hopes for additional derived features. Although morphological and floristic studies of Orchidaceae have been carried out extensively, anatomical investigations on Orchids from Nepal have been inadequate so far. The present study dealt with morphological, micromorphological and anatomical study of genus *Dendrobium* of Nepal Himalaya.

Dendrobium with ca. 1500 species are distributed worldwide, ranging from Sri Lanka throughout tropical Asia Pacific region, reaching as far north as Japan, east to Tahiti and south to New Zealand while being absent in Africa and America (Schuiteman & Adams, 2014). Rajbhandari & Rai (2017) had reported 26 species of *Dendrobium* and 3 species of *Epigeneium* from Nepal Himalaya. But according to update classification, *Epigeneium* and *Flickingeria* were merged into *Dendrobium* s.l. (Schuiteman & Adams, 2014). So altogether 29 species of *Dendrobium* are present in Nepal Himalaya. *Dendrobium* species were categorized into 6 sections viz. section I. *Aporum* Blume, section II. *Crinifera* Pfitzer, section III. *Dendrobium*, section IV.

Formosae (Benth. & Hook.f.) Hook.f. section V. *Sarcopodium* Benth. & Hook.f. section VI. *Stachyobium* Lindl.

The main objectives of the study were to investigate the taxonomic significance of characters (gross morphological, anatomical and micromorphological) within the species of *Dendrobium* of Nepal Himalaya and to establish the interrelationships among the species of *Dendrobium* using cluster analysis.

The present study was based on collected live specimens and voucher specimens deposited at different herbaria. Morphological studies were carried out on live and voucher specimens whereas micromorphological and anatomical studies were carried out on collected live specimens. The specimens were identified by tallying with protologues, valid taxonomic literatures and type specimens deposited at different herbaria of the world. The protologue texts and literature used for authentic identification of each specimen were acquired from different sources. The type specimens were acquired from different online websites and through personal contacts.

The gross morphological characters like habit and height of plants; surface and shape of stems or pseudobulbs; position, texture, phyllotaxy, number and size of leaves; type and orientation of inflorescence; length of rachis; shape, apex, no. of veins and length of floral bracts; colour and size of flowers; length of pedicel with ovary; shape, size, apex and no. of veins of dorsal sepal, shape, size, apex and no. of veins of lateral sepals; shape, size, apex and no. of veins of petals; size, margin and apex of lip; nature of ornamentation on disc; shape and size of pollinia were studied. The morphological study of the species of *Dendrobium* revealed that the characters like height of plant, leaf texture, leaf phyllotaxy, inflorescence orientation, rachis, flower size, lip type and nature of ornamentation on disc were taxonomically important for delimiting the different species of the genus *Dendrobium*.

The anatomical study was carried out on vegetative parts, leaves and stems or pseudobulbs of 26 species of *Dendrobium*. Remaining 3 species were excluded from the study due to unavailability of species.

The anatomical variations in cuticle layer, hypodermal layer, mesophyll layer, stegmata and water storage cells of leaves were studied. The anatomical variations in epidermal cells, hypodermal layers, shape and size of vascular bundles, stegmata and water storage cells of stem were studied. The anatomical characters like cuticle layer,

hypodermal layer, mesophyll layer, stigmata, water storage cells in leaves and the epidermal cells, hypodermal layers, shape and size of vascular bundles, stigmata and water storage cells of stem or pseudobulb were found taxonomically significant in delimiting the species of *Dendrobium*.

The micromorphological characters like stomata and stigmata were studied on leaf surfaces of 26 species of *Dendrobium*. The micromorphological variations in the type of epidermal cells, type and shape of stomata and presence or absence of stigmata containing rough surfaced spherical silica bodies were studied. The micromorphological characters like type of epidermal cells like parenchymatous, sclerenchymatous and type and shape of stomata like a-tetra-monocyclic, b-tetra-monocyclic, c-tetra-monocyclic, eupara twi-monocyclic, hexa monocyclic type with elliptic, circular, suborbicular stomata and presence and absence of stigmata with rough-surfaced spherical silica bodies were found to be taxonomically significant for the understanding of infraspecific relationships within species of *Dendrobium*.

Cluster analysis based on the results of gross morphological, micromorphological and anatomical studies was carried out in 29 species of *Dendrobium* to distinguish the interrelationships among the species of *Dendrobium*. Altogether 104 morphological, micromorphological and anatomical characters were considered for cluster analysis.

Cluster analysis was also carried out in 26 species of *Dendrobium* based on anatomical characters with micromorphological characters to find out the interrelationships among the species.

The cluster dendrogram based on gross morphological, micromorphological and anatomical studies revealed two main clusters: cluster A with *D. formosum*, *D. moschatum*, *D. chrysanthum*, *D. fimbriatum*, *D. gibsonii*, *D. fugax*, *D. denneanum* and *D. densiflorum* and cluster B with the remaining species. The remaining species formed two distinct clusters: cluster E with *D. anceps*, *D. bicameratum*, *D. crepidatum*, *D. aphyllum*, *D. nobile*, *D. polyanthum*, *D. amoenum*, *D. transparens*, *D. longicornu*, *D. heterocarpum* and *D. moniliforme* and cluster F with *D. amplum*, *D. fuscescens*, *D. rotundatum*, *D. denudans*, *D. porphyrochilum*, *D. eriiflorum* and *D. monticola*. Cluster with *D. eriiflorum* and *D. monticola* formed an important significant cluster with AU *p*-value of 97% and BP *p*-value of 76% values. This cluster showed that *D. eriiflorum* and *D. monticola* were closely related. As *D. eriiflorum* and *D. monticola* were closely interrelated, with further research, these two

species may be merged into a single species. The significant clusters with high values were well supported by gross morphological characters along with micromorphological like stomata and stigmata and anatomical characters.

The cluster dendrogram of *Dendrobium* based on anatomical characters revealed two main significant clusters: cluster A with *D. anceps*, *D. longicornu*, *D. polyanthum*, *D. porphyrochilum*, *D. denudans*, *D. transparens* and cluster B with *D. moniliforme*, *D. eriiflorum*, *D. monticola*, *D. bicameratum*, *D. amoenum*, *D. aphyllum*, *D. heterocarpum*, *D. rotundatum*, *D. amplum*, *D. fuscescens*, *D. fugax*, *D. formosum*, *D. nobile*, *D. densiflorum*, *D. moschatum*, *D. chrysanthum*, *D. gibsonii*, *D. crepidatum*, *D. denneanum* and *D. fimbriatum*. Within them, two significant clusters; one with AU *p*-value of 98% and BP *p*-value of 74% was formed by *D. rotundatum*, *D. amplum* and *D. fuscescens* and another with AU *p*-value of 98% and BP *p*-value of 85% was formed by *D. densiflorum* and *D. moschatum*. The significant clusters with high values were characterized by the presence of anatomical characters of leaf and stem with micromorphological characters like stomata and stigmata.

The cluster analysis based on gross morphological, micromorphological, anatomical characters and anatomical characters with micromorphological characters showed different results. The cluster dendrogram resulted from gross morphological, micromorphological and anatomical characters revealed two main significant clusters: a cluster with AU *p*-value of 97% and BP *p*-value of 11% and another cluster AU *p*-value of 96% and BP *p*-value of 3% whereas the cluster dendrogram resulted from anatomical characters with micromorphological characters revealed two insignificant clusters: a cluster with AU *p*-value of 45% and BP *p*-value of 19% and another cluster with AU *p*-value of 49% and BP *p*-value of 18%. From the result of cluster analysis, it was quite evident that gross morphological characters along with micromorphological and anatomical characters with significant clusters rather than anatomical characters with insignificant clusters could be used as additional parameters in solving taxonomic problems.

With further research into the genus *Dendrobium*, a new classification as well as the phylogeny of the species of *Dendrobium* could be deduced.

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APPENDICES

APPENDIX I: GLOSSARY

Glossary of botanical terms used in Orchidaceae

Within the definitions, *italics* indicate terms that are defined in this glossary. Adapted from the glossary in Pridgeon, A. M. *et al.* (eds.). 1999—Genera Orchidacearum, 1—. Oxford & New York: Oxford University Press.

abaxial – Facing away from the stem, like the “under” surface of a leaf.

acuminate – Having long, sharp point.

adaxial – Developing next to the stem, as in axillary inflorescence or branch.

adventitious – applied to roots that do not rise from the radicle but from the stem, etc.;
also applied to embryolike structures in a seed that arise from outside the true embryo and often abort.

anatomy – In botanical parlance, microscopic structure of plants and study thereof.

ancipitous – Double-edged.

anther – Pollen-bearing organ of an angiosperm, located at the end of stamen.

anther cap – a lid formed from the dry outer wall of an anther.

aseptate – without a *septum*.

auricle – a small lobe or ear, applied to the *lip*; also a small lateral out- growth on the anther.

autotroph (adjective autotrophic) – a plant that produces its own nutrition by means of photosynthesis, containing chlorophyll and hence green.

axillary – Arising from the angle between the stem and branch of leaf.

basionym – Name given to a taxon when it was first described. In a taxonomic revision, it is recorded for each species that has undergone a name change. Used as official name for type species.

bract – a frequently leaflike organ (often very reduced or absent) subtending a flower, inflorescence, or partial inflorescence in its axil, sometimes brightly colored.

calceolate – slipper-shaped.

callus (plural calli) – a waxy, fleshy, or other protuberance, as on the *lip*.

caudicle – an extension of tissue derived from the anther and connecting the *pollinia* to the *stipe* or, in orchids without a stipe, directly to the *viscidium*.

caudiculate – with *caudicles*.

claw – the conspicuously narrowed base of an organ; in the orchids usually applied to the *lip*, but can also be applied to the *sepals* or *petals*.

clinandrium – the portion of the orchid *column* underneath the anther.

column – an organ of the orchid flower representing the fusion of filaments and style.

column foot – an extension at the base of the *column* in some orchids, to which the *lip* and sometimes the lateral *sepals* are attached.

column wings – distinct wings on the column of some orchids; these are not “column arms” or *stelia*.

conduplicate – folded together lengthwise with the adaxial surfaces facing each other (e.g., a leaf).

coriaceous – Leathery.

cortex – layer of tissue just inside the epidermis of stem and root.

cuticle – outer layer; skin.

dendrogram – Treelike branching chart of relationships among taxa.

disk – usually in orchids the area between the lateral lobes in the basal half of the *lip*, the place where the *callus* is usually placed, or sometimes the removable part of the *rostellum* projection.

dorsal sepal – referring to the apparently upper *sepal* of a flower; in the majority of orchids this is actually the lower sepal because the flowers are *resupinate*.

elaters – spiral thickenings or hairs which help to disperse spores or seeds, often by hygroscopic action.

emarginate – Notched at the end.

entire – unbroken, smooth.

epichile – terminal lobe of a *lip* that is differentiated into a *hypochile*, sometimes a *mesochile*, and an epichile.

epidermis – outer layer of cells on a plant organ.

epiphyte (adjective epiphytic) – a plant growing on another plant as its substrate, but not parasitic.

equitant – 2-ranked *conduplicate* leaves or bracts with overlapping, clasping bases.

erose – edge of flower that is not entire or fimbriate but has a margin that appears finally gnawed.

exine – outer wall of pollen grain, often intricately sculpted.

foliage leaf – an ordinary, fully developed, and functioning leaf.

filiform – threadlike.

guard cells – pair of cells enclosing a leaf stoma; their engorgement closes the stoma.

gullet – interior of a conical orchid flower, which the pollinator enters, as in most species of *Dendrobium*.

gynandrium, *gynostemium* – see *column*.

holotype – single specimen or illustration on which a taxon is based.

homoplasy – In cladistics, similarity due to evolutionary convergence, parallelism, or reversal, rather than genetic relationship.

hypochile – basal lobe of a *lip* that is differentiated into a hypochile, sometimes a *mesochile*, and an *epichile*.

isotype – a duplicate of the holotype.

labellum – see *lip*.

lanceolate – leaf shape: ovate with pointed tip.

lectotype – a type selected later if none was originally designated by the author of the taxon.

linear – leaf shape: with parallel edges, blunt ends.

lip – the median, modified petal of an orchid flower.

lithophyte (adjective lithophytic) – a plant that grows on rock as its substrate.

mentum – a spurlike or chinlike extension of the flower composed of the variably united *column foot*, *lip*, and lateral *sepals*.

mesochile – the middle lobe of a *lip* that is differentiated into a *hypo- chile*, sometimes a *mesochile*, and an *epichile*.

monophyletic – phylogenetic term denoting a group that includes all descendants of the same ancestors.

monopodial – having a shoot that grows indefinitely making adventitious roots.

mucronate – having a abrupt, sharp tip.

naked pollinia – *pollinia* of orchids that lack *caudicles* and other elements of the *pollinarium*.

neotype – a new type designated after the original type has been lost.

oblong – elliptical, but with parallel sides, not tapered.

operculum – see *anther cap*.

ovate – like an egg, more tapered at one end.

parenchyma – functional, in contrast to supportive.

petal – any of the whorl of flower parts generally just inside the *sepals*, usually colorful and showy.

phloem – the food conducting tissue of plants.

pollen – male reproductive grains found in anther.

pollinarium (plural pollinaria) – the functional unit of pollen transfer in orchid pollination, consisting of two or more *pollinia* (sometimes with *caudicles*), often a *stipe*, and a *viscidium*.

pollinium (plural pollinia) – a coherent mass of pollen grains.

pseudobulb – the variously thickened portion of an aerial orchid stem.

raceme – inflorescence with flowers on pedicels along a single stem.

rachis – elongated inflorescence axis.

resupinate – with the pedicel twisted so that the *lip* is always in the same position (usually at the bottom of the flower) regardless of the position of the inflorescence.

retuse – slightly notched at the apex.

rhizome – the indeterminate stem or system of stems of many plants, such as *sympodial* orchids, which successively give rise to new shoots and flowers, often horizontal or underground but sometimes appressed to branches or rocks.

rostellum – part of the median stigma lobe of orchid flowers.

sclerenchyma – tissue of cells with thickened walls having support function.

sepal – any of the outermost whorl of lower parts, often as colorful and showy as the *petals* in orchids.

spur – a saccate or tubular extension of the *lip* (or other floral parts) in many orchids, often containing nectar.

stelidium (plural stelidia) – a discrete arm or projection borne on each side of the *column*, near the apex, middle, or base, often slender and elongated; e.g., in *Bulbophyllum* and *Dendrochilum*; usually interpreted as staminodia (sterile anthers).

stigma – female portion of column, that receives pollinia.

stoma (plural: stomata) – pore in leaf, enabling gas exchange.

sympodium (plural sympodia, adjective sympodial) – a discontinuous main axis, where the stem is made up of a series of superposed branches, these imitating a single main axis: each new shoot developing from an axillary bud on the

previous shoot unit; stem, where growth is, continued not by the main stem but by lateral branches; prevalent in monocots.

syntype – designates specimens from the original collection when no holotype was chosen.

terete – pencil-like, with round cross section, usually referring to leaves.

viscarium – see *viscidium*.

viscidium (plural viscidia) – the sticky portion of the *rostellum*, which is often connected to *pollinia*.

xylem – tissue of vessels that carry water.

Plate 1. Type Specimens of *Dendrobium* species:

- A. *Dendrobium anceps* Swartz (Not on sheet, s.n., Holotype: S);
- B. *Dendrobium fugax* Rchb.f. (*Dendrobium roseopunctatum* Ridl., Ridley, s.n., Holotype: SING);
- C. *Dendrobium plicatile* Lindl. (Quisumbing, 84713, Isotype: AMES);
- D. *Dendrobium amoenum* Wall. ex Lindl. (*Dendrobium egertoniae* Lindl., s.coll., s.n., Syntype: K).

APPENDIX II: TYPE SPECIMENS

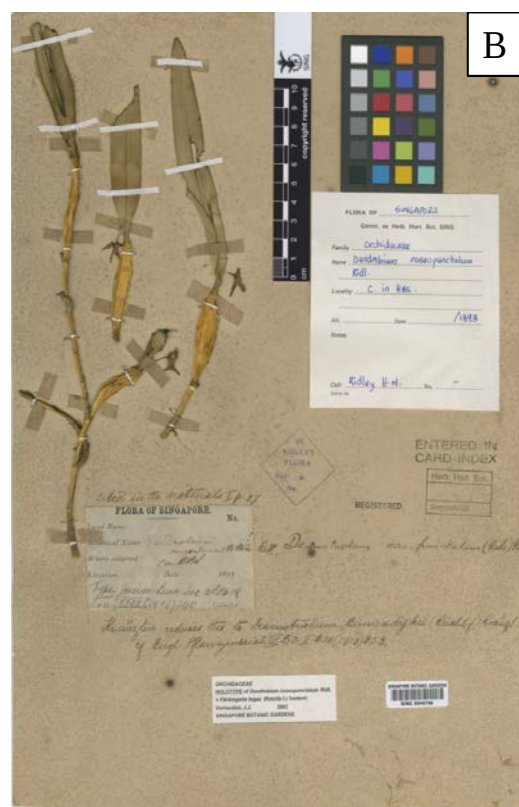
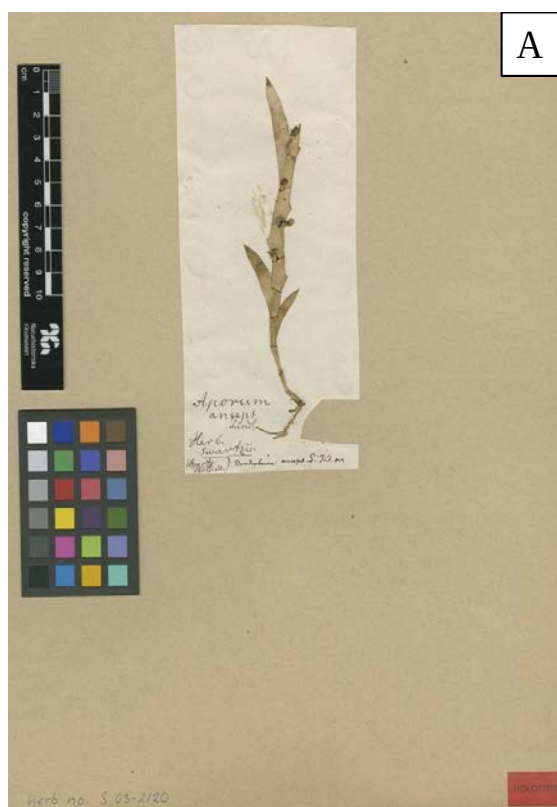


Plate 1. (Contd.)

- E. *Dendrobium aphyllum* (Roxb.) G.E.C. Fischer (*Dendrobium pierardi* Roxb., Wallich, 2007.3, Syntype: K);
- F. *Dendrobium bicameratum* Lindl. (*Dendrobium bolboflorum* Falc. ex Hook.f., Gamble, 10510, Syntype: K);
- G. *Dendrobium chrysanthum* Wall. ex Lindl. (Wallich, 2012, Syntype: K)
- H. *Dendrobium chryseum* Rolfe (s. coll. s.n., Syntype: K).



Plate 1. (Contd.)

- I. *Dendrobium crepidatum* Lindl. & Paxton (s.coll. s.n., Syntype: K);
- J. *Dendrobium denneanum* Kerr (*Dendrobium clavatum* Wall. ex Lindl., s. coll. 2004, Syntype: K);
- K. *Dendrobium densiflorum* Lindl. (Wallich 2000, Syntype: K);
- L. *Dendrobium fimbriatum* Hook. (Wallich 2011, Syntype: K).



Plate 1. (Contd.)

M. *Dendrobium gibsonii* Paxton (*Dendrobium fuscatum* Lindl., Hooker s.n., Isotype: P);

N. *Dendrobium heterocarpum* Wall. ex Lindl. (Macrae 68, Syntype: K);

O. *Dendrobium moniliforme* (Linn.) Swartz (Wilson 4621, Syntype: P);

P. *Dendrobium moschatum* (Buch.-Ham.) Swartz (*Epidendron moschatum* Buch.-Ham., Buchanan s.n., Syntype: BM).



Plate 1. (Contd.)

Q. *Dendrobium nobile* Lindl. (*Dendrobium lindleyanum* Griff., Hooker s.n., Syntype: M);

R. *Dendrobium polyanthum* Wall.ex Lindl. (Wallich 2009, Syntype: K);

S. *Dendrobium transparens* Wall.ex Lindl. (Wallich 2008 A, Isotype: E);

T. *Dendrobium formosum* Roxb. ex Lindl. (Wallich # s.n., Holotype: BM).



Plate 1. (Contd.)

U. *Dendrobium longicornu* Lindl. (Wallich 1997.1, Syntype: K);

V. *Dendrobium amplum* Lindl. (*Dendrobium angulatum* Lindl., Wallich 2001, Syntype: K);

W. *Dendrobium fuscescens* Griff. (Griffith 1123, Holotype: K);

X. *Dendrobium rotundatum* (Lindl.) Hook.f. (*Sarcopodium rotundatum* Lindl., Hooker s.n., Syntype: K).

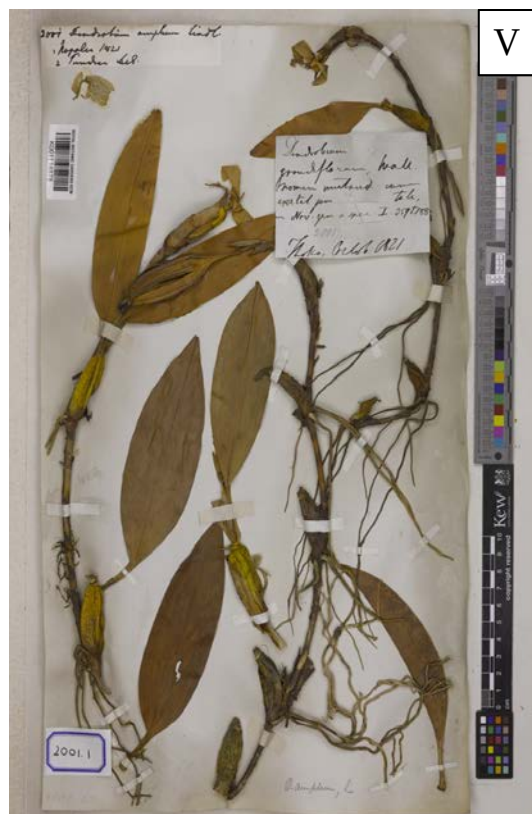


Plate 1. (Contd.)

Y. *Dendrobium denudans* D. Don (Wallich s.n., Isotype GH);

Z. *Dendrobium eriiflorum* Griff. (Griffith 131, Syntype: K);

I. *Dendrobium monticola* P.F. Hunt & Summerh. (*Dendrobium alpestre* Royle, Royle s.n., Syntype: K);

II. *Dendrobium porphyrochilum* Lindl. (Hooker, s.n., Isotype: P).



APPENDIX III: SPECIMENS EXAMINED

***Dendrobium anceps* Swartz**

Central Nepal: Makawanpur, Hetauda, 459 m, 10.6.2012, B. M. Pradhan 2026 (TUCH); Sindhuli, Kamalamai, 537 m, 24.4.2015, B. M. Pradhan 2047 (TUCH); Sindhuli, Dadiguranshe, 437 m, 24.4.2015, B. M. Pradhan 2050 (TUCH); Makawanpur, Churiyamai, 670 m, 10.5.2016, B. M. Pradhan 2057 (TUCH). **East Nepal:** Morang, Raja-Rani, 570 m, 4.6.1974, P. Pradhan, M. Amatya and R. Shrestha 29/74 (KATH); Morang, Raja-Rani, 570 m, 19.4.1979, P. Pradhan, R. Niraula and M. Gorkhali 783 (KATH); Ilam, 12.8.1963, H. Hara et al. 6307325 (TI); Ilam, 12.9.1963, H. Hara et al. 6307325 (TI); Ilam, Godak, 550 m, 16.4.1979, P. Pradhan, R. Niraula and M. Gorkhali 739 (KATH); Ilam, Godak-Rangapani, 579 m, 10.6.1978, P. Pradhan and R. Niraula 505 (KATH); Ilam, Garuwa, 200 m, 18.4.1979, P. Pradhan, R. Niraula and M. Gorkhali 781 (KATH); Ilam, Godak, 579 m, 18.6.2014, B. M. Pradhan 2032 (TUCH).

***Dendrobium fugax* Rchb.f.**

Central Nepal: Makwanpur, Makal Daman, 500 m, 15.5.1987, N. P. Manandhar and L. P. Kattel 11827 (KATH); Makawanpur, Churiyamai, 670 m, 10.5.2016, B. M. Pradhan 2058 (TUCH); Morang, Letang, 241 m, 15.4.2016, B. M. Pradhan 2053 (TUCH); 25.5.1971, J. D. A. Stainton 6903 (BM).

***Dendrobium plicatile* Lindl.**

East Nepal: Stainton 6903 (BM).

***Dendrobium amoenum* Wall. ex Lindl.**

Central Nepal: Myagdi, Dandagaur, 1760 m, 28.5.1992, N. P. Manandhar and S. K. Acharya 428-92 (KATH); Gorkha, Jagat, 1300 m, 25.5.1983, P. R. Shakya, M. K. Adhikari and M. N. Subedi 7626 and 7627 (KATH); Gorkha, Khorlak- Machhakhola, 840 m, 10.6.1983, P. R. Shakya, M. K. Adhikari and M. N. Subedi 7801 (KATH); Dhading, Near Hindung, 2000 m, 23.5.1973, P. R. Shakya and T. K. Bhattacharya 2278 (KATH); Rasuwa, 1840 m, 6.4.1985, M. Suzuki and S. Noshiro 8541078 (TI); Rasuwa, Thale, 2000 m, 2.6.1969, H. Kanai 623030 (KATH); Nuwakot above Kintang, 1700 m, 15.6.1983, P. R. Shakya, M.K. Adhikari and M. N. Subedi 7815 (KATH); Kathmandu, Temple Hill, 1676 m, 30.5.1965, A. D. Schilling and C. D. Sayers 325 (KATH); 1.6.1962, J.D.A. Stainton 3801 (BM); 18.5.1954, J. D. A.

Stainton, W. R. Sykes and L. H. J. Williams 542 (BM); E00783648 (E); Kaski, Kande, 1700 m, 28.5.2001, M. R. Shrestha 46 (TUCH); Kaski, Kaskikot, 1600 m, 5.5.2003, S. Subedi 7 (TUCH); Kaski, Lumle, 1600 m, 30 5. 2001, D. J. Chapagain, 18 (TUCH); Kaski, Sabune, 1600 m, 26.5.2005, L.J. Gurung 389 (TUCH); Palpa, Basenikhola, 1700 m, 5.9.2004, R. B. Mahata 794 (TUCH); Palpa, Shrinagar, 1300 m, 4.6.2003, B. Paudel 18 (TUCH); Palpa, Shrinagar, 1200 m, 4.6.2003, K. Sharma 28 (TUCH); Sindhupalchok, Thumpakhori, 24.5.2001, N. Phuyyal 22 (TUCH); Sindhupalchok, 1760 m, 24.5.2001, S. Shrestha sn (TUCH); Kathmandu and Bhaktapur, Sundarijal and Nagarkot, 28.3.1981, G. Amatya sn (TUCH); Bhaktapur, Suryabinayak, 1500 m, 2.4.2001, S. Mishra 25 (TUCH); Kathmandu, Chandragiri, 1800 m, 3.6.1982, Mahesh sn (TUCH); Kathmandu, Chandragiri, 1800 m, 11.4.1981, G. Poudyal sn (TUCH); Lalitpur, Phulchoki, 1500 m, 16.7.2001, S. Pant 88 (TUCH), Lalitpur, Phulchoki, 1500 m, 16.7.2001, B. Pant 88 (TUCH), Kavre, Champbhanjyang, 600 m, 1.6.2003, S. Maharjan 21 (TUCH). Makawanpur, Mahaveer, 1750 m, 9.6.2012, B. M. Pradhan 2022 (TUCH); Lalitpur, Bajrabarahi, 1450 m, 18.5.2013, B. M. Pradhan 2013 (TUCH); Sindhuli, Sindhuligadhi, 1424 m, 24.4.2015, B. M. Pradhan 2044 (TUCH); Sindhuli, Kamalamai, 537 m, 24.4.2015, B. M. Pradhan 2046 (TUCH); Sindhuli, Dadiguranshe, 437 m, 24.4.2015, B. M. Pradhan 2049 (TUCH); Kaski, Syaulibazar, 1390 m, 20.5.2016, B. M. Pradhan 2060 (TUCH); Kaski, Panchase, 2552 m, B. M. Pradhan 2063 (TUCH); **East Nepal** Sankhuwasabha, Hadanga, 1270 m, 6.7.1977, P. R. Shakya 4569 (KATH); Sankhuwasabha, Ikhuwakhola-Hadanga, 1010 m, 5.5.1977, P. R. Shakya 4564 (KATH); Dhankuta, 1840 m, 7.2.1988, M. Suzuki *et al.* 8850067(TI); Dhankuta, Dharapani, 1250 m, 2.6.1972, P. R. Shakya 1289 (KATH); Sunsari, Sanguribhanjyang, 1433 m, 4.10.1972, T. B. Shrestha and T. K. Bhattachan 72- 501 (KATH); Sunsari, Sanguribhanjyang, 1372 m, 21.5.1969, T. B. Shrestha 12383 (KATH); Sunsari, Sanguribhanjyang, 1311 m, 18.6.1978, P. Pradhan and R. Niraula 552 (KATH); Panchthar, Below Yaktin, 1280 m, 20.4.1977, P. R. Shakya 4100 (KATH), Ilam, Hanspokhari, 1666 m, 12.7. 1974, P. Pradhan, M. Amatya and R. Shrestha 262/74 (KATH); Ilam, Hanspokhari, 1666 m, 12.7. 1974, P. Pradhan, M. Amatya and R. Shrestha 265/74 (KATH); Ilam, Itabiigoan, Hanspokhari, 1219 m, 12.6.1974, P. Pradhan, M. Amatya and R. Shrestha 260/74 (KATH); Ilam, Bhalukhop, 1615 m, 9.6.1978, P. Pradhan and R. Niraula 488 (KATH); Ilam, Hanspokhari, 1589 m, 6.6.1978, P. Pradhan and R. Niraula 448 (KATH); Ilam, Garuwa, 200 m, 18.4.1979,

P. Pradhan, R. Niraula and M. Gorkhali 776 (KATH); Ilam, Sulubung, 1802 m, 17.6.2014, B. M. Pradhan 2041 (TUCH).

***Dendrobium aphyllum* (Roxb.) G. E. C. Fischer**

Central Nepal: Makawanpur, Simatkhola, 290 m, 19.4.1969, H. Kanai and M. S. Bista 1197 (KATH); Lalitpur, Tinpanibhanjyang, 2134 m, 3.5.1978, P. Pradhan & Party 415 (KATH); Kaski, Pame Forest, 1200 m, 12.6.2001, A. Amatya 30 (TUCH); Lamjung, Duradanda, 935 m, 17.5.2003, B. Adhikari 289 (TUCH); Lalitpur, Bajrabarahi, 1355 m, 13.4.2001, M. Ghimire 106 (TUCH); Makawanpur, Hetauda, 459 m, 10.6.2012, B. M. Pradhan 2027 (TUCH); 16.4.1956, J. D. A. Stainton 3801 (BM); 27.4.1973, C.R. Lancaster 12 (BM); E00783651 (E); Sindhuli, Sindhuligadhi, 1424 m, 24.4.2015, B. M. Pradhan 2045 (TUCH); Sindhuli, Dadiguranshe, 437 m, 24.4.2015, B. M. Pradhan 2051 (TUCH); Sindhuli, Kamalamai, 537 m, 24.4.2015, B. M. Pradhan 2048 (TUCH). **East Nepal:** Dolkha, Suryadobhan, 1050 m, 16.5.1979, N. P. Manandhar and M. K. Adhikari 1432 (KATH); Sankhuwasabha, 30.10.1963, H. Hara *et al.* s.n. (TI); Sankhuwasabha, Above Siswatar, 750 m, 8.6.1994, P. R. Shakya and K. K. Dangol 10016 (KATH); Sunsari, Sanguribhanjyang, 1372 m, 21.5.1969, T. B. Shrestha 12383 (KATH), Taplejung, 1380 m, 5.12.1992, M. Suzuki *et al.* 9240042 (TI); Taplejung, 11.24.1963, H. Hara *et al.* s.n. (TI); Panchthar, 11.28.1963, H. Hara *et al.* s.n. (TI); Panchthar, Angbung, 1220 m, 23.4.1977, P. R. Shakya 4133 (KATH); Ilam, 12.8.1963, H. Hara *et al.* 6307319 (TI); Ilam, 12.9.1963, H. Hara *et al.* 6307320 (TI); Ilam, Godak, 1000 m, 15.4.1979, P. Pradhan *et al.* 731 (KATH); Ilam, Godak, 550 m, 16.4.1979, P. Pradhan *et al.* 731 (KATH); Ilam, Chisapani, 488 m, 3.6.1981, S. Dahal *et al.* 198 (KATH); Ilam, Godak, 579 m, 18.6.2014, B. M. Pradhan 2033 (TUCH).

***Dendrobium bicameratum* Lindl.**

West Nepal: Dailekh, Bhaisakot, 1450 m, 27.7.1985, P. R. Shakya, M. N. Subedi and R. Uprety 8385 (KATH). **Central Nepal:** Lalitpur, Godavari, 2134 m, 25.7.1977, P. Pradhan and Party 9580 (KATH); Dolkha, 1700 m, 10.7.1985, N. Bhattarai, M. Shrestha, N. Pradhan and S. Shakya 13 (KATH); Kukhure dol, 2438 m, 6.8.1967, N. P. Manandhar and Party 7181 (KATH); Makawanpur, Tistung, 1900 m, 9.6.2012, B. M. Pradhan 2019 (TUCH).

***Dendrobium chrysanthum* Wall. ex Lindl.**

Central Nepal: 28.8.1954, J. D. A. Stainton, W. R. Sykes and L. H. J. Williams 6975 (BM); 18.22.1820, N. Wallich 2012 (K); Baglung, Malika, 1600 m, 27.9.1979, P. Sapkota 48 (TUCH); Kaski, Pame forest, 1214 m, 12.5.2001, A. Amatya 43 (TUCH).

East Nepal: Sunsari, Sanguribhanjyang, 1433 m, 4.10.1972, T. B. Shrestha and T. K. Bhattacharya 72-502 (KATH); Ilam, Hanspokhari, 1585 m, 1.10.1977, P. Pradhan, K. R. Rajbhandari and R. Niraula 636 (KATH); Ilam, Hanspokhari, 1585 m, 1.10.1977, P. Pradhan, K. R. Rajbhandari and R. Niraula 903 (KATH); Ilam, Hanspokhari, 1585 m, 28.8.1979, R. B. Thapa, S. Tamang and S. Major 908 (KATH); Ilam, Hanspokhari, 1596 m, 18.6.2014, B. M. Pradhan 2036 (TUCH).

***Dendrobium chryseum* Rolfe**

Central Nepal: 24.5.1954, J. D. A. Stainton, W. R. Sykes and L. H. J. Williams 609 (E).

***Dendrobium crepidatum* Lindl. & Paxton**

Central Nepal: Lalitpur, Phulchoki, 2134 m, 1.6.1979, R. Bahadur 803 (KATH); 8.4.1953, P. C. Gardner 196 (BM); Kaski, Raniban Forest, 950 m, 10.3.2001, A. Subedi 700 (TUCH); Kaski, Pame Forest, 1217 m, 12.5.2001, A. Amatya 50 (TUCH); Makawanpur, Churiyamai, 670 m, 10.5.2016, B. M. Pradhan 2056 (TUCH); Makawanpur, Daman, 2320 m, 28.4.2015, B. M. Pradhan 2070 (TUCH).

***Dendrobium denneanum* Kerr. J.**

Central Nepal: 1821, N. Wallich 2004 (K); 24.9.1954, J. D. A. Stainton, W. R. Sykes & L. H. J. Williams 609 (BM); Lalitpur, Phulchoki, 2135 m, 1.6.1979, R. Bahadur 803 (KATH).

***Dendrobium densiflorum* Lindl.**

Central Nepal: 1821, N. Wallich 2000 (K); 27.4.1968, J. D. A. Stainton 6249 (BM); 12.4.1953, P. C. Gardner 325 (BM); E00783659 (E); 1150 m, 12.5.1968, T. Kumata 7267 (TI); Lalitpur, Bajrabarahi, 1420 m, 13.4.2001, M. Ghimire 107 (TUCH); Lalitpur, Bajrabarahi, 1450 m, 18.5.2013, B. M. Pradhan 2031 (TUCH). **East Nepal:** Dolkha, Chhetchhet to Lamabagar, 1800 m, 15.7.1977, K. R. Rajbhandari and B. Roy 1390 (KATH); Sankhuwasabha, Mewa Khola, 1700 m, 23.5.1977, P. R. Shakya 4396 (KATH); Ilam, Godak, 1000 m, 15.4.1979, P. Pradhan, R. Niraula and M. Gorkhali

714 (KATH); Ilam, Godak, 1067 m, 3.10.1977, P. Pradhan, K. R. Rajbhandari and R. Niraula 410 (KATH).

***Dendrobium fimbriatum* Hook.**

West Nepal: Pyuthan, Swargdwari, 2100 m, 6.5.2016, B. M. Pradhan 2054 (TUCH).

Central Nepal: 1821, N. Wallich 2011 (K); 14.5. 1964, David J. McCosh 67 (BM); 27.4.1973, C. R. Lancaster 11 (BM); Gorkha, Yaru-Jagat, 1300 m, 25.5.1983, P. R. Shaky, M. K. Adhikari and M. N. Subedi 7622 (KATH); Makwanpur, Makwanpur, 1000 m, 25.4.1978, R. Bahadur 408 (KATH); Lalitpur, Tinpani-bhanjyang, 2134 m, 19.11.1977, R. Bahadur 445 (KATH); Lalitpur, Tinpani-bhanjyang, 1981 m, 2.5.1978, P. Pradhan and Party 802 (KATH); Makawanpur, Hetauda, 459 m, 10.6.2012, B. M. Pradhan 2028 (TUCH); Makawanpur, Lamidanda, 2316 m, 10.5.2016, B. M. Pradhan 2059 (TUCH); **East Nepal:** Morang, Raja-Rani, 570 m, 19.4.1979, P. Pradhan, R. Niraula and M. Gorkhali 782 (KATH); Ilam, Rangapani, 500 m, 16.4.1979, P. Pradhan, R. Niraula and M. Gorkhali 742 (KATH); Morang, Letang, 241 m, 15.4.2016, B. M. Pradhan 2052 (TUCH).

***Dendrobium gibsonii* Paxton**

Central Nepal: 19.8.1956, J. D. A. Stainton 1379 (BM); Kaski, Panchase, 2552 m, 3.9.2016, B. M. Pradhan 2065 (TUCH).

***Dendrobium heterocarpum* Wall. ex Lindl.**

Central Nepal: 26.4.1967, G. Murata 10073 (BM); Lalitpur, Phulchoki, 2134 m, 28.3.1979, P. Party 690 (KATH); Lalitpur, Tinpane-bhanjyang, 1981 m, 2.5.1978, P. Pradhan and Party 417 (KATH); Lalitpur, Tinpane-bhanjyang, 2134 m, 12.4.1978, P. Pradhan and Party 399 (KATH); Arghakhanchi, Narapani, 1490 m, 26.4.2000, M. P. Panthi 396 (TUCH); Lamjung, Sindure-5, Thulodanda, Turling, 1450 m, 25.2.2008, B. Adhikari 263 (TUCH); Kathmandu, Daksinkali, 1500 m, 3.2.2002, A. Amatya 33 (TUCH); Kathmandu and Bhaktapur, Sundarijal and Nagarkot, 28.3 1981. G. Amatya sn (TUCH); Lalitpur, Bajrabahari, 1290 m, 13.4.2001, M. Ghimire 108 (TUCH); Chandragiri, Chitlang, Hattiban, Pharping, Bajrabahari, Godavari and Suryabinayak, 24.3.2003, G. Paudyal sn (TUCH); Bhaktapur, Suryabinayak, 1401 m, 2.5.2011, B. M. Pradhan 2017 (TUCH). **East Nepal:** Taplejung, Num Jungle, 1600 m, 30.7.1977. S. K. Dhungana 182 (KATH); Dhankuta, Chitray, 2200 m, 16.8.1972, J. F. Dobremez 1490 (KATH); Panchthar, Sudap, 1800 m, 1.5.1977, P. R. Shaky 4185

(KATH); Panchthar, Near Phidim, 1450 m, 18.11.1978, P. Pradhan, N. P. Manandhar and N. Amatya 685 (KATH).

***Dendrobium moniliforme* (Linnaeus) Swartz**

Central Nepal: N. Wallich s.n. K000718410 (K); 22.1954, J. D. A. Stainton, W. R. Sykes and L. H. J. Williams 4975 (BM); Lalitpur, Tinpani-bhanjyang, 2134 m, 2.5.1978, P. Pradhan & Party 416 (KATH); Lalitpur, Lele-bhanjyang, 1600 m, 25.4.1969, H. Kanai, 11892 (KATH); Dolkha, Nigale, 2360 m, 14.5.1979, N. P. Manandhar & M. K. Adhikari, 1362 (KATH); Kaski, Pame forest, 1202 m, 10.7.2001, A. Amatya, 37 (TUCH); Makawanpur, Tistung, 1900 m, 9.6.2012, B. M. Pradhan 2018 (TUCH); Makawanpur, Daman, 2320 m, 12.4.2017, B. M. Pradhan 2069 (TUCH); **East Nepal:** Taplejung, 13.11.1963, H. Kanai *et al.* s.n. (TI); Panchthar, 27.11.1963, H. Hara *et al.* 6305482 (TI); Dhankuta, Chitray, 2256 m, 11.5.1978, N. Shrestha & M. K. C., 433 (KATH).

***Dendrobium moschatum* (Buch.-Ham.) Swartz**

Central Nepal: N. Wallich s.n. BM000505463 (BM); 23.6.1954, J. D. A. Stainton, W. R. Sykes and L. H. J. Williams 5884 (BM); E00783666 (E); Makawanpur, Chitwan, 200 m, 21.6.1987, R. Uprety sn (KATH); Makawanpur, Hetauda, 200 m, 20.6.1985, D. P. Joshi 11 (KATH); Kathmandu, Amrit Campus, 1400 m, 15.1.2012, B. M. Pradhan 2015 (TUCH); Makawanpur, Shahid Smarak Park, 600 m, 10.6.2012, B. M. Pradhan 2025 (TUCH); Makawanpur, Hetauda, 459 m, 10.6.2012, B. M. Pradhan 2029 (TUCH). **East Nepal:** Ilam, Rangapani, 579 m, 10.10.1977, P. Pradhan, K. R. Rajbhandari and R. Niraula 650 (KATH); Ilam, Godak, 579 m, 18.6.2014, B. M. Pradhan 2034 (TUCH); Ilam, Hanspokhari, 1596 m, 18.6.2014, B. M. Pradhan 2035 (TUCH); Ilam, Chulachuli, 169 m, 18.6.2014, B. M. Pradhan 2037 (TUCH).

***Dendrobium nobile* Lindl.**

Central Nepal: Myagdi, Himkhola, 1341 m, 10.4.1967, S. B. Malla 7715 (KATH); Gorkha, 3330 m, 16.4.2003, T. Watanabe and K. J. Malla s.n. (TI); Dhading, Kattike, 1150 m, 4.6.2003, S. Maharjan 46 (TUCH); **East Nepal:** Ilam, Godak, 1097 m, 3.10.1979, P. Pradhan, K. R. Rajbhandari and R. Niraula 409 (KATH); Ilam, Godak, 1000 m, 15.4.1979, P. Pradhan, R. Niraula and M. Gorkhali 715 (KATH); Jhapa, 807 m, 10.4.2001, A. Amatya 85 (TUCH); Ilam, Deurali, 1026 m, 20.4.2016, B. M. Pradhan 2068 (TUCH).

***Dendrobium polyanthum* Wall. ex Lindl.**

West Nepal: Doti, Mahapani, 1400 m, 15.4.1973, J. F. Dobremez sn (KATH).

Central Nepal: 12.4.1953, P. C. Gardner 289 (BM); 18.4.1973, J. F. Dobremez 1878 (E); Makwanpur, Churia Hill, 671 m, 15.3.1989, K. J. White 2 (KATH); Makawanpur, Churiyamai, 670 m, 10.5.2016, B. M. Pradhan 2055 (TUCH).

***Dendrobium transparens* Wall. ex Lindl.**

Central Nepal: N. Wallich 2008, K000894335 (K); N. Wallich, 2008 A (E); 6.5.1954, J. D. A. Stainton, W. R. Sykes and L. H. J. Williams 5253 (BM); 15.6.1957, K. R. Fell 44 (BM); 800 m, 17.5.1968, T. Kumata 7284 (TI); Kaski, Pame forest, 1209 m, 12.5.2001, A. Amatya 91 (TUCH); Lamjung, Durodanda, Simlagaon, 1060 m, 17.5.2003, B. Adhikari 277 (TUCH); Dhading, Champbhanjyang, 600 m, S. Adhikari 1.6.2003, 25 (TUCH); Sundarijal and Nagarkot, 28.3.1981, G. Amatya sn (TUCH); Chitlang, Suryabinayak, Bajrabarahi and Godavari, 18.6.1981, G. Paudyal sn (TUCH); 800m, 5.17.1968, T. Kumata 7284 (TI); Dolkha, Dolkha town, 723 m, 7.5.2008, S. Dahal 20076 (KATH); Kathmandu, Amrit Campus, 1400 m, 15.1.2012, B. M. Pradhan 2016 (TUCH); Makawanpur, Mahaveer, 2320 m, 9.6.2012, B. M. Pradhan 2021 (TUCH).

***Dendrobium formosum* Roxb. ex Lindl.**

Central Nepal: 1821, N. Wallich 1998 (K); 22.6.1971, J. D. A. Stainton 6882 (BM); 9.6.1976, R. G. Troth 880 (BM); Dhading, Kattike, 1150 m, 4.6.2003, S. Maharjan 47 (TUCH); Dhading, Kattike, 1480 m, 4.6.2003, S. Adhikari 51 (TUCH); Makawanpur, Hetauda, 600 m, 10.6.2012, B. M. Pradhan 2024 (TUCH). **East Nepal:** Ilam, Godak, 579 m, 10.6.1978, P. Pradhan and R. Niraula 503 (KATH); Jhapa, Soktim, 660 m, 10.6.1974, P. Pradhan, M. Amatya and R. Shrestha 215/74 (KATH).

***Dendrobium longicornu* Lindl.**

West Nepal: Dailekh, Dasera, 1740 m, 1.3.1991, N. P. Manandhar 58391 (KATH);

Central Nepal: 1821, N. Wallich 1997 (K); 19.9.1954, J. D. A. Stainton, W. R. Sykes and L. H. J. Williams 8988 (BM); 26.10.1967, Anon 7495 (BM); Makwanpur, Chitlang Danda, 2300 m, 10.1.1975, D. P. Joshi, K. R. Rajbhandari and M. K. Ghimire 75/219 (KATH); Makwanpur, Kaitar, 1730 m, 11.11.1989, N. P. Manandhar 13314 (KATH); Sindhupalchok, on the way to Lisanku, 2134 m, 8.10.1960, S. B. Rajbhandari and S. B. Malla 356 (KATH); Kathmandu, Sanomati Danda, Manichur,

2500 m, 13.3.1975, D. P. Joshi and K. R. Rajbhandari 75/544 (KATH); Kathmandu, 16.12.1969, H. Kanai 674488 (TI); 1200 m, 7.9.1977, H. Ohashi *et al.* s.n. (TI); Kathmandu, Manichur, 2000 m, 27.10.1986, N. K. Bhattarai 86/1230 (KATH); Kathmandu, Budhanilkantha, 5.3.1973, M. Amatya and T. K. Bhattacharya 13914 (KATH); Lalitpur, 2130 m, 3.10.1995, M. Mikage *et al.* 9552661 (TI); Lalitpur, Phulchoki, 2438 m, 26.10.1967, K. R. Manandhar and Party 7890 (KATH); Lalitpur, Phulchoki, 2438 m, 26.10.1967, K. R. Manandhar and Party 7496 (KATH); Lalitpur, Phulchoki, 2134 m, 7.11.1977, P. Pradhan and Party 375 (KATH); Lalitpur, Phulchoki, 2134 m, 28.9.?, B.F. C. Sinnott 71686 (KATH); Lalitpur, Phulchoki, 2134 m, 3.10.1970, R. Bahadur and R. Krishan 17887 (KATH); Lalitpur, Phulchoki, 1981 m, C. T. Maharjan and B.F.C. Sinnott 71287 (KATH); Lalitpur, Phulchoki, 1600 m, 12.11.1966, D.J. Nicolson 786 (KATH); Lalitpur, Godavari, 1530 m, 25.9.1975, S. Bhattarai, M. Gorkhali and H. Sainju 269 (KATH); Arghakhanchi, Maseena, Narapani, 2013 m, 9.11.2001, M. P. Panthi 352 (TUCH); Kaski, Sardikhola, 1219 m, 14.6.2002, K. P. Acharya K.11 (TUCH); Kaski, Pame Forest, 1207 m, 10.5.2001, A. Amatya 90 (TUCH); Gorkha, Pandrung, Tarang, 1300 m, 3.6.2005, B. Devkota 114 (TUCH); Kathmandu, Chandragiri, 2400 m, 10.2.2002, J. Sthapit, R. Rajbhandari and N. Manandhar 90 (TUCH); Bhaktapur, Dhulikhel, 1600 m, 19.11.1982, R. Shrestha 244 (TUCH); Bhaktapur, Nagarkot, ?, 1.10.1994, S. Swar 2 (TUCH); Lalitpur, Phulchoki, 1650 m, 28.10.1997, P. K. Lamsal 38 (TUCH); Lalitpur, Godawari, 1525 m, 12.12.2011, B. M. Pradhan 2011 (TUCH); Lalitpur, Phulchoki, 2760 m, 26.12.2011, B. M. Pradhan 2012 (TUCH); Kathmandu, Amrit Campus, 1400 m, 15.1.2012, B. M. Pradhan 2013 (TUCH); Makawanpur, Daman, 2320 m, 7.1.2012, B. M. Pradhan 2020 (TUCH); Kaski, Panchase, 2552 m, 3.9.2016, B. M. Pradhan 2065 (TUCH). **East Nepal:** Panchthar, 27.11.1963, H. Kanai *et al.* 6307314 (TI); Panchthar, 26.11.1963, H. Kanai *et al.* 6307315 (TI); Sankhuwasabha, 30.10.1963, H. Hara *et al.* 6307316 (TI); Sankhuwasabha, 29.10.1963, H. Hara *et al.* s.n. (TI); Sankhuwasabha, Khandbari, 2438 m, 26.9.1956, J.D.A. Stainton 1768 (KATH); Dhankuta, 2200 m, 25.10.1963, H. Hara *et al.* s.n. (TI); Dhankuta, Chitray, 2316 m, 11.9.1977, P. Pradhan and N. Shrestha 77 (KATH); Ilam, Maipokhari, 2123 m, 16.6.2014, B. M. Pradhan 2038 (TUCH).

***Dendrobium amplum* Lindl.**

Central Nepal: 1821, N. Wallich 2001 (K); 10.1.1992, J. Renz (S); Parbat, Tikhedhunga-Hile, 1300 m, 11.9.1979, R. Niraula and N. Pradhan 9/1979 (KATH).

East Nepal: Ilam, Hanspokhari, 1585 m, 1.10.1977, P. Pradhan, K. R. Rajbhandari and R. Niraula 654 (KATH!); Ilam, Hanspokhari, 1585 m, 1.10.1977, P. Pradhan, K. R. Rajbhandari and R. Niraula 192 (KATH); Ilam, Maipokhari, 2123 m, 16.6.2014, B. M. Pradhan 2039 (TUCH).

***Dendrobium fuscescens* Griff.**

East Nepal: Ilam, Alubari, 1777 m, 12.4.1967, S. B. Malla. 7731 (KATH); Ilam, Alubari, 1750 m, 12.4.1967, D. H. Nicolson 3245 (KATH); Ilam, Maipokhari, 1890 m, 10.10.1977, P. Pradhan, K. R. Rajbhandari and R. Niraula 72 (KATH); Sankhuwasawa, Deurali, 2020 m, 9.2.2009, G. D. Bhatt and A. P. Bhattarai 1 (KATH).

***Dendrobium rotundatum* (Lindl.) Hook.f.**

Central Nepal: 12.4.1967, D. H. Nicolson 3245 (BM); **East Nepal:** Ilam, Maipokhari, 2123 m, 16.6.2014, B. M. Pradhan 2040 (KATH).

***Dendrobium darjeelingense* Pradhan**

Central Nepal: Makwanpur, Lamidanda, 2316 m, 3.1992, K. J. White 25 (KATH).

***Dendrobium denudans* D. Don**

Specimens Examined: Central Nepal: 1821, N. Wallich 2014 (K); 1821, N. Wallich 2014 (GH); 1821, N. Wallich 2014 (BM); 16.10.1952, O. Polunin, W. R. Sykes and L. H. J. Williams 5757 (BM); 17.8.1974, J. H. de Haas 2801 (BM); 22.9.1956, J. D. A. Stainton 1765 (BM); E00783655 (E); Lalitpur, Bajrabarahi, 1400 m, 10.10.1996, S. Desai 30 (KATH); Makawanpur, Lamidada, Below Churia, 1000 m, KJ White 25 (KATH); Manang, Tal, 2000 m, 12.11.2001, Subedi, Chaudhary and Shakya. 781 (TUCH); Lalitpur, Bajrabarahi, 1450 m, 15.10.2014, B. M. Pradhan 2043 (TUCH).

***Dendrobium eriiflorum* Griff.**

West Nepal: Achham, Silinge to Khaptad, 1490-1880 m, 19.9.1981, I. Sharma, R. Joshi, R. Uprety and I. Pandey 571 (KATH); Rolpa, Liwang, 1280 m, 3.9.1982, N. P. Manandhar and N. K. Bhattarai 8769 (KATH); Baitadi, Rim, 1950 m, 9.10.2000, N. N. Bhatta 2 (TUCH). **Central Nepal:** Mustang, 1910 m, 28.8.1988, M Suzuki *et al.*

8860760(TI); Mustang, 2000 m, 28.8.1988, M. Suzuki *et al.* 8881534 (TI); Mustang, 1700 m, 3.9.1988, M. Suzuki *et al.* 8881729 (TI); Manang, Thonge-tal, 2200 m, 7.8.1979, P. R. Shakya, S. R. Adhikari and K. R. Amatya 5306 (KATH); Manang, Dharapani, 1850 m, 7.8.1983, K. R. Rajbhandari 9054 (KATH); Manang, Neor-tal, 1700 m, 20.9.1995, B. K. Basnet 19 (KATH); Manang, Dharapani, 1950 m, 19.8.1974, D. P. Joshi and T. K. Bhattacharya 2521/74 (KATH); Gorkha, 1800 m, 25.7.1994, M. Suzuki *et al.* 9470179 (TI); Parbat, Tikhedhunga-Hile, 1300 m, 11.98.1979, R. Niraula and N. Pradhan 8/1979 (KATH); Rasuwa, Between Dhaibungket and Ramche, 1550 m, 15.9.1966, Nicolson 2337 (KATH); Makawanpur, Makawanpurgadi, 1000 m, 1.3.1992, K. J. White and B. R. Sharma 24 (KATH); Sindhupalchok, Lisankhu-Golang Khola, 1524 m, 11.9.1964, M. L. Banerji, T. B. Shrestha and A. V. Upadhyay 2669 (KATH); Lalitpur, Bajrabarahi, 1400 m, 12.10.2000, M. Ghimire 101 (KATH); Ramechap, 18.8.1985, H. Ohba *et al.* 8571728 (TI); Dolakha, Lamabagar, 1950 m, 19.7.1977, K. R. Rajbhandari and B. Roy 1557 (KATH); Ardhakhanchi, Narapani, 2000 m, 8.10.2001, M. P. Panthi 351 (TUCH); 26.8.1956, J. D. A. Stainton 1435 (BM); 7. 3. 1962, A. H. Norkett 10008 (BM); 3.9.1988, M. Suzuki, N. Naruhashi, S. Kurosaki *et al.* 81729 (BM); 18.9.1995, M. Mikage, N. Anjiki, N. Kondo, R. Lacoul and K. Yonekura 9552267 (E); 26.7.2008, H. Ikeda, T. Kawahara, O. yano, M. F. Watson, Z. H. Li, M. N. Subedi and S. K. Acharya 20817054 (E); Lalitpur, Bajrabarahi, 1240 m, 12.10.2000, M. Ghimire 101 (TUCH); Makawanpur, Mahaveer, 1750 m, 9.6.2012, B. M. Pradhan 2023 (TUCH); Myagdi, 1920 m, 18.9.1995, M. Suzuki *et al.* 952267 (TI); Kaski, Panchase, 2552 m, 3.9.2016, B. M. Pradhan 2064 (TUCH). **East Nepal:** Taplejung, 1500 m, 8.11.1963, H. Hara *et al.* 6307321 (TI); Taplejung, 5.11.1963, H. Hara *et al.* 6307322 (TI); Taplejung, 6.11.1963, H. Hara *et al.* 6307323 (TI); Taplejung, 12.11.1963, H. Kanai *et al.* s.n. (TI); Taplejung, 9.11.1963, H. Kanai *et al.* s.n. (TI); Panchthar, 28.11.1963, H. Kanai *et al.* s.n. (TI); Sankhuwasabha, 1940 m, 17.8.1998, S. Noshiro *et al.* 9820037 (TI); Sankhuwasabha, Hatiar, North of Num, 2134 m, 26.8.1956, J. D. A. Stainton 1435 (KATH); Sankhuwasabha, Ridak, 2300 m, 8.8. 1977, S. K. Dhungana 442 (KATH); Sankhuwasabha, Eastern side of Arun Valley, 1210 m, 15.10.1991, D. G. Long, R. J. D. Mcbeath, D. R. Mckean, D. A. H. Rae, N. K. Bhattarai and Emak 818 (KATH); Ilam, Maimajhuwa, 2179 m, 25.10.2014, B. M. Pradhan 2042 (TUCH).

***Dendrobium monticola* P. F. Hunt & Summerh.**

Central Nepal: 31.8.1949, O. V. Polunin 1826 (BM); E00783662 (E); Manang, Tal, 1710 m, 10.8.1983, N.P. Manandhar 9631 (KATH); Lamjung, Jagat, 1430-2000 m, 9.7.1973, M. Amatya and D.P. Joshi 73/382 (KATH); Gorkha, Ganesh Himal, 1950 m, Anon 129 (KATH); Rasuwa, Dhunche, 2000 m, 2.9.1980, S. Bhattarai, L.R. Sharma and S. Dahal 80111 (KATH); Rasuwa, Thade-Dhunche, 1829 m, 27.8.1977, H.K. Sainju and P.M. Amatya 21/77 (KATH); Rasuwa, Thade-Dhunche, 1800 m, 2.10.1977, T.K. Rajbhandari, V.L. Gurung and D.P. Joshi 2167(KATH); Kathmandu, Shivapuri, 2732 m, 25.8.2016, B. M. Pradhan 2062 (TUCH).

***Dendrobium porphyrochilum* Lindl.**

Central Nepal: 29.8.19325, F. M. Bailey s.n. (BM); J. D. A. Stainton, W. R. Sykes and L.H.J. Williams 7532 (BM); 8.6.1969, L. H. J. Williams 491 (BM); 26.6.1981, J. D. A. Stainton 8379 (BM); Lalitpur, 18.9.1970, H. Kanai s.n. (TI); Kaski, Panchase, 2552 m, 3.9.2016, B. M. Pradhan 2067 (TUCH). **East Nepal:** Ilam, Chhintapu, 2591 m, 8.6.1969, T. B. Shrestha 15534 (KATH); Kaski.

Appendix IV: Table on distribution of *Dendrobium* species

S. N.	TAXA	REGION	ALTITUDE RANGE	HOST PLANT	FLOWERING TIME
1	<i>Dendrobium amoenum</i> Wall. ex Lindl.	Central / East Nepal	200-2000 m	<i>Alnus nepalensis</i>	May
2	<i>Dendrobium amplum</i> Lindl.	Central / East Nepal	1300 – 2100 m	<i>Schima wallichii</i>	September-November
3	<i>Dendrobium anceps</i> Swartz	Central/East Nepal	200-1400 m	<i>Schima wallichii</i>	April-May
4	<i>Dendrobium aphyllum</i> (Roxb.) G.E.C. Fischer	Central / East Nepal	200-1500 m	<i>Castanopsis indica</i>	April-June
5	<i>Dendrobium bicameratum</i> Lindl.	West / Central Nepal	1400-2400 m	<i>Schima wallichii</i>	July-August
6	<i>Dendrobium chrysanthum</i> Wall. ex Lindl.	Central / East Nepal	1300-2000 m	<i>Castanopsis indica</i>	August-October
7	<i>Dendrobium chryseum</i> Rolfe	Central Nepal	1200-2100 m	<i>Castanopsis indica</i>	May-June
8	<i>Dendrobium crepidatum</i> Lindl. & Paxton	Central Nepal	600-1400 m	<i>Shorea robusta</i>	April-May
9	<i>Dendrobium darjeelingense</i> Pradhan	Central Nepal	1500-1900 m	<i>Shorea robusta</i>	October-November
10	<i>Dendrobium denneanum</i> Kerr	Central Nepal	600-2500 m	Rock	May-June
11	<i>Dendrobium densiflorum</i> Lindl.	Central / East Nepal	900-1500 m	<i>Schima wallichii</i>	April-May
12	<i>Dendrobium denudans</i> D. Don	Central Nepal	1000-2200 m	<i>Schima wallichii</i>	August-September
13	<i>Dendrobium eriiflorum</i> Griff.	West/ Central / East Nepal	1500-2100 m	<i>Berberis asiatica</i>	September-October
14	<i>Dendrobium fimbriatum</i> Hook.	West / Central / East Nepal	500-1000 m	<i>Schima wallichii</i>	April-May
15	<i>Dendrobium formosum</i> Roxb. ex Lindl.	Central / East Nepal	500-1000 m	<i>Shorea robusta</i>	June
16	<i>Dendrobium fugax</i> Rchb.f.	Central Nepal	500-1600 m	<i>Syzygium cumini</i>	May-June

17	<i>Dendrobium fuscescens</i> Griff.	East Nepal	600-1800 m	<i>Castanopsis indica</i>	March-April
18	<i>Dendrobium gibsonii</i> Paxton	Central Nepal	900-2000 m	<i>Schima wallichii</i>	June-July
19	<i>Dendrobium heterocarpum</i> Wall. ex Lindl.	Central/East Nepal	900-2130 m	<i>Quercus glauca</i>	March-May
20	<i>Dendrobium longicornu</i> Lindl.	West/Central / East Nepal	1300-2900 m	<i>Quercus semicarpifolia</i>	September-November
21	<i>Dendrobium moniliforme</i> (Linn.) Swartz	Central / East Nepal	1700-2500 m	<i>Schima wallichii</i>	April-May
22	<i>Dendrobium monticola</i> P. F. Hunt & Summerh	Central Nepal	1700-2200 m	<i>Schima wallichii</i>	July-August
23	<i>Dendrobium moschatum</i> (Buch.-Ham.) Sw.	Central / East Nepal	200-1200 m	<i>Schima wallichii</i>	May-July
24	<i>Dendrobium nobile</i> Lindl.	Central / East Nepal	400-1500 m	<i>Schima wallichii</i>	April-May
25	<i>Dendrobium plicatile</i> Lindl.	East Nepal	500-2400 m	<i>Syzygium cumini</i>	April-June
26	<i>Dendrobium polyanthum</i> Wall. ex Lindl.	West / Central Nepal	400-1400 m	<i>Syzygium cumini</i>	March-April
27	<i>Dendrobium porphyrochilum</i> Lindl.	Central / East Nepal	1800-2500 m	<i>Rhododendron arboreum</i>	July-August
28	<i>Dendrobium rotundatum</i> (Lindl.) Hook.f.	Central/East Nepal	1300-2500 m	<i>Rhododendron arboreum</i>	March-May
29	<i>Dendrobium transparens</i> Wall. ex Lindl.	West / Central / East Nepal	700-2100 m	<i>Castanopsis indica</i>	May-June

Appendix V. Publications

Taxonomic significance of stomatal complex in fifteen species of *Dendrobium* Swartz (Orchidaceae) of Nepal

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ABSTRACT

Dendrobium Swartz is one of the largest and most problematic genus of the tribe Dendrobieae of the family Orchidaceae. Nepal harbors about thirty-one species of *Dendrobium*. Micromorphological characters like the stomatal complex in fifteen species of *Dendrobium* Swartz (Orchidaceae) of Nepal were studied for understanding the taxonomic significance of stomatal complex within the genus. For the study of stomatal complex of leaf, Carpenter's method was followed. Stomatal index and stomatal frequency were calculated using formula given by Salisbury. The terminologies used for the stomatal complex type were followed those of Patel. In all species the leaf surface was found hypostamitic. Tetracytic (a-tetra-monocyclic, b-tetra-monocyclic and c-tetra-monocyclic) and eupara two-monocyclic with hexa-monocyclic types of stomata were recorded in the genus. Tetracytic type was found in fourteen species and eupara two-monocyclic with hexa-monocyclic was found in only one species. The elliptical shape of stomata was found in more species than the circular shape. The epidermal cells of leaf were found rectangular, square, polygonal to irregular. The distribution of stomata on leaf surface, type of stomata and shape of epidermal cells were found to be taxonomically significant. These characters could be used as distinguishing characters to delimit the species in the genus.

Keywords: anatomical key, *Dendrobium*, epidermal cells, micromorphological character, stomatal variation

INTRODUCTION

The family Orchidaceae is widely distributed in the tropical and subtropical regions of the world and is regarded as one of the largest, most diverse and distinctive families of flowering plants (Burns-Balogh & Funk, 1986; Dressler, 1981, 1993). *Dendrobium* Swartz is a dominant genus of the tribe Dendrobieae of the family Orchidaceae. The genus was established by Olof Swartz (1799) based on *Dendrobium moniliforme* (L.) Sw. as the type species of the genus. The genus *Dendrobium* Swartz consists of about 900 species, widely distributed in China, Japan, India, Malaysia, Indonesia to New Guinea, Australia, New Zealand and the Pacific islands (Seidenfaden, 1985; Pearce & Cribb, 2002). In Nepal they are distributed from tropical to alpine regions. Hara *et al.* (1978) and Press *et al.* (2000) recorded 26 species of *Dendrobium* from Nepal. However, Rokaya *et al.* (2013) enumerated 31 species of *Dendrobium* from Nepal Himalaya. Species of *Dendrobium* are mostly epiphytes with some

are lithophytes. The distinguishing characters of the genus *Dendrobium* are presence of cane-like stem with pseudobulb covered with or without sheathing leaf bases, distichous or duplicate leaves, spiral flowers with basally jointed lips with prominent spurs formed by the column foot and naked pollinia.

Micromorphological study on leaf epidermal surface had been widely used in taxonomic and phylogenetic studies as they can provide valuable information (Patel, 1979; Stace, 1980; Davis, 1997). The notable work on stomatal patterns in some angiosperms had studied by Stebbins & Khush (1961), and Croxdale (2000). Leaf epidermal anatomy particularly of stomata was reported to provide valuable taxonomic and systematic evidence in both living and fossil plants (Wilkinson, 1979; Kong, 2001). In Orchidaceae, several micromorphological studies on stomatal types based on their structures have been done by Kaushik (1983) and Khasim & Rao (1990). Singh & Singh (1974) studied the organization of stomatal complex in family Orchidaceae. Kaushik (1983) and Rasmussen (1987) studied the ecological significance of dermal characters. Yukawa *et al.* (1992) reported the existence of two types of stomatal shape in the genus *Dendrobium* and its systematic significance. Arditti (1992) suggested that the shape of subsidiary cells had been used to distinguish the stomatal complex of Orchidaceae into several types. Vij *et al.* (1991) also examined epidermal feature of Indian orchids for taxonomic and ecological implications. Where Himalayan species are concerned, among the twelve species of the genus *Oberonia*, eight types of stomata had classified according to the arrangement of subsidiary cells (Shakya, 1999). In case of Himalayan genus *Eria* seven types of stomata complex has been studied (Bajracharya, 2005). The stomatal types had been reported to be significant in establishing the various ranks and clarifying the interrelationship among the different taxa and also resolving many taxonomic problems (Baranova, 1992).

Dendrobium is one of the largest and most problematic genera with respect to its intrageneric classification and relationships to other taxa in the family orchidaceae. The large number of species and diversity of gross morphology are the most prominent reasons for the complexity of *Dendrobium* taxonomy and the confusion over its intrageneric relationships. Under such circumstances orchid systematics needs a thorough revision using parameters other than gross morphology to clarify the intrageneric relationships among *Dendrobium* species. So in the present study the preliminary attempts were made on the study of distribution of stomata on leaf surface, stomatal types and epidermal cell types to clarify the intrageneric relationship among these taxa.

MATERIALS AND METHODS

In present study 15 species of *Dendrobium* Swartz viz. *D. amoenum* Wall. ex Lindl., *D. anceps* Sw., *D. aphyllum* (Roxb.) C.E.C. Fisch., *D. bicameratum* Lindl., *D. chrysanthum* Wall. ex Lindl., *D. crepidatum* Lindl. & Paxton, *D. densiflorum* Lindl., *D. denudans* D. Don., *D. eriiflorum* Griff., *D. formosum* Roxb. ex Lindl., *D. heterocarpum* Wall. ex Lindl., *D. longicornu* Lindl., *D. moniliforme* (L.) Sw., *D. moschatum* (Buch.-Ham.) Sw., *D. transparens* Wall. ex Lindl. were studied. The study was based on the live specimens. Field visits were carried out in different parts of Nepal to collect the live specimens. Live specimens were identified by studying protologues, type specimens and authentic herbarium specimens deposited at KATH, TUCH, CAL, BM, K, P and TI. Protologues and images of type specimens have been downloaded

from different websites including www.botanicus.org, www.biodiversitylibrary.org, www.plants.jstor.org, www.kew.org and www.nybg.org. Update nomenclature of *Dendrobium* species have been acquired from websites www.kew.org/wcsp/monocots and www.theplantlist.org.

The study of stomata was done on the fresh leaves of *Dendrobium* species collected from various localities of Nepal Himalaya. For the study of stomata, the method described by Carpenter (2005) with some modification was followed. Stomatal index and stomatal frequencies were calculated using the formula given by Salisbury (1928). The terminologies used for stomatal complex types were followed those of Patel (1979).

RESULTS AND DISCUSSION

The stomatal complex of 15 species of *Dendrobium* had examined with light microscope. The species of *Dendrobium* were found hypostamic leaf surfaces (i.e., stomata occurring on the abaxial surface only). The stomata were largely of tetracytic type (a, b and c-tetra-monocyclic) whereas eupara twi-monocyclic with hexa-monocyclic rarely present in some species. The stomata possess four to five subsidiary cells.

The stomatal distribution on the leaf surface, stomatal size with guard cells, stomatal pore size, stomatal frequency, stomatal index, shape of stomata, type of stomata, shape and type of epidermal cells on the abaxial surface of leaves was found to be variable in different species of *Dendrobium* (table 1).

The epidermal cells on abaxial surface are rectangular to polygonal and regular to irregular in shape. In most of species like *D. amoenum*, *D. anceps*, *D. aphyllum*, *D. eriiflorum*, *D. formosum*, *D. heterocarpum*, *D. longicornu*, *D. moniliforme*, *D. moschatum* and *D. transparens* the epidermal cells were found to be rectangular to polygonal where as in species like *D. bicameratum*, *D. chrysanthum*, *D. crepidatum*, *D. densiflorum* and *D. denudans* the epidermal cells were found to be squarish, pentagonal, hexagonal to polygonal and irregular size in some species with anticlinal wall varying from straight-sided to curvilinear. The epidermal cells were mostly parenchymatous (thin-walled or thick-walled) in species like *D. amoenum*, *D. anceps*, *D. aphyllum*, *D. bicameratum*, *D. chrysanthum*,

TABLE 1. Micromorphological characters of leaf surface in species of *Dendrobium*.

(Abbreviations used : Rect.= Rectangular, poly. = polygonal, Squa. = Squarish, Paren. = Parenchymatous, Scleren. = Sclerenchymatous)

Taxa	Leaf surface	Stomatal size with guard cells (LxB) μm	Stomatal pore size (LxB) μm	Stomatal frequency mm^2	Stomatal index %	Shape of stomata	Type of stomata	Shape of epidermal cells	Type of epidermal cells
<i>D. amoenum</i>	Abaxial	29.97 x 23.31	13.32 x 4.99	76.92	5.81	Elliptic	b-tetra-monocyclic	Rect. to poly.	Paren.
<i>D. anceps</i>	Abaxial	29.97 x 25.30	13.32 x 6.66	46.15	3.75	Elliptic	eupara twi-monocyclic +hexa-monocyclic	Rect. to poly.	Paren.
<i>D. aphyllum</i>	Abaxial	33.30 x 23.31	16.65 x 9.99	46.15	7.31	Elliptic	a-tetra-monocyclic	Rect. to poly.	Paren.
<i>D. bicameratum</i>	Abaxial	33.30 x 29.97	23.31 x 9.99	76.92	7.04	Elliptic	a-tetra-monocyclic	Squa. to poly.	Paren.
<i>D. chrysanthum</i>	Abaxial	33.30 x 23.31	16.65 x 6.66	76.92	5.68	Circular	a-tetra-monocyclic	Squa. to poly.	Paren.
<i>D. crepidatum</i>	Abaxial	32.63 x 26.64	15.32 x 7.32	130.77	13.04	Elliptic	b-tetra-monocyclic	Squa. to poly.	Paren.
<i>D. densiflorum</i>	Abaxial	33.30 x 26.64	26.64 x 13.32	76.92	6.76	Elliptic	a-tetra-monocyclic	Squa. to poly.	Scleren.
<i>D. denudans</i>	Abaxial	39.96 x 26.64	26.64 x 9.99	92.3	10.71	Elliptic	a-tetra-monocyclic	Squa. to poly.	Paren.
<i>D. eriiflorum</i>	Abaxial	38.62 x 25.97	20.64 x 10.65	123.07	10.66	Elliptic	c-tetra-monocyclic	Rect. to poly.	Paren.
<i>D. formosum</i>	Abaxial	45.96 x 41.96	24.64 x 6.66	76.92	12.5	Circular	c-tetra-monocyclic	Rect. to poly.	Scleren.
<i>D. heterocarpum</i>	Abaxial	38.30 x 33.30	16.65 x 10.00	92.3	13.04	Circular	a-tetra-monocyclic	Rect. to poly.	Paren.
<i>D. longicornu</i>	Abaxial	29.97 x 23.31	13.32 x 4.99	123.07	10.53	Elliptic	a-tetra-monocyclic	Rect. to poly.	Paren.
<i>D. moniliforme</i>	Abaxial	38.30 x 34.00	16.65 x 6.66	138.5	12.5	Circular	a-tetra-monocyclic	Rect. to poly.	Paren.
<i>D. moschatum</i>	Abaxial	27.97 x 26.64	16.65 x 9.99	76.92	5.0	Circular	a-tetra-monocyclic	Rect. to poly.	Paren.
<i>D. transparens</i>	Abaxial	33.30 x 27.31	17.98 x 6.66	138.46	10.71	Elliptic	b-tetra-monocyclic	Rect. to poly.	Paren.

D. crepidatum, *D. denudans*, *D. eriiflorum*, *D. heterocarpum*, *D. longicornu*, *D. moniliforme*, *D. moschatum* and *D. transparens* and in remaining species like *D. densiflorum* and *D. formosum* the epidermal cells were sclerenchymatous type.

The stomata were found mostly tetracytic type (a, b and c-tetra-monocyclic). In species like *D. aphyllum* (table 1, plate-I C), *D. bicameratum* (table 1, plate-I D), *D. chrysanthum* (table 1, plate-I E), *D. densiflorum* (table 1, plate-I G), *D. denudans* (table 1, plate-I H), *D. heterocarpum* (table 1, plate-II B), *D. longicornu* (table 1, plate-II C), *D. moniliforme* (table 1, plate-II D) and *D. moschatum* (table 1, plate-II E) a-tetra-monocyclic type was found whereas b-tetra-monocyclic type was found in *D. amoenum* (table 1, plate-I A), *D. crepidatum* (table 1, plate-I F), *D. transparens* (table 1, plate-II F) and c-tetra-monocyclic type was found in *D. eriiflorum* (table 1, plate-I I) and *D. formosum* (table 1, plate-II A). Eupara two-monocyclic with hexa-monocyclic was found in *D. anceps* (table 1, plate-I B).

Shape of stomata in *Dendrobium* varied from elliptical to circular. Elliptic type of stomata had found more in number than circular type. In species like *D. amoenum* (table 1, plate-I A), *D. anceps* (table 1, plate-I B), *D. aphyllum* (table 1, plate-I C), *D. bicameratum* (table 1, plate-I D), *D. crepidatum* (table 1, plate-I F), *D. densiflorum* (table 1, plate-I G), *D. denudans* (table 1, plate-I H), *D. eriiflorum* (table 1, plate-I I), *D. longicornu* (table 1, plate-II C) and *D. transparens* (table 1, plate-II F) the stomata were elliptical type whereas the species like *D. chrysanthum* (table 1, plate-I E), *D. formosum* (table 1, plate-II A), *D. heterocarpum* (table 1, plate-II B), *D. moniliforme* (table 1, plate-II D) and *D. moschatum* (table 1, plate-II E) had circular type.

The largest stoma was found in *D. formosum* with the area of $1928.48 \mu\text{m}^2$ and the smallest in *D. amoenum* and *D. longicornu* with the area of $698.60 \mu\text{m}^2$. The stomatal pore size was found smallest in *D. amoenum* and *D. longicornu* ranging from $66.46 \mu\text{m}$ to largest size $354.84 \mu\text{m}$ in *D. densiflorum*. The stomatal frequency varied from 46.15 mm^2 – 138.50 mm^2 . The highest stomatal frequency was found in *D. moniliforme* with 138.50 mm^2 and the lowest in *D. anceps* and *D. aphyllum* with 46.15 mm^2 . The stomatal index was found highest in *D. heterocarpum* with 13.04 and the lowest in *D. anceps* with 3.75.

On the basis of micromorphological characters like distribution of stomata on leaf surface, shape of epidermal cell, type of stomata, *Dendrobium* species of Nepal has been divided into different groups to delimit the taxa.

Anatomical key for *Dendrobium* species

Epidermal cell sclerenchymatous:

- A. Rectangular to polygonal shaped epidermal cells, c-tetra-monocyclic with circular stomata -----*D. formosum*
- B. Square to polygonal shaped epidermal cells, a-tetra-monocyclic with elliptical stomata-----*D. densiflorum*

Epidermal cells parenchymatous:

- A. Rectangular to polygonal shaped epidermal cells, a, b or c-tetra-monocyclic, eupara-two-monocyclic with elliptical or circular stomata

- a, b or c-tetra-monocyclic, eupara-twi-monocyclic with elliptical stomata
 - a-tetra-monocyclic -----*D. aphyllum*, *D. longicornu*
 - b-tetra-monocyclic -----*D. amoenum*, *D. transparens*
 - c-tetra-monocyclic -----*D. eriiflorum*
 - eupara twi-monocyclic -----*D. anceps*
- a-tetra-monocyclic with circular stomata----- *D. heterocarpum*, *D. moniliforme*, *D. moschatum*
 - B. Square to polygonal shaped epidermal cells, a or b-tetra-monocyclic with elliptical or circular stomata
- a or b-tetra-monocyclic with elliptical stomata
 - a-tetra-monocyclic -----*D. bicameratum*, *D. denudans*
 - b-tetra-monocyclic -----*D. crepidatum*
- a-tetra-monocyclic with circular stomata -----*D. chrysanthum*

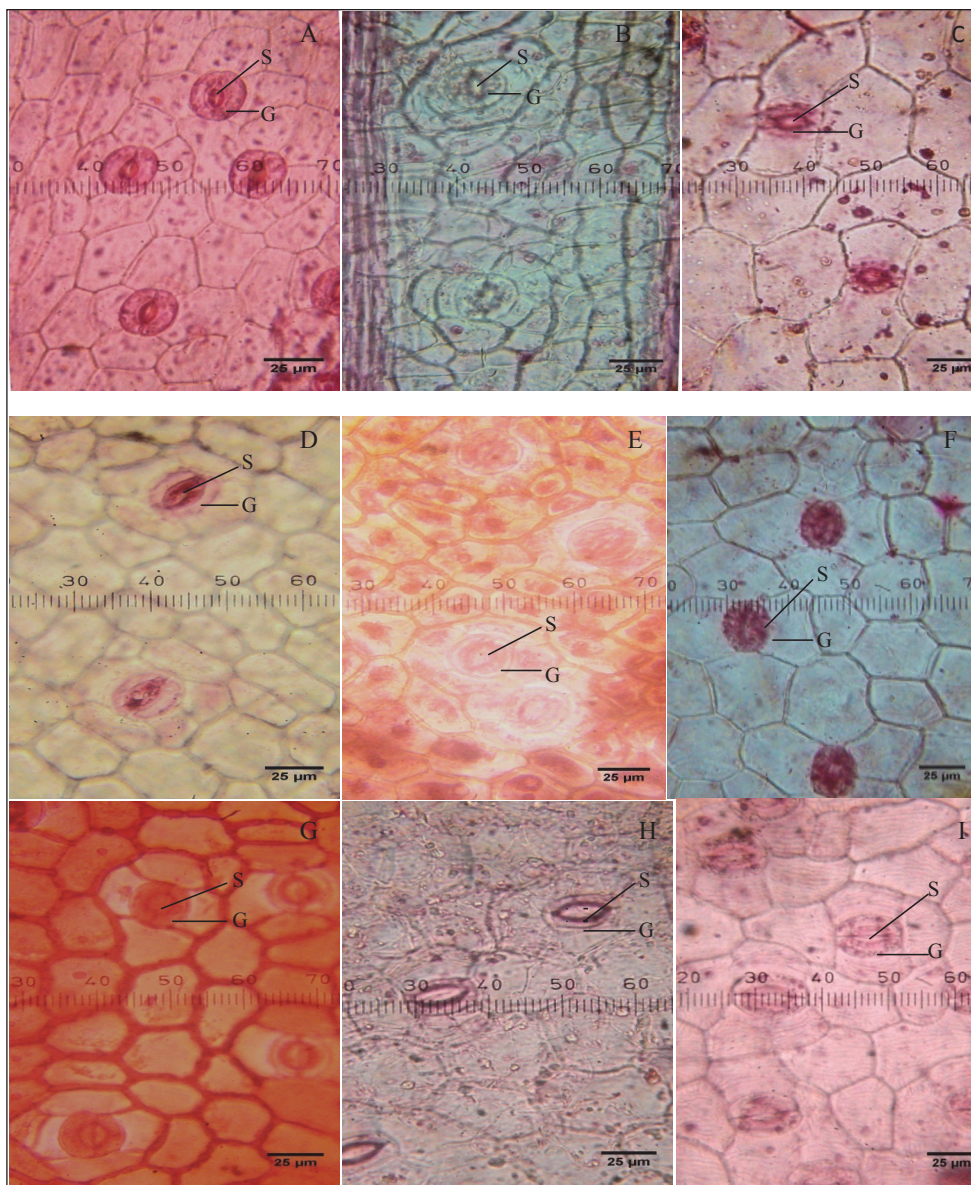


PLATE – I. Stomatal variations in different species of *Dendrobium* Swartz
 (Abaxial surface of leaf): A. *D. amoenum* (b-tetra-monocyclic); B. *D. anceps*
 (eupara twi-monocyclic); C. *D. aphyllum* (a-tetra-monocyclic); D. *D. bicameratum*
 (a-tetra-monocyclic); E. *D. chrysanthum* (a-tetra-monocyclic); F. *D. crepidatum*
 (b-tetra-monocyclic); G. *D. densiflorum* (a-tetra-monocyclic); H. *D. denudans* (a-tetra-
 monocyclic). I. *D. eriiflorum* (c-tetra-monocyclic) (Abbreviations used on photos: S =
 Stoma; G = Guard cell).

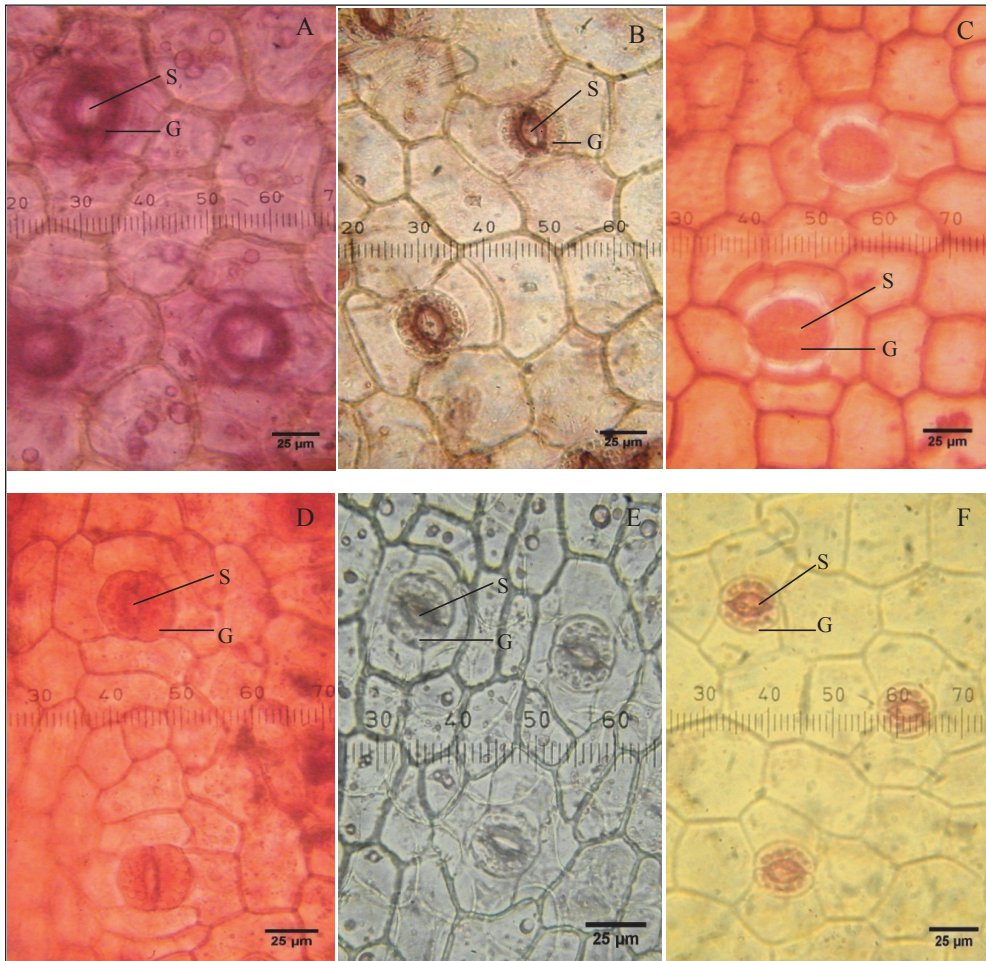


PLATE II. Stomatal variations in different species of *Dendrobium* Swartz (Abaxial surface of leaf): A. *D. formosum* (c-tetra-monocyclic); B. *D. heterocarpum* (a-tetra-monocyclic); C. *D. longicornu* (a-tetra-monocyclic); D. *D. moniliforme* (a-tetra-monocyclic); E. *D. moschatum* (a-tetra-monocyclic); F. *D. transparens* (b-tetra-monocyclic). (Abbreviations used on photos: S = Stoma; G = Guard cell).

The present study revealed the stomatal complex of *Dendrobium* which showed variation in types of epidermal cells, shape, size and types of stomata, stomatal frequency and stomatal index.

All species of *Dendrobium* showed hypostomatic leaf surface. The leaves are found hypostomatic condition in most of orchids (Avadhani *et al.*, 1982). Stomata were found only on the abaxial surface (hypostomatic). This is because these plants are adapted to aerial habitats to minimize

water loss through stomata (Stebbins & Khush, 1961). The epidermal cells on the abaxial surface varied from rectangular, squarish, pentagonal, hexagonal to polygonal, irregular with thick or thin walled parenchymatous cells and some species with sclerenchymatous cells. The anticlinal walls of epidermal cell varied from straight-sided to curvilinear.

The shape of stomata varied from elliptical to circular. Elliptical stomata were found in most species of *Dendrobium* whereas few species had circular stomata. Various modifications of stomatal shape such as elliptical, circular, transversely elliptical and angular are known to exist within Orchidaceae (Rasmussen, 1987). All modifications except the angular shape were found in *Dendrobium* (Yukawa *et al.*, 1992). Two types of stomatal shape (Stoma I and Stoma II) were reported in *Dendrobium* (Yukawa *et al.*, 1992). Stoma I is elliptical with a slit-like opening whereas Stoma II is circular with a round to spindle-shaped opening. Similarly two types of stomatal shape i.e. elliptical and circular were found in our study. The size of stomata showed a wide variation from 698.60 μm^2 to 1928.48 μm^2 . The largest stoma was found in *D. formosum* and the smallest in *D. amoenum* and *D. longicornu*.

Tetracytic type of stomata had been reported in many monocotyledons (Metcalfe, 1961). Mostly three types of stomata paracytic, tetracytic and anomocytic were reported in mostly in monocots (Cheadle, 1953; Stebbins & Khush, 1961). Stebbins & Khush (1961) reported that anomocytic type is limited only to the orders closely related to Liliales. Patel (1979) distinguished five types of stomata i.e. tetracytic (a-tetra-monocyclic, b-tetra-monocyclic and c-tetra-monocyclic), twicytic, perihaplocytic, anisocytic and hexacytic and each type with four to six subsidiary cells. Rasmussen (1987) distinguished four types of stomata such as tetracytic, anisocytic, cyclocytic and floating stomatal complexes. In the present study tetracytic type (a-tetra-monocyclic, b-tetra-monocyclic and c-tetra-monocyclic) was found in most species of *Dendrobium* whereas eupara two-monocyclic with hexa-monocyclic types was found in one species (*D. anceps*). In the stomatal type the monocyclic means the guard cells of the stomata are surrounded by a single cycle of subsidiary cells (Patel, 1979).

The stomatal frequency ranged from 46.15 mm^{-2} to 138.50 mm^{-2} . The highest stomatal frequency was found in *D. moniliforme* and lowest in *D. anceps* and *D. aphyllum*. The reduced stomatal frequency was distinctly related with the extent of leaf succulence and more the succulence lesser the frequency of stomata (Goh *et al.*, 1977). Similarly in species from marshy habitat, the highest stomatal frequency was recorded (Ziegenspeck, 1936). The stomatal index ranged from 3.75 to 13.04. The highest stomatal index was found in *D. heterocarpum* and lowest in *D. anceps*. Similar variation in stomatal index was reported in orchid species (Saadu *et al.*, 2009). The variation in stomatal index could be on account of variation in sunlight intensity (Santosh *et al.*, 2015). A direct correlation between light intensity and stomatal index was observed in orchids (Rasmussen, 1987).

These studies clearly indicated that the micromorphological characters such as distribution of stomata on leaf surface, type of stomata and shape of epidermal cells were found to be taxonomically significant. This parameter will be helpful in solving the existing problems in *Dendrobium* species.

ACKNOWLEDGEMENTS

Authors are thankful to National Herbarium and Plant Laboratories, Godawari, Nepal (KATH) and Tribhuvan University Central Herbarium, Kirtipur, Nepal (TUCH) for their cooperation and allowing me to study the herbarium specimens housed over there. My sincere thanks go to Patan Multiple Campus and Amrit Campus for providing the laboratories facilities.

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Anatomical study of *Dendrobium* (Orchidaceae) of Nepal

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Abstract: *Dendrobium* Swartz is one of the largest and most problematic genus of subtribe Dendrobiinae, tribe Malaxideae of family Orchidaceae. Twenty-six species of *Dendrobium* investigated are characterized by the variations in anatomical characters of leaves, stems, stomata and stigmata. These anatomical characters are taxonomically significant and used as distinguishing characters for delimiting taxa at infrageneric level. An artificial dichotomous key based on anatomical characters of leaves and stems for the identification of *Dendrobium* species of Nepal is provided. The cluster analysis based on anatomical with micromorphological characters is carried out with the aim of investigating interrelationships among the species of *Dendrobium* present in Nepal.

Keywords: *Dendrobium*; Orchidaceae; Anatomy; Stomata; Stegmata; Cluster analysis

Introduction

Dendrobium is a dominant genus of Orchidaceae and was established by Olof Swartz in 1799. *Dendrobium moniliforme* (L.) Sw. is the type for the genus *Dendrobium* (Holtum, Brieger & Cribb 1979). Species of *Dendrobium* are mostly epiphytes with some are lithophytes. *Dendrobium* Swartz comes under subtribe Dendrobiinae and it consists of about 1450 species worldwide (Schuiteman, 2014). Rajbhandari *et al.*, (1999) reported that largest number of epiphytic orchids are found in the lower temperate regions of Central and Eastern Nepal, The Subtribe Dendrobiinae is represented by genera *Dendrobium*, *Epigeneium* and *Flickingeria* (Dressler, 1993). But according to update classification of Orchidaceae (Chase *et al.*, 2015) two genera *Epigeneium* and *Flickingeria* were merged into single genus *Dendrobium*. The distinguishing characters of the genus *Dendrobium* are presence of cane-like stem with pseudo-bulb covered with or without sheathing leaf bases, distichous or duplicate leaves, spiral flowers with basally jointed lips with prominent spurs formed by the column foot and naked pollinia.

Although morphological and floristic studies of Orchidaceae have been carried out extensively, anatomical investigations are yet inadequate on orchids from Nepal. Only a few anatomical characters have been explored by some of the

scientists as a supplementary portion of the revision of respective genera (*Coelogyne*, *Dendrobium*, *Eria*, *Gastrochilus*, *Oberonia* and *Pholidota*) in Nepal. In subtribe Dendrobiinae, only certain species have been studied anatomically as a part of a broad investigation (Morris *et al.*, 1996). Kaushik (1983) explored the ecological and anatomical marvels of the Himalayan Orchids and discussed the impact of anatomy on the classification of the family and formulated the phylogenetic classification based on the morpho-anatomical characters. Morris *et al.*, (1996) studied the vegetative anatomy and systematic of subtribe Dendrobiinae. They found that the anatomy of plants reflects a high degree of morphological diversity and many of the anatomical characters appear to be homoplasious. They also recommended that a more detailed understanding of the phylogeny of subtribe Dendrobiinae will require the characters from morphology, micromorphology, anatomy and DNA studies. Carlsward *et al.*, (1997) studied the comparative leaf anatomy and systematic in *Dendrobium*, Sections *Aporum* and *Rhizobium* and concluded that two sections of *Dendrobium* are hypothesized to be sister taxa because of synapomorphies in their foliar anatomy. The cladistic analysis performed with various anatomical characters of the leaf demo-

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nstrates that both groups are monophyletic. Anatomical characterization helps in the identification of plant taxa when morphological characters are similar. It also helps in understanding the physiological processes and phylogenetic relationships among plant species (Liu and Zhu, 2011).

Micromorphological study on leaf epidermal surface had been widely used in taxonomic and phylogenetic studies. Singh and Singh (1974) studied the organization of stomatal complex in some Orchidaceae and concluded that the presence of tetracytic stomata was considered significant in evolutionary relationships of the family. Kaushik (1983) and Rasmussen (1987) studied the ecological significance of dermal characters. Khasim and Mohana Rao (1990) studied anatomy in relation to taxonomy in some members of Epidendroideae. Vij *et al.*, (1991) studied the epidermal features of Indian orchids for taxonomic and ecological implications. Yukawa *et al.*, (1992) reported the existence of two types of stomatal shape in the genus *Dendrobium* and its systematic significance. Arditti (1992) suggested that the shape of subsidiary cells had been used to distinguish the stomatal complex of Orchidaceae into several types. In concerning about Himalayan species, Shakya (1999) classified eight types of stomatal complex according to the arrangement of subsidiary cells among the twelve species of the genus *Oberonia*. Bajracharya (2003) observed seven types of stomata within the Himalayan genus *Eria*. Dangol (2006) studied the anatomical structures of subtribe Coelogyninae.

Stegmata or silica cell in orchids was reported and illustrated by Link (1849) for the first time but described them as projections from the sclerenchyma. The stegmata are restricted to the monocotyledon families Orchidaceae, Palmae, Maranthaceae, Musaceae, and with some doubt Juncaceae and not found in dicotyledons (Kohl, 1889). He distinguished two main kinds of stegmata in orchids one with conical bodies and other with spherical bodies. Stegmata with conical bodies are widespread within the family and those with spherical bodies are found in vandoid orchids and *Dendrobium*. Although the distribution of stegmata in orchids seems to be

of systematic value and phylogenetic interest, little attention has been paid to them since then. Moller & Rasmussen (1984) studied the distribution of stegmata in 130 species representing 105 genera in Orchidales. They reported that the stegmata bearing silica bodies occur in longitudinal files lining fibre bundles and vascular bundle sheaths of rhizomes, stems and especially in the leaves and rarely in roots. Dressler (1993) reported that in most orchids the silica cells are roughly conical in shape but they are spherical and rather lumpy in the *Vandae*, *Eriinae*, *Podochilinae* and *Dendrobiinae*. Carlsward *et al.*, (1997) reported that stegmata containing rough-surfaced spherical bodies are found associated with phloic sclerenchyma of the larger bundles of *Dendrobium leonis*, *D. anceps*, *D. brevimentum*, *D. aloifolium*, *D. distichum*, *D. indivisum*, *D. mannii*, *D. rosellum* and *D. nathaniele* and they are absent along vascular bundle sclerenchyma in *D. acinaciforme*. Bajracharya (2003) studied the stegmata on leaf surface of 28 species of *Eria*. He reported that the study of stegmata reveal valuable characters that had been used in delimiting the taxa *Eria* at species level.

Presently 29 species of *Dendrobium* are reported from Nepal Himalaya. Out of 29 species, 26 species of *Dendrobium* were studied for anatomical structures. Remaining 3 species (*D. darjeelingense* Pradhan, *D. chryseum* Rolfe and *D. plicatile* Lindley) were excluded from anatomical study because these species could not be collected from field visits. This may be due to extinction of orchids from their natural habitats because of their medicinal values, deforestation or landslides. In concerning about *D. darjeelingense* it was known that this species was destroyed due to forest firing. This study will provide the taxonomic significance, relationships and variations among different species of *Dendrobium* of Nepal.

Materials and Methods

Study sites and sample collection

In this study, the plant materials were collected from West, Central and East Nepal on the basis of those regions mentioned in the herbaria and also from the available literature. The collected specimens were preserved in FAA (Formalin

0.5 parts, glacial acetic acid 0.5 parts, 70% ethanol 9 parts) and stored in 70% ethanol for anatomical studies. These techniques involve killing and fixing the tissues in FAA and then storing in 70 % ethanol before sectioning.

Anatomical study

Anatomical studies of the different parts of the plant body such as leaves and stems or pseudobulbs were studied on the collected materials by two methods *viz.*, Free hand sections and Microtomy.

In Free hand sections method, the plant parts were hand sectioned into 25-30 μm with the help of sharp blades and dehydrated with different alcohol series. Double staining was done by Safranin-fast green combination (Johansen, 1940) and the sections were mounted in DPX. The different anatomical characters were observed and measured using compound light microscopes (Olympus) fitted with ocular micrometer scale. Microscopic photography was carried out of the observed specimens. In Microtomy method, sections were prepared using standard micro-technical methods for anatomy by using a rotary microtome (Yorco Spencer type) as described by Cutler (1978). For microtome sections, leaf and stem parts of specimens were dehydrated in alcohol and xylene series, infiltrated and embedded in paraffin wax (melting point 60-62°C). The embedded materials in the block of wax were sectioned with a rotary microtome at a thickness of 15-30 μm . Staining, measurement and photography were same as in free hand sections method.

Micromorphological study

Stomata

The leaf material for epidermal peeling was prepared by immersing in Potassium hydroxide solution (5%) overnight, rinsed with deionized water and again immersed in fresh solution of potassium hydroxide solution for few hours, then washed with water and treated with glacial acetic acid for 2-5 minutes (Carpenter 2005; with some modification). The peeled epidermal layer was then treated with Sodium hypochlorite (4%) until the tissue got discolored. It was then washed with water for several times and stained in Safranin (1%) and

mounted in glycerin. The leaf epidermis was observed under light microscope. The size of stomata and stomatal pore of each specimen were measured by using the standardized ocular micrometer scale. The microscopic photography was carried out. The stomatal distribution on the both surfaces were observed and noted. The terminologies used for stomatal complex types were followed those of Patel (1979). The data were stored in the tabulated form. Stomatal index and stomatal frequencies were calculated using the formula given by Salisbury (1928).

$$SI = S / E + S \times 100,$$

Where, SI = Stomata Index, E = Average number of epidermal cells per unit area or microscopic field, S = Average number of stomata in microscopic field.

$$SF = S/A \text{ per mm}^2$$

Where, SF = Stomata frequency, A = Area of microscopic field.

$$A = \pi r^2$$

Where, π = 3.14, r = radius of the microscopic field.

Stegmata

Stegmata were studied on the leaf surfaces of specimen by peeling the epidermal layer, stained in Safranin (1%) and mounted on glycerin. The leaf epidermis was observed under light microscope and microscopic photography was carried out.

Cluster analysis

In the present study, the character and character states based on collected live specimens and herbarium specimens were described to carry out the cluster analysis. Altogether 60 characters (anatomical with micromorphological) were considered to perform the cluster analysis.

Data matrix

Altogether 60 variable anatomical characters were scored as multistate characters. The multistate characters were coded as 0-4. The complete data matrix of characters and character states are presented in Table 1. The data matrix of different species is presented in Table 2.

Data analysis

The cluster analysis was performed on the anatomical with micromorphological data with pvclust (Suzuki & Shimodaira, 2011), an R

package (R version 3.1.0, 2014). The pvclust is an implementation of bootstrap analysis on a statistical software R for hierarchical clustering with *p*-values. The pvclust calculates probability values (*p*-values) for each cluster during bootstrap resampling techniques. In pvclust, two types of *p*-values are available: Approximately Unbiased (AU) *p*-value and Bootstrap Probability (BP) *p*-value. Multiple bootstrap resampling is used for the calculation of AU *p*-value which has superiority in bias over BP value calculated by normal bootstrap resampling. R-pvclust analysis was performed on anatomical data with 10000 bootstrapping to get the stronger cluster supported by data. The average cluster analysis with correlation distance was used to analyze the data set.

Results

Anatomy with micromorphology

Leaf Surface

Epidermis: cells vary from square to rectangular to polygonal in shape. Rectangular to polygonal epidermal cells are present in species of all the species of *Dendrobium* except in *D. bicameratum*, *D. chrysanthum*, *D. crepidatum*, *D. denneanum*, *D. densiflorum*, *D. denudans*, *D. fuscescens*, *D. fugax* and *D. porphyrochilum* are found square to polygonal epidermal cells are present.

Stomata: present on abaxial surface only in all species of *Dendrobium*. a, b and c tetramonocyclic stomata are present in all species of *Dendrobium* except in *D. anceps* (eupara twi-monocyclic with hexa-monocyclic stomata) and *D. fugax* (eupara twi-monocyclic stomata).

Three types of stomata i.e. elliptical, circular and sub-orbicular are present in all species of *Dendrobium*. Largest stoma was found in *D. formosum* and smallest in *D. fuscescens*. Largest stomatal pore was found in *D. nobile* and smallest in *D. porphyrochilum*.

Stegmata: with rough surfaced spherical silica bodies are present all the species of *Dendrobium* and not present in *D. densiflorum*, *D. formosum*, *D. longicornu* and *D. polyanthum* (Table 3, Plates 1, 2, 3, 4, 5, 6, 7, 8).

Leaf (T.S.)

Cuticle: Thin cuticles are present in *D. aphyllum*, *D. crepidatum*, *D. denudans*, *D. eriiflorum*, *D. fimbriatum*, *D. formosum*, *D. gibsonii*, *D. heterocarpum*, *D. longicornu*, *D. monticola*, *D. moschatum*, *D. nobile*, *D. polyanthum*, *D. porphyrochilum* and *D. transparens* whereas thick cuticles are present in *D. amoenum*, *D. amplum*, *D. anceps*, *D. bicameratum*, *D. chrysanthum*, *D. denneanum*, *D. densiflorum*, *D. fuscescens*, *D. fugax*, *D. moniliforme* and *D. rotundatum*. Cuticle is intermittently domed in *D. anceps*.

Epidermis: cells vary from square to rectangular to hexagonal to polygonal. The adaxial cells are larger than abaxial cells.

Hypodermis: single layer of rounded small cells is present abaxially in *D. anceps* and adaxially in *D. densiflorum* and absent in other species.

Fibre bundles: present in one series both on adaxial and abaxial sides subtending the hypodermis in *D. anceps* and absent in other species.

Mesophyll: homogenous and heterogenous. Heterogenous mesophylls are present in *D. amplum* and *D. rotundatum* whereas homogenous mesophylls are present in remaining species. Cells are thin walled, columnar to oval to polygonal. Cell layers range from 6 in *D. monticola* to 18 in *D. anceps* in homogenous mesophylls. In heterogenous mesophylls, palisade layers 2 in *D. amplum* and *D. rotundatum* whereas spongy layers 7 in *D. amplum* and 8 in *D. rotundatum*.

Vascular bundle: conjoint, collateral and closed bundles are arranged in one row with a large bundle at midrib. Midrib vascular bundle is oval to oblong to flask shaped to circular to conical. U-shaped fibre caps are present at xylem poles and C-shaped fibre caps at phloem poles of midrib vascular bundles. In case of *D. moschatum*, and *D. densiflorum* dome-shaped fibre caps are present at xylem poles.

Table 1. Characters and character states used in Cluster analysis of *Dendrobium*

S.No.	Character	Character states
0	Stomatal shape	(0) elliptic; (1) circular; (2) sub-orbicular
1	Stomatal type	(0) a-tetra-monocyclic; (1) b-tetra-monocyclic; (2) c-tetra-monocyclic; (3) eupara-twi-monocyclic; (4) eupara-twi-monocyclic+hexa-monocyclic
2	Stomata length, μm	(0) < 33; (1) 33 - 37; (2) > 37
3	Stomata width, μm	(0) < 26; (1) 26 - 28; (2) > 28
4	Stomatal pore length, μm	(0) < 16; (1) 16 - 18; (2) > 18
5	Stomatal pore width, μm	(0) < 7; (1) 7 - 9.99; (2) > 9.99
6	Stomatal frequency, mm^2	(0) < 80; (1) 80-120; (2) > 120
7	Stomatal index, %	(0) < 7; (1) 7 - 10; (2) > 10 %
8	Leaf epidermal cell type	(0) parenchyma; (1) sclerenchyma
9	Stegmata	(0) absent; (1) present; (2) indistinct
10	Cuticle layer of leaf	(0) thick; (1) thin
11	Adaxial leaf epidermal cell width (largest), μm	(0) < 46; (1) 46 - 67; (2) > 67
12	Adaxial leaf epidermal cell length (largest), μm	(0) < 28; (1) 28 - 40; (2) > 40
13	Abaxial leaf epidermal cell width (largest), μm	(0) < 28; (1) 28 - 42; (2) > 42
14	Abaxial leaf epidermal cell length (largest), μm	(0) < 18; (1) 18 - 24; (2) > 24
15	Leaf hypodermis position	(0) absent; (1) adaxial; (2) abaxial
16	Leaf hypodermal layer	(0) absent; (1) 1
17	Mesophyll layer type	(0) homogenous; (1) heterogenous
18	Homogenous mesophyll layers	(0) absent; (1) ≤ 7 ; (3) 8 - 10
19	Heterogenous mesophyll spongy layers	(0) absent; (1) 7; (2) 8
20	Water storage cells in mesophyll	(0) absent; (1) present
21	Calcium oxalate crystals in mesophyll	(0) absent; (1) present
22	Midrib vascular bundle shape	(0) oval; (1) flask-shaped; (2) conical; (3) oblong; (4) circular
23	Midrib vascular bundle length, μm	(0) < 140; (1) 140 - 200; (2) > 200
24	Midrib vascular bundle width, μm	(0) < 120; (1) 120 - 170; (2) > 170
25	Fibre bundle	(0) absent; (1) present
26	Major vascular bundle at leaf pole	(0) absent; (1) present
27	Fibre cap on midrib bundle	(0) absent; (1) present
28	Xylem fibre cap layers in midrib bundle	(0) absent; (1) < 4; (2) 4 - 6; (3) > 6
29	Phloem fibre cap layers in midrib bundle	(0) absent; (1) < 4; (2) 4 - 5; (3) > 5

30	Xylem fibre cap length, μm	(0) absent; (1) < 30; (2) 30 - 50; (3) > 50
31	Xylem fibre cap width, μm	(0) absent; (1) < 120; (2) 120 - 150; (3) > 150
32	Phloem fibre cap length, μm	(0) absent; (1) < 27; (2) 27 - 37; (3) > 37
33	Phloem fibre cap width, μm	(0) absent; (1) < 130 (2) 130 - 175; (3) > 175
34	Xylem length (largest), μm	(0) < 19; (1) 19 - 25; (2) > 25
35	Xylem width (largest), μm	(0) < 10; (1) 10 - 17; (2) > 17
36	Phloem length (largest), μm	(0) < 6; (1) 6 - 9; (2) > 9
37	Phloem width (largest), μm	(0) < 4.0; (1) 4.0 - 6.5; (2) > 6.5
38	Stem epidermal cell shape	(0) rectangular to polygonal; (1) rectangular to square; (2) rectangular to angular; (3) rectangular; (4) barrel-shaped
39	Stem epidermal cell width (largest), μm	(0) < 18; (1) 18 - 25; (2) > 25
40	Stem epidermal cell length (largest), μm	(0) < 12; (1) 12 - 16; (2) > 16
41	Stem hypodermal layer	(0) absent; (1) 1; (2) 2 - 3; (3) 4 - 5
42	Stem hypodermal cell shape	(0) absent; (1) oblong-Polygonal; (2) rectangular-polygonal; (3) polygonal; (4) oval-polygonal
43	Stem vascular bundle shape	(0) oval; (1) elongate
44	Stem vascular bundle no.	(0) 60; (1) 60 - 70; (2) > 70
45	Stem vascular bundle length (smallest), μm	(0) < 100; (1) 100 - 130; (2) > 130
46	Stem vascular bundle width (smallest), μm	(0) < 80; (1) 80 - 90; (2) > 90
47	Stem vascular bundle length (largest), μm	(0) < 190; (1) 190 - 230; (2) > 230
48	Stem vascular bundle width (largest), μm	(0) < 100; (1) 100 - 130; (2) > 130
49	Fibre cap in vascular bundle of stem	(0) absent; (1) present
50	Xylem fibre cap length (largest), μm	(0) absent; (1) $\leq$ 45; (2) > 45
51	Xylem fibre cap width (largest) μm ,	(0) absent; (1) $\leq$ 100; (2) > 100
52	Phloem fibre cap length (largest), μm	(0) absent; (1) < 30; (2) 30 - 37; (3) > 37
53	Phloem fibre cap width (largest), μm	(0) absent; (1) < 80; (2) 80 - 100; (3) > 100
54	Xylem length (largest), μm	(0) < 18; (1) 18 - 27; (2) > 27
55	Xylem width (largest), μm	(0) < 15; (1) 15 - 20 ; (2) > 20
56	Phloem length (largest), μm	(0) < 7; (1) 7 - 10; (2) > 10
57	Phloem width (largest), μm	(0) < 5; (1) 5 - 8; (2) > 8
58	Stegmata in vascular bundle of stem	(0) absent; (1) present
59	Raphide bundles in stem	(0) absent; (1) present.

Table 2: Data matrix for cluster analysis of *Dendrobium*

S. N.	Taxa	Characters and character states with codes																													
	<i>Dendrobium</i>																														
		0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1	<i>D. amoenum</i>	0	1	0	0	0	0	0	0	0	1	1	2	1	2	1	0	0	0	1	0	0	1	0	1	1	0	0	1	2	1
2	<i>D. amplum</i>	2	1	1	2	1	0	1	0	1	1	0	1	1	2	1	0	0	1	0	1	0	0	1	1	1	0	0	1	2	3
3	<i>D. anceps</i>	0	4	0	0	0	0	0	0	0	2	0	0	0	0	0	2	1	0	3	0	1	1	4	0	1	1	1	1	1	1
4	<i>D. aphyllum</i>	0	0	1	0	1	1	0	1	0	1	1	2	2	2	2	0	0	0	2	0	1	0	0	0	0	0	0	1	1	1
5	<i>D. bicameratum</i>	0	0	1	2	2	1	0	1	0	2	0	1	1	1	0	0	0	0	2	0	0	0	0	0	0	0	0	1	1	1
6	<i>D. chrysanthum</i>	1	0	1	0	1	0	0	0	0	1	1	2	0	1	1	0	0	0	2	0	0	0	0	2	2	0	0	1	3	2
7	<i>D. crepidatum</i>	0	1	0	1	0	1	2	2	0	1	1	0	2	0	2	0	0	0	2	0	0	1	2	2	1	0	0	1	2	3
8	<i>D. denneanum</i>	1	0	0	1	1	1	2	1	1	1	0	0	0	0	0	0	0	0	2	0	0	1	2	2	2	0	0	1	2	2
9	<i>D. densiflorum</i>	0	0	1	1	2	2	0	0	1	0	0	0	0	0	1	1	1	0	3	0	0	1	2	2	2	0	0	1	3	3
10	<i>D. denudans</i>	0	0	2	1	2	1	1	2	0	2	1	0	0	1	0	0	0	0	1	0	0	1	3	0	0	0	0	1	1	1
11	<i>D. eriiflorum</i>	0	2	2	0	2	2	2	2	0	2	1	0	2	0	2	0	0	0	1	0	0	1	0	0	0	0	0	1	2	2
12	<i>D. fimbriatum</i>	1	0	1	2	1	1	2	2	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	1	2	2
13	<i>D. formosum</i>	1	2	2	2	2	0	0	2	1	0	1	2	2	2	2	0	0	0	2	0	0	1	0	2	2	0	0	1	3	2
14	<i>D. fugax</i>	1	3	0	2	0	2	2	2	1	2	0	0	0	0	0	0	0	0	3	0	0	1	1	2	1	0	0	1	3	3
15	<i>D. fuscescens</i>	1	0	0	0	0	0	0	0	1	1	0	0	0	1	1	0	0	1	0	1	0	0	1	2	1	0	0	1	2	3
16	<i>D. gibsonii</i>	0	0	1	0	2	0	0	1	0	1	1	1	1	1	0	0	0	0	2	0	0	1	0	2	2	0	0	1	2	2
17	<i>D. heterocarpum</i>	1	0	2	2	1	2	1	2	0	1	1	2	2	1	2	0	0	0	1	0	0	1	0	1	0	0	0	1	2	1
18	<i>D. longicornu</i>	0	0	0	0	0	0	2	2	0	0	1	1	2	2	2	0	0	0	2	0	0	1	4	1	1	0	0	1	2	2
19	<i>D. moniliforme</i>	1	0	2	2	1	0	2	2	0	2	0	1	2	0	1	0	0	0	2	0	0	1	0	0	1	0	0	1	1	2
20	<i>D. monticola</i>	0	0	2	1	2	1	2	2	0	2	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1
21	<i>D. moschatum</i>	1	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0	0	0	3	0	1	1	2	2	2	0	0	1	3	3
22	<i>D. nobile</i>	0	2	2	2	2	2	1	2	0	1	1	2	1	2	2	0	0	0	2	0	1	1	0	1	1	0	0	1	1	1
23	<i>D. polyanthum</i>	0	1	0	1	1	0	0	1	0	0	1	0	0	1	0	0	0	0	2	0	1	0	4	2	2	0	0	1	3	2
24	<i>D. porphyrochilum</i>	0	0	1	0	0	0	0	1	0	1	1	2	1	1	1	0	0	0	1	0	1	1	3	0	0	0	0	0	0	0
25	<i>D. rotundatum</i>	2	2	0	0	0	0	1	1	1	2	0	1	1	1	2	0	0	1	0	2	1	1	1	1	1	0	0	1	2	3
26	<i>D. transparens</i>	0	1	1	1	1	0	2	2	0	1	1	1	2	2	1	0	0	0	2	0	0	1	4	1	1	0	0	1	2	2

S. N.	Taxa	Characters and character states with codes																													
	<i>Dendrobium</i>	2	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	
		0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1	<i>D. amoenum</i>	3	2	2	2	2	A	1	1	0	1	0	2	3	0	2	2	2	0	1	1	0	0	2	2	2	2	2	2	1	0
2	<i>D. amplum</i>	1	2	3	2	1	2	1	1	1	1	1	2	3	1	0	2	0	2	2	1	2	2	3	3	2	1	1	1	1	0
3	<i>D. anceps</i>	1	1	1	2	0	0	0	0	4	0	0	2	3	0	1	1	0	1	0	1	1	1	3	2	0	0	0	1	0	0
4	<i>D. aphyllum</i>	1	1	1	1	1	1	1	1	4	0	2	1	3	0	2	2	2	2	1	1	0	0	2	2	1	1	2	1	1	1
5	<i>D. bicameratum</i>	1	1	1	1	0	0	1	0	4	0	0	2	3	1	2	0	1	1	0	1	0	0	2	1	2	2	0	1	1	0
6	<i>D. chrysanthum</i>	2	3	2	3	1	2	2	2	4	1	1	2	4	1	1	1	1	2	2	1	0	0	2	2	2	2	1	1	0	1
7	<i>D. crepidatum</i>	2	2	3	2	1	1	1	1	0	2	0	1	1	0	0	1	1	1	0	1	0	0	1	1	1	1	1	2	0	0
8	<i>D. denneanum</i>	2	3	2	3	1	1	1	1	4	1	1	3	2	1	2	2	2	2	2	1	0	0	3	3	2	2	2	2	0	0
9	<i>D. densiflorum</i>	3	3	3	3	2	1	2	2	3	0	2	3	2	0	2	1	1	1	2	1	0	0	2	3	0	1	0	0	1	1
10	<i>D. denudans</i>	0	1	1	1	1	0	1	1	3	2	1	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0
11	<i>D. eriiflorum</i>	2	1	1	1	1	1	1	1	3	2	1	0	0	0	1	1	1	1	1	1	0	0	1	1	0	0	0	0	0	1
12	<i>D. fimbriatum</i>	2	1	2	1	1	1	1	1	4	0	0	3	2	0	1	2	2	1	2	1	0	0	3	3	2	0	2	2	0	0
13	<i>D. formosum</i>	3	3	2	3	2	2	2	2	0	2	2	2	3	0	1	2	2	2	2	1	0	0	3	3	2	0	2	2	1	0
14	<i>D. fugax</i>	3	3	2	3	2	1	2	2	4	1	2	2	3	1	2	1	1	1	2	1	0	0	2	2	1	1	0	1	1	0
15	<i>D. fuscescens</i>	3	1	3	3	1	1	2	2	1	2	2	2	3	0	2	0	1	2	1	1	2	2	1	1	1	1	1	1	0	0
16	<i>D. gibsonii</i>	3	3	3	3	2	2	2	2	2	0	1	2	3	0	0	1	2	2	2	1	0	0	3	2	2	1	2	2	0	1
17	<i>D. heterocarpum</i>	1	1	1	1	1	1	1	1	2	1	1	2	3	0	2	1	2	0	1	1	0	0	3	2	0	0	1	1	0	1
18	<i>D. longicornu</i>	2	3	2	1	1	1	1	2	0	1	1	2	3	1	1	0	1	0	1	1	0	0	3	2	1	1	2	2	1	1
19	<i>D. moniliforme</i>	1	1	1	2	0	0	0	0	0	1	1	2	3	1	0	2	2	2	2	1	0	0	1	1	1	1	2	2	0	1
20	<i>D. monticola</i>	1	1	1	1	0	0	1	1	3	2	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0
21	<i>D. moschatum</i>	3	3	3	3	2	2	2	2	4	0	2	2	3	0	2	2	2	0	2	1	1	1	2	3	0	0	0	0	0	1
22	<i>D. nobile</i>	2	3	1	3	1	2	2	2	0	2	1	2	3	0	2	1	1	1	2	1	0	0	2	2	1	1	0	1	0	0
23	<i>D. polyanthum</i>	3	3	3	2	1	1	1	1	0	2	2	1	3	1	0	0	0	2	2	1	0	0	2	3	2	2	2	2	1	1
24	<i>D. porphyrochilum</i>	0	0	0	0	0	0	0	0	0	2	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
25	<i>D. rotundatum</i>	2	3	3	1	2	2	1	1	1	2	2	2	3	0	2	0	1	0	1	1	0	0	3	2	1	1	2	2	1	1
26	<i>D. transparens</i>	2	2	1	2	1	1	1	1	1	1	2	2	3	1	0	0	0	0	0	1	0	0	1	1	0	0	1	1	1	1

In *D. fimbriatum* xylem pole and phloem pole are completely surrounded by fibre cap. STEGMATA with rough surfaced spherical silica bodies are present along the outer margin of xylem and phloem caps in *D. amoenum*, *D. chrysanthum*, *D. fugax* and *D. moschatum*; along xylem cap in *D. bicameratum*; along phloem cap in *D. aphyllum*, *D. crepidatum*, *D. denudans*, *D. fuscescens*, *D. gibsonii*, *D. nobile*; outer margin of fibre bundle in *D. anceps*; indistinct in *D. amplum*, *D. denneanum*, *D. densiflorum*, *D. fimbriatum*, *D. formosum*, *D. heterocarpum*, *D. longicornu*, *D. polyanthum*, *D. porphyrochilum*, *D. transparens*; *D. rotundatum* and lacking in *D. eriiflorum*, *D. moniliforme* and *D. monticola* (Table 4, Plates 1, 2, 3, 4, 5, 6, 7, 8).

Stem (T.S.)

Cuticle: thick and smooth in most species of *Dendrobium* but in *D. porphyrochilum* it is thin and smooth. Cuticle is intermittently in *D. anceps*.

Epidermis: cells vary from rectangular to square to polygonal to angular to barrel-shaped in shape. Cells are thin walled in *D. anceps*, *D. porphyrochilum* and thick walled in other species.

Hypodermis: one to two layers of polygonal parenchymatous cells are present in *D. anceps*, *D. aphyllum*, *D. crepidatum* and *D. polyanthum*. In remaining species, two to five layers of rectangular to oval to polygonal sclerenchymatous cells are present. Outer hypodermal cells are smaller than inner cells. Hypodermal cells are smaller than ground tissues.

Ground tissue: no differentiation of cortex, endodermis, pericycle and pith. A mass of thin walled parenchymatous cells with intercellular spaces are present in ground tissue. The cells are of two types: many, small, living, round to polygonal assimilatory parenchymatous cells and fewer, large, scattered, dead, water-storage cells with unpleated outlines in *D. anceps*, *D. crepidatum*, *D. densiflorum*, *D. fimbriatum*, *D. moschatum*, *D. nobile*, *D. polyanthum* and with pleated outlines in other species.

Starch grains are present in parenchymatous cells in all species except *D. amoenum*, *D. anceps*, *D. denneanum*, *D. denudans*, *D. monticola* and raphide bundles are present in *D. aphyllum*, *D. chrysanthum*, *D. densiflorum*, *D. eriiflorum*, *D. gibsonii*, *D. heterocarpum*, *D. longicornu*, *D. moniliforme*, *D. moschatum*, *D. polyanthum*, *D. rotundatum* and *D. transparens*. Calcium oxalate crystals are present in *D. porphyrochilum*.

Vascular bundle: conjoint, collateral and closed bundles are scattered in the ground tissue. Number of vascular bundle ranges from 16 (*D. polyanthum*) to 118 (*D. bicameratum*). Vascular bundles are oval to elongate in shape. The inner vascular bundles are larger than outer bundles. Sclerenchymatous bundle sheaths are present surrounding vascular bundles in *D. amoenum*, *D. anceps*, *D. chrysanthum*, *D. crepidatum*, *D. denudans*, *D. eriiflorum*, *D. fuscescens*, *D. heterocarpum*, *D. longicornu*, *D. porphyrochilum* and only xylem in *D. amplum*, *D. aphyllum*, *D. bicameratum*, *D. denneanum*, *D. densiflorum*, *D. fimbriatum*, *D. formosum*, *D. fugax*, *D. gibsonii*, *D. moniliforme*, *D. monticola*, *D. moschatum*, *D. nobile*, *D. polyanthum*, *D. rotundatum* and *D. transparens*. Fibre caps are present above phloem in *D. amoenum*, *D. longicornu*, *D. monticola*; surrounding xylem and phloem in *D. anceps*, *D. fuscescens* and surrounding phloem in remaining species.

Stegmata with rough surfaced spherical silica bodies are present along the outer margin of phloem cap in *D. amoenum*, *D. amplum*, *D. aphyllum*, *D. bicameratum*, *D. densiflorum*, *D. formosum*, *D. fugax*, *D. longicornu*, *D. polyanthum*, *D. rotundatum*, *D. transparens*; absent in *D. eriiflorum*, *D. moniliforme*, *D. monticola* and indistinct in remaining species (Table 5, Plates 1, 2, 3, 4, 5, 6, 7, 8). From the present study, the stomatal complex, stegmata and anatomical characters of leaves and stems were found to be taxonomically important for delimiting the taxa. Based on characters such as stomatal complex, stegmata and anatomical characters of leaves and stems, an anatomical key has been prepared to delimit the taxa within genus *Dendrobium*.

Table 3: Stomatal and Stegmatal characters in species of *Dendrobium*

S.No.	Taxa	Stomatal size with guard cells (l x w) µm	Stomatal pore size (l x w) µm	Stomatal Frequency mm ²	Stomatal Index %	Shape of Stomata	Type of Stomata	Shape of Epidermal cells	Type of Epidermal cells	Stegmata
1	<i>Dendrobium amoenum</i> Wallich ex Lindley	29.97 x 23.31	13.32 x 4.99	76.92	5.81	Elliptic	b-tetra-monocyclic	Rect. to poly.	Paren.	Spherical
2	<i>D. amplum</i> Lindley	33.30 x 29.97	16.65 x 6.66	107.69	6.03	Sub- orbicular	b-tetra-monocyclic	Rect. to poly.	Scleren.	Spherical
3	<i>D. anceps</i> Swartz	29.97 x 25.30	13.32 x 6.66	46.15	3.75	Elliptic	eupara twi + hexa- monocyclic	Rect. to poly.	Paren.	Indistinct
4	<i>D. aphyllum</i> (Roxburgh) C.E.C. Fischer	33.30 x 23.31	16.65 x 9.99	46.15	7.31	Elliptic	a-tetra-monocyclic	Rect. to poly.	Paren.	Spherical
5	<i>D. bicameratum</i> Lindley	33.30 x 29.97	23.31 x 9.99	76.92	7.04	Elliptic	a-tetra-monocyclic	Squa. to poly.	Paren.	Indistinct
6	<i>D. chrysanthum</i> Wallich ex Lindley	33.30 x 23.31	16.65 x 6.66	76.92	5.68	Circular	a-tetra-monocyclic	Squa. to poly.	Paren.	Spherical
7	<i>D. crepidatum</i> Lindley & Paxton	32.63 x 26.64	15.32 x 7.32	130.77	13.04	Elliptic	b-tetra-monocyclic	Squa. to poly.	Paren.	Spherical
8	<i>D. denneanum</i> Kerr	26.64 x 26.64	16.65 x 9.99	123.07	7.34	Circular	a-tetra-monocyclic	Squa. to poly.	Scleren.	Spherical
9	<i>D. densiflorum</i> Wallich	33.30 x 26.64	26.64 x 13.32	76.92	6.76	Elliptic	a-tetra-monocyclic	Squa. to poly.	Scleren.	N.P
10	<i>D. denudans</i> D. Don	39.96 x 26.64	26.64 x 9.99	92.3	10.71	Elliptic	a-tetra-monocyclic	Squa. to poly.	Paren.	Indistinct
11	<i>D. eriiflorum</i> Griffith	38.62 x 25.97	20.64 x 10.65	123.07	10.66	Elliptic	c-tetra-monocyclic	Rect. to poly.	Paren.	Indistinct
12	<i>D. fimbriatum</i> Hooker	33.30 x 34.60	16.65 x 9.99	123.07	10.38	Circular	a-tetra-monocyclic	Rect. to poly.	Scleren.	Spherical
13	<i>D. formosum</i> Roxburgh ex Lindley	45.96 x 41.96	24.64 x 6.66	76.92	12.5	Circular	c-tetra-monocyclic	Rect. to poly.	Scleren.	N.P
14	<i>D. fugax</i> Reichenbach	29.97 x 29.97	13.32 x 13.32	184.61	10.17	Circular	eupara twi- monocyclic	Squa. to poly.	Scleren.	Indistinct
15	<i>D. fuscescens</i> Griffith	23.31 x 23.31	13.32 x 6.66	76.92	5.37	Circular	a-tetra-monocyclic	Squa. to poly.	Scleren.	Spherical
16	<i>D. gibsonii</i> Paxton	33.30 x 24.98	19.98 x 6.66	76.92	8.33	Elliptic	a-tetra-monocyclic	Rect. to poly.	Paren.	Spherical
17	<i>D. heterocarpum</i> Wallich ex Lindley	38.30 x 33.30	16.65 x 10.00	92.3	13.04	Circular	a-tetra-monocyclic	Rect. to poly.	Paren.	Spherical
18	<i>D. longicornu</i> Lindley	29.97 x 23.31	13.32 x 4.99	123.07	10.53	Elliptic	a-tetra-monocyclic	Rect. to poly.	Paren.	N.P
19	<i>D. moniliforme</i> (L.) Swartz	38.30 x 34.00	16.65 x 6.66	138.5	12.5	Circular	a-tetra-monocyclic	Rect. to poly.	Paren.	Indistinct
20	<i>D. monticola</i> Hunt & Summerhayes	39.96 x 26.64	23.31 x 9.99	200	10.83	Elliptic	a-tetra-monocyclic	Rect. to poly.	Paren.	Indistinct
21	<i>D. moschatum</i> (Buchanan-Hamilton) Swartz	27.97 x 26.64	16.65 x 9.99	76.92	5	Circular	a-tetra-monocyclic	Rect. to poly.	Paren.	Spherical
22	<i>D. nobile</i> Lindley	44.95 x 39.96	27.30 x 17.98	92.31	15.79	Elliptic	c-tetra-monocyclic	Rect. to poly.	Paren.	Spherical
23	<i>D. polyanthum</i> Wallich ex Lindley	32.63 x 26.64	16.65 x 4.99	76.92	7.94	Elliptic	b-tetra-monocyclic	Rect. to poly.	Paren.	N.P
24	<i>D. porphyrochilum</i> Lindley	36.63 x 19.98	13.32 x 3.33	76.92	7.14	Elliptic	a-tetra-monocyclic	Squa. to poly.	Paren.	Spherical
25	<i>D. rotundatum</i> (Lindley) Hooker	26.64 x 23.31	13.32 x 6.66	92.3	8.33	Sub- orbicular	c-tetra-monocyclic	Rect. to poly.	Scleren.	Indistinct
26	<i>D. transparens</i> Wallich ex Lindley	33.30 x 27.31	17.98 x 6.66	138.46	10.71	Elliptic	b-tetra-monocyclic	Rect. to poly.	Paren.	Spherical

Abbreviations used: N.P = Not present; Rect. = Rectangular; poly. = Polygonal; Squa. = Square; Paren = Parenchyma; Scleren. = Sclerenchyma.

Table 4: Anatomical characters of leaf in species of *Dendrobium*

S.No.	Taxa	Cuticle layer	Shape	Epidermal cell		Hypodermis		Fibre bundle	Mesophyll		Mid Vascular bundle		Fibre cap size		Xylem size (l x w) μm	Phloem size (l x w) μm
				Size (w x l) μm		Position	Layer		Shape	Layer	Shape	Size (l x w) μm	Xylem cap (l x w) μm	Phloem cap (l x w) μm		
				Adaxial	Abaxial											
1	<i>Dendrobium amoenum</i> Wallich ex Lindley	Thin	Rect. to Poly.	19.98–69.93 x 19.98–33.30	13.32–43.29 x 9.99–23.31	N.P	N.P	N.P	Colu. to Poly.	7	Oval	193.14 x 133.20	83.25 x 143.19	33.30 x 133.20	9.99 – 29.97 x 6.66 – 26.64	4.99–6.66 x 3.33–4.99
2	<i>D. amplum</i> Lindley	Thick	Rect. to Poly.	19.98–56.61 x 16.65–29.97	16.65–49.95 x 9.99–19.98	N.P	N.P	N.P	Pali. Poly. to Colu. Spon.Oval to Poly.	Pali. 2 Spon. 7	Flask-shaped	199.80 x 143.19	16.65 x 139.86	46.62 x 166.50	6.66–23.31 x 4.99–19.98	3.33–6.66 x 2.66–4.99
3	<i>D. anceps</i> Swartz	Thick	Poly.	16.65–36.63 x 6.66–13.32	16.65–23.31 x 6.66–13.32	Abaxial	1	Present	Oval to Poly.	18	Circular	139.06 x 136.53	23.31 x 119.88	26.64 x 139.86	6.66 – 9.99 x 4.99 - 9.99	3.33–4.99 x 2.66–3.33
4	<i>D. aphyllum</i> (Roxburgh) C.E.C. Fischer	Thin	Rect. to Hexa.	46.62–76.59 x 36.63–49.95	23.31–66.60 x 13.32–29.97	N.P	N.P	N.P	Oval to Poly.	9	Oval	126.54 x 106.56	19.98 x 86.58	19.98 x 89.91	9.99–19.98 x 6.66 – 16.65	4.99–6.66 x 3.33–4.99
5	<i>D. bicameratum</i> Lindley	Thick	Rect. to Poly.	13.32–49.95 x 19.98–29.97	13.32–36.63 x 9.99–13.32	N.P	N.P	N.P	Oval to Poly.	8	Oval	119.88 x 93.24	26.64 x 89.91	19.98 x 93.24	6.66 – 13.32 x 4.99 – 6.66	3.99–6.66 x 2.66–3.33
6	<i>D. chrysanthum</i> Wallich ex Lindley	Thin	Rect. to Poly.	19.98–73.26 x 16.65–26.64	9.99–36.63 x 9.99–19.98	N.P	N.P	N.P	Rect.	8	Oval	219.79 x 209.78	49.95 x 186.48	36.63 x 183.15	9.9–19.98 x 8.32–19.98	6.66–9.99 x 3.33–6.66
7	<i>D. crepidatum</i> Lindley & Paxton	Thin	Rect. to Poly.	19.98–43.29 x 13.32–43.29	8.32–26.64 x 13.32–26.64	N.P	N.P	N.P	Rect. to Poly.	10	Conical	233.10 x 166.50	43.29 x 126.54	53.28 x 173.16	13.32–19.98 x 11.65–13.32	4.99–8.32 x 3.33–4.99

8	<i>D. denneanum</i> Kerr	Thick	Rect. to Poly.	19.98–33.30 x 13.32–16.65	16.65–26.64 x 8.32–9.99	N.P	N.P	N.P	Rect. to Poly.	8	Conical	216.45 x 189.81	49.95 x 166.50	33.30 x 176.49	6.66–19.98 x 4.99–16.65	3.33–6.66 x 3.33–4.99
9	<i>D. densiflorum</i> Wallich	Thick	Rect. to Poly.	23.31–36.63 x 13.32–23.31	16.65–26.64 x 13.32–19.98	Adaxial	1	N.P	Oval to Poly.	13	Conical	586.52 x 386.57	213.28 x 319.92	146.63 x 413.23	16.65–29.97 x 6.66–16.65	4.99–9.99 x 3.33–6.66
10	<i>D. denudans</i> D. Don	Thin	Rect. to Poly.	23.31–43.29 x 9.99–19.98	23.31–29.97 x 9.99–16.65	N.P	N.P	N.P	Rect. to Poly.	7	Oblong	126.54 x 53.28	23.31 x 53.28	23.31 x 56.61	13.32–19.98 x 4.99–6.66	4.99–6.66 x 3.99–4.99
11	<i>D. eriiflorum</i> Griffith	Thin	Rect. to Poly.	19.98–43.29 x 26.64–43.29	13.32–23.31 x 19.98–29.97	N.P	N.P	N.P	Rect. to Poly.	7	Oval	116.55 x 69.93	43.39 x 59.94	23.31 x 76.59	6.66–19.98 x 4.99–13.32	3.33–6.66 x 2.66–4.99
12	<i>D. fimbriatum</i> Hooker	Thin	Rect. to Poly.	16.65–39.96 x 13.32–26.64	9.99–23.31 x 6.66–16.65	N.P	N.P	N.P	Rect. to Poly.	7	Oval	169.83 x 123.21	43.29 x 116.55	33.30 x 129.80	9.99–19.98 x 9.99–16.65	3.33–6.66 x 1.66–4.99
13	<i>D. formosum</i> Roxburgh ex Lindley	Thin	Rect. to Poly.	36.63–76.59 x 33.30–46.62	19.98–43.29 x 19.98–33.30	N.P	N.P	N.P	Oval to Poly.	9	Oval	216.45 x 193.14	73.26 x 183.15	33.30 x 206.46	13.32–29.97 x 6.66–19.98	3.33–13.32 x 3.33–9.99
14	<i>D. fugax</i> Reichenbach	Thick	Rect. to Squa.	19.98–33.30 x 9.99–16.65	13.32–23.31 x 9.99–16.65	N.P	N.P	N.P	Oval to Poly.	15	Flask-shaped	223.11 x 166.50	56.61 x 166.50	36.63 x 199.80	9.99–26.64 x 9.99–16.65	4.99–9.99 x 3.33–6.66
15	<i>D. fuscescens</i> Griffith	Thick	Rect. to Poly.	23.31–43.29 x 16.65–26.64	16.65–39.96 x 16.65–23.31	N.P	N.P	N.P	Pali. Poly. to Oval Spon.Oval to Poly.	Pali. 2 Spon. 7	Flask-shaped	209.79 x 156.51	56.61 x 113.22	49.95 x 179.82	9.99–23.31 x 6.66–16.65	4.99–9.99 x 4.99–6.66

16	<i>D. gibsonii</i> Paxton	Thin	Rect. to Poly.	23.31– 66.60 x 13.32– 33.30	16.65– 33.30 x 13.32– 16.65	N.P	N.P	N.P	Rect. to Poly.	8	Oval	289.71 x 233.10	83.25 x 199.80	49.95 x 233.10	13.32–29.97 x 6.66–23.31	4.99– 9.99 x 3.33– 8.32
17	<i>D. heterocarpum</i> Wallich ex Lindley	Thin	Rect. to Poly.	26.64– 73.26 x 26.64– 53.28	9.99– 33.30 x 13.32– 26.64	N.P	N.P	N.P	Rect. to Poly.	7	Oval	149.85 x 116.55	19.98 x 99.90	19.98 x 86.58	6.66–19.98 x 4.99–16.65	3.99– 6.66 x 3.66– 4.99
18	<i>D. longicornu</i> Lindley	Thin	Rect. to Hexa.	23.31– 53.28 x 19.98– 46.62	19.98– 49.95 x 13.32– 33.30	N.P	N.P	N.P	Oval to Poly.	8	Circular	166.50 x 166.50	33.30 x 156.51	33.30 x 126.54	9.99–23.31 x 6.66–16.65	4.99– 6.66 x 3.33– 6.66
19	<i>D. moniliforme</i> (L.) Swartz	Thick	Rect. to Poly.	23.31– 56.61 x 36.63– 46.62	9.99– 26.64 x 13.32– 19.98	N.P	N.P	N.P	Rect. to Poly.	8	Oval	119.88 x 133.20	26.64 x 106.56	23.31 x 133.20	9.99–10.65 x 4.99–6.66	3.99– 5.99 x 2.66– 3.33
20	<i>D. monticola</i> Hunt & Summerhayes	Thin	Rect. to Poly.	13.32– 53.28 x 19.98– 33.30	13.32– 19.98 x 9.99– 19.98	N.P	N.P	N.P	Rect. to Poly.	6	Oval	99.90 x 66.60	23.31 x 53.28	13.32 x 66.60	6.66–9.99 x 3.33–8.32	4.99– 6.66 x 3.33– 4.99
21	<i>D. moschatum</i> (Buchanan- Hamilton) Swartz	Thin	Rect. to Hexa.	26.64– 66.60 x 16.65– 26.64	16.65– 23.31 x 9.99– 16.65	N.P	N.P	N.P	Oval to Poly.	16	Conical	506.54 x 333.25	159.96 x 319.92	106.64 x 333.25	19.98–39.96 x 6.66–26.64	4.99– 9.99 x 3.33– 8.32
22	<i>D. nobile</i> Lindley	Thin	Rect. to Hexa.	36.63– 83.25 x 73.26– 99.90	16.65– 53.28 x 23.31– 46.62	N.P	N.P	N.P	Oval to Poly.	9	Oval	199.80 x 166.50	49.95 x 166.50	26.64 x 159.84	19.98–23.31 x 9.99–19.98	6.66– 9.99 x 4.99– 6.66
23	<i>D. polyanthum</i> Wallich ex Lindley	Thin	Rect. to Hexa.	16.65– 33.30 x 9.99– 26.64	13.32– 29.97 x 9.99– 13.32	N.P	N.P	N.P	Oval to Poly.	8	Circular	213.12 x 199.80	83.25 x 193.14	43.29 x 173.16	6.66–23.31 x 3.33–6.66	4.99– 6.66 x 3.33– 4.99

24	<i>D. porphyrochilum</i> Lindley	Thin	Rect. to Hexa.	49.95– 73.26 x 19.98– 39.96	23.31– 39.96 x 16.65– 23.31	N.P	N.P	N.P	Oval to Poly.	6	Oblong	99.90 x 93.24	N.P	N.P	4.99–13.32 x 3.99–9.99	3.33– 4.99 x 2.66– 3.33
25	<i>D. rotundatum</i> (Lindley) Hooker	Thick	Rect. to Poly.	23.31– 49.95 x 16.65– 33.30	9.99– 39.96 x 16.65– 26.64	N.P	N.P	N.P	Pali. Poly. to Colu. Spon. Oval to Poly.	Pali. 2 Spon. 8	Flask- shaped	183.15 x 133.20	39.96 x 193.14	53.28 x 126.54	13.32–26.64 x 6.66–19.98	4.99– 6.66 x 3.33– 4.99
26	<i>D. transparens</i> Wallich ex Lindley	Thin	Rect. to Hexa.	23.31– 66.60 x 36.63– 59.94	13.32– 43.29 x 13.32– 23.31	N.P	N.P	N.P	Oval to Poly.	8	Circular	149.85 x 146.52	33.30 x 149.85	26.64 x 146.52	13.32–19.98 x 9.99–16.65	3.33– 6.66 x 3.33– 4.99

Abbreviations used: N.P=Not Present; Rect.=Rectangular; Poly.=Polygonal; Squa.= Square; Hexa.=Hexagonal; Colu.=Columnar; Pali.=Palisade layer; Spon.=Spongy layer.

Table 5: Anatomical characters of stem in species of *Dendrobium*

S.N.	Taxa	Cuticle	Epidermal cell		Hypodermis		Vascular bundle			Fibre cap size		Xylem size (l x w) µm	Phloem size (l x w) µm
			Shape	Size (w x l) µm	Shape	Layer	Shape	No.	Size (l x w) µm	Xylem cap (l x w) µm	Phloem cap (l x w) µm		
1	<i>Dendrobium amoenum</i> Wallich ex Lindley	Thick	Rect. to Poly.	9.99–19.98 x 4.99–9.99	Poly.	2	Oval	76	143.19–183.15 x 93.24–113.22	N.P	26.64–33.30 x 83.25–96.57	9.99–29.97 x 6.66–23.31	6.66–16.65 x 4.99–9.99
2	<i>D. amplum</i> Lindley	Thick	Rect. to Squa.	9.99–19.98 x 9.99–13.32	Poly.	2	Elongate	50	133.20–333.00 x 66.60–149.85	43.29– 56.61 x 106.56– 133.20 16.65– 26.64 x 79.92– 86.58	33.30–99.90 x 83.25–116.55	11.65–26.64 x 9.99–16.65	3.33–9.99 x 3.33–6.66
3	<i>D. anceps</i> Swartz	Thick	Barr.	9.99–16.65 x 6.66–9.99	Poly.	2	Oval	64	116.55–199.80 x 73.26–99.90	N.P	19.98–49.95 x 73.26–99.90	13.32–16.65 x 4.99–13.32	4.99–6.66 x 3.33–6.66
4	<i>D. aphyllum</i> (Roxburgh) C.E.C. Fischer	Thick	Barr.	9.99–13.32 x 16.65–26.64	Poly.	1	Oval	82	133.20–236.43 x 103.23– 106.56	N.P	29.97–33.30 x 99.90–93.24	13.32–26.64 x 9.99–19.98	6.66–13.32 x 4.99–6.66
5	<i>D. bicameratum</i> Lindley	Thick	Barr.	9.99–13.32 x 6.66–9.99	Poly.	2 to 3	Elongate	118	93.24–199.80 x 83.25–93.24	N.P	16.65–33.30 x 49.95–66.60	13.32–33.30 x 6.66–26.64	4.99–6.66 x 3.33–6.66

6	<i>D. chrysanthum</i> Wallich ex Lindley	Thick	Barr.	13.32-19.98 9.99-13.32	x	Oval poly.	to	2	Elongate	70	103.23-266.40 x 83.25-133.20	N.P	16.65-33.30 83.25-96.57	x	9.99-33.30 9.99-29.97	x	4.99-9.99 3.33-6.66	x
7	<i>D. crepidatum</i> Lindley & Paxton	Thick	Rect. to Poly.	13.32-36.63 6.66-6.65	x	Oblo. Poly.	to	1	Oval	60	123.21-209.79 x 83.25-99.90	N.P	19.98-26.64 49.95-66.60	x	13.32-26.64 6.66-19.98	x	4.99-9.99 3.33-9.32	x
8	<i>D. denneanum</i> Kerr	Thick	Barr.	9.99-19.98 6.66-13.32	x	Rect. Poly.	to	4	Elongate	97	163.17-299.70 x 143.19-149.85	N.P	39.96-49.95 116.55-119.88	x	43.29-49.95 23.31-23.31	x	9.99-13.32 x 6.66-9.99	x
9	<i>D. densiflorum</i> Wallich	Thick	Rect.	6.66-9.99 16.65-16.65	x	Rect. Poly.	to	4 to 5	Oval	78	106.56-206.46 x 89.91-153.18	N.P	26.64-36.63 83.25-119.88	x	9.99-13.32 6.66-9.99	x	3.33-4.99 2.66-3.33	x
10	<i>D. denudans</i> D. Don	Thick	Rect.	13.32-26.64 6.66-13.32	x	N.P	N.P	N.P	Oval	50	66.60-119.88 x 56.61-76.59	N.P	16.65-16.65 49.95-56.6	x	9.99-13.32 6.66-9.99	x	3.33-4.99 2.66-3.33	x
11	<i>D. eriiflorum</i> Griffith	Thick	Rect.	13.32-26.64 6.66-13.32	x	N.P	N.P	N.P	Oval	70	113.22-199.80 x 86.58-126.54	N.P	19.98-29.97 49.95-66.60	x	13.32-16.65 9.99-13.32	x	3.33-6.66 3.33-4.99	x
12	<i>D. fimbriatum</i> Hooker	Thick	Barr.	13.32-16.65 9.99-11.65	x	Rect. Poly.	to	4 to 5	Oval	62	133.20-199.80 x 109.89-133.20	N.P	39.96-43.29 106.56-123.21	x	26.64-49.95 9.99-13.32	x	6.66-16.65 4.99-9.99	x
13	<i>D. formosum</i> Roxburgh ex Lindley	Thick	Rect. to Poly.	16.65-39.96 9.99-16.65	x	Poly.	2	Oval	64	166.50-233.10 x 119.88-153.18	N.P	33.30-53.28 89.91-109.89	x	26.64-49.95 9.99-13.32	x	6.66-16.65 4.99-9.99	x	
14	<i>D. fugax</i> Reichenbach	Thick	Barr.	13.32-23.31 9.99-16.65	x	Poly.	2	Elongate	71	116.55-216.45 x 86.58-166.50	N.P	26.64-33.30 79.92-99.90	x	13.32-23.31 9.99-16.65	x	4.99-6.66 3.33-6.66	x	
15	<i>D. fuscescens</i> Griffith	Thick	Rect. to Squa.	9.99-26.64 6.66-19.98	x	Poly.	2	Oval	83	99.90-243.09 x 89.91-116.55	16.65-49.95 59.94-116.55	x	16.65-26.64 59.94-66.60	x	6.66-23.31 6.66-16.65	x	3.33-9.99 3.33-6.66	x
16	<i>D. gibsonii</i> Paxton	Thick	Rect. to Angu.	13.32-16.65 6.66-13.32	x	Poly.	2	Oval	30	123.31-316.35 x 93.24-183.15	N.P	16.65-69.93 76.59-93.24	x	16.65-29.97 9.99-19.98	x	4.99-13.32 3.33-9.99	x	
17	<i>D. heterocarpum</i> Wallich ex Lindley	Thick	Rect. to Angu.	13.32-19.98 6.66-13.32	x	Poly.	2	Oval	80	116.55-179.82 x 99.90-109.89	N.P	16.65-43.29 73.26-83.25	x	9.99-16.65 4.99-13.32	x	6.66-9.99 4.99-6.66	x	
18	<i>D. longicornu</i> Lindley	Thick	Rect. to Poly.	13.32-19.98 6.66-13.32	x	Poly.	2	Elongate	68	76.59-183.15 x 89.91-119.88	N.P	16.65-46.62 79.92-83.25	x	9.99-26.64 4.99-19.98	x	4.99-11.65 3.33-9.99	x	
19	<i>D. moniliforme</i> (L.) Swartz	Thick	Rect. to Poly.	13.32-23.31 6.66-13.32	x	Poly.	2	Elongate	55	199.80-233.10 x 113.22-166.50	N.P	23.31-29.97 49.95-66.60	x	19.80-23.31 13.32-19.98	x	9.99-13.32 4.99-9.99	x	
20	<i>D. monticola</i> Hunt & Summerhayes	Thick	Rect.	16.65-36.63 6.66-9.99	x	N.P	N.P	N.P	Elongate	20	66.60-89.91 x 49.95-53.28	N.P	13.32-16.65 43.29-49.95	x	6.66-13.32 4.99-9.99	x	4.99-6.66 3.33-4.99	x

21	<i>D. moschatum</i> (Buchanan-Hamilton) Swartz	Thick	Barr.	9.99-13.32 x 13.32-16.65	Poly.	3	Oval	78	133.20-166.50 x 113.22- 133.20	26.64- 43.29 x 66.60- 99.90	33.30-36.63 x 113.22-133.20	13.32-16.65 x 9.99-13.32	3.33-6.66 x 3.33-4.99
22	<i>D. nobile</i> Lindley	Thick	Rect. to Poly.	13.32-26.64 x 6.66-13.32	Poly.	2	Oval	82	116.55-216.45 x 86.58-166.50	N.P	26.64-33.30 x 79.92 - 99.90	13.32-19.98 x 9.99-16.65	4.99-6.66 x 3.33-6.66
23	<i>D. polyanthum</i> Wallich ex Lindley	Thick	Rect. to Poly.	19.98-39.96 x 13.32-16.65	Poly.	1	Elongate	16	99.90-289.71 x 49.95-133.20	N.P	33.30-36.30 x 63.27-119.88	9.99-39.96 x 6.66-23.31	4.99-16.65 x 3.33-13.32
24	<i>D. porphyrochilum</i> Lindley	Thin	Rect. to Poly.	29.97-46.62 x 19.98-23.31	N.P	N.P	Elongate	40	89.91-166.50 x 66.60- 83.25	N.P	N.P	9.99-16.65 x 6.66-9.99	6.66-8.32 x 3.33-6.66
25	<i>D. rotundatum</i> (Lindley) Hooker	Thick	Rect. to Squa.	16.65-29.97 x 9.99-16.65	Poly.	2	Oval	82	99.90-166.50 x 83.25-116.55	N.P	13.32-39.96 x 33.30-99.90	16.65-23.31 x 13.32-19.98	3.33-13.32 x 3.33-9.99
26	<i>D. transparens</i> Wallich ex Lindley	Thick	Rect. to Squa.	13.32-19.98 x 9.99-19.98	Poly.	2	Elongate	50	96.57-133.32 x 63.27-79.92	N.P	23.31-26.64 x 59.94-76.59	9.99-16.65 x 6.66-9.99	6.66-8.32 x 3.33-6.66

Abbreviations used: N.P = Not present; Rect. = Rectangular; Poly. = Polygonal; Angu. = Angular; Squa. = Square; Barr. = Barrel-shaped.

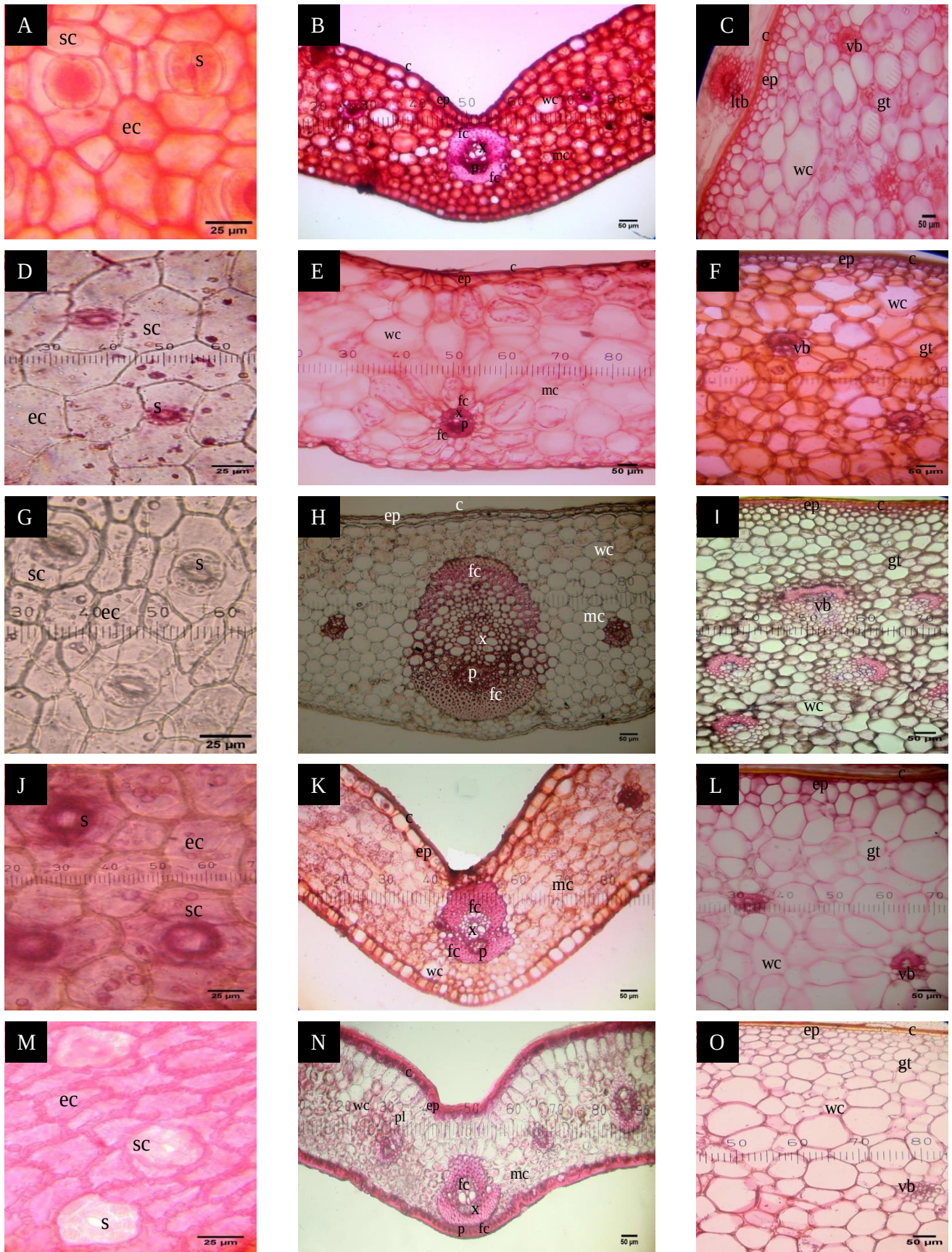


PLATE 1: *D. longicornu* A. Stomata , B. T.S. Leaf, C. T.S. Stem; *D. aphyllum* D., Stomata, E. T.S. Leaf, F. T.S. Stem; *D. moschatum* G. Stomata, H. T.S. Leaf, I. T.S. Stem; *D. formosum* J. Stomata , K. T.S. Leaf, L. T.S. Stem; *D. rotundatum* M. Stomata, N. T.S. Leaf, O. T.S. Stem. Stomata showing stoma (s), subsidiary cell (sc), epidermal cell (ec); T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc), palisade layer (pl), water-storage cell (wc); T.S. Stem showing cuticle (c), epidermis (ep), leaf trace bundle (ltb), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

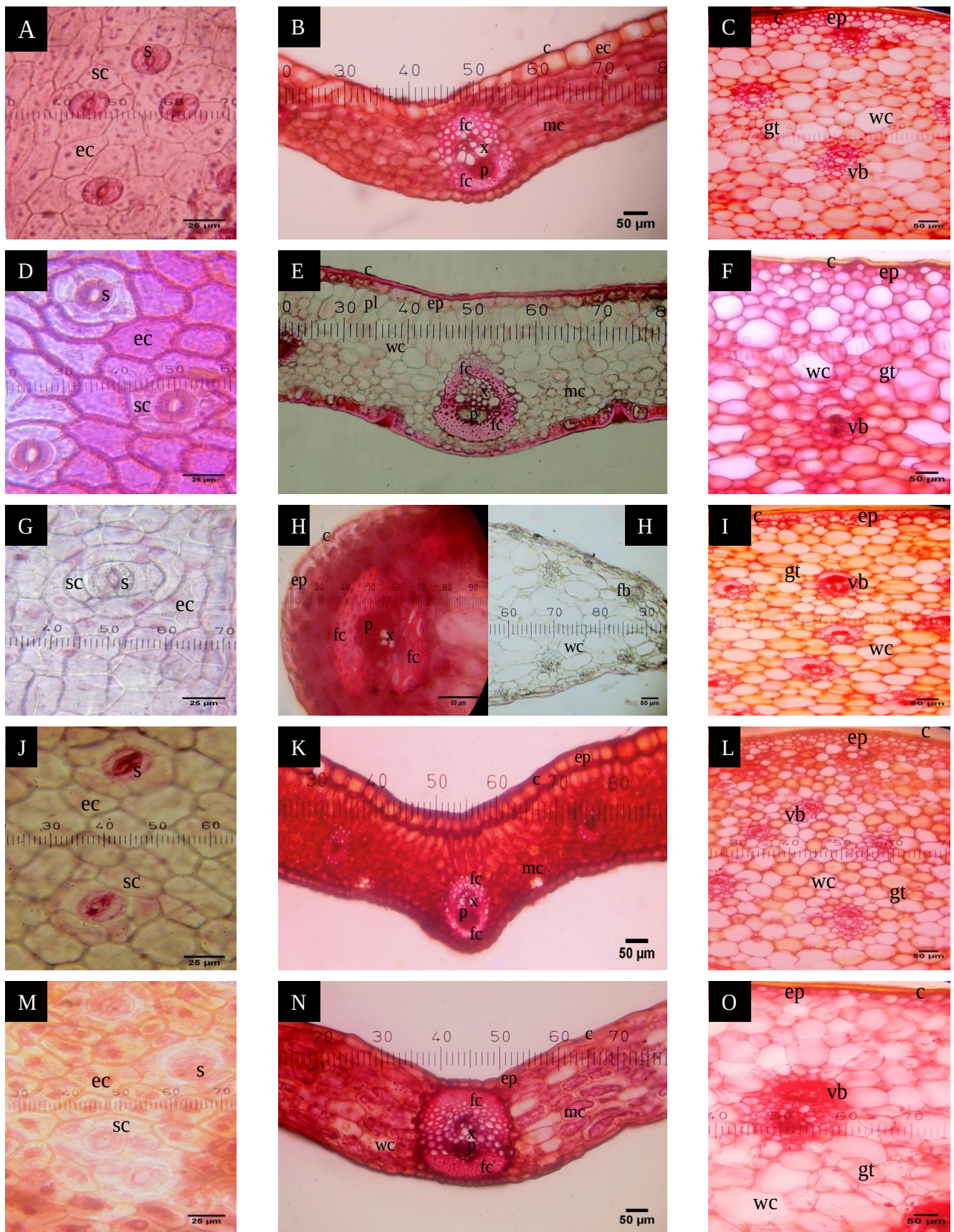


PLATE 2: *D. amoenum* A. Stomata , B. T.S. Leaf, C. T.S. Stem; *D. amplum* D. Stomata , E. T.S. Leaf, F. T.S. Stem; *D. anceps* G. Stomata, H. T.S. Leaf, I. T.S. Stem; *D. bicameratum* J. Stomata , K. T.S. Leaf, L. T.S. Stem; *D. chrysanthum* M. Stomata, N. T.S. Leaf, O. T.S. Stem. Stomata showing stoma (s), subsidiary cell (sc), epidermal cell (ec); T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc), palisade layer (pl), water-storage cell (wc); T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

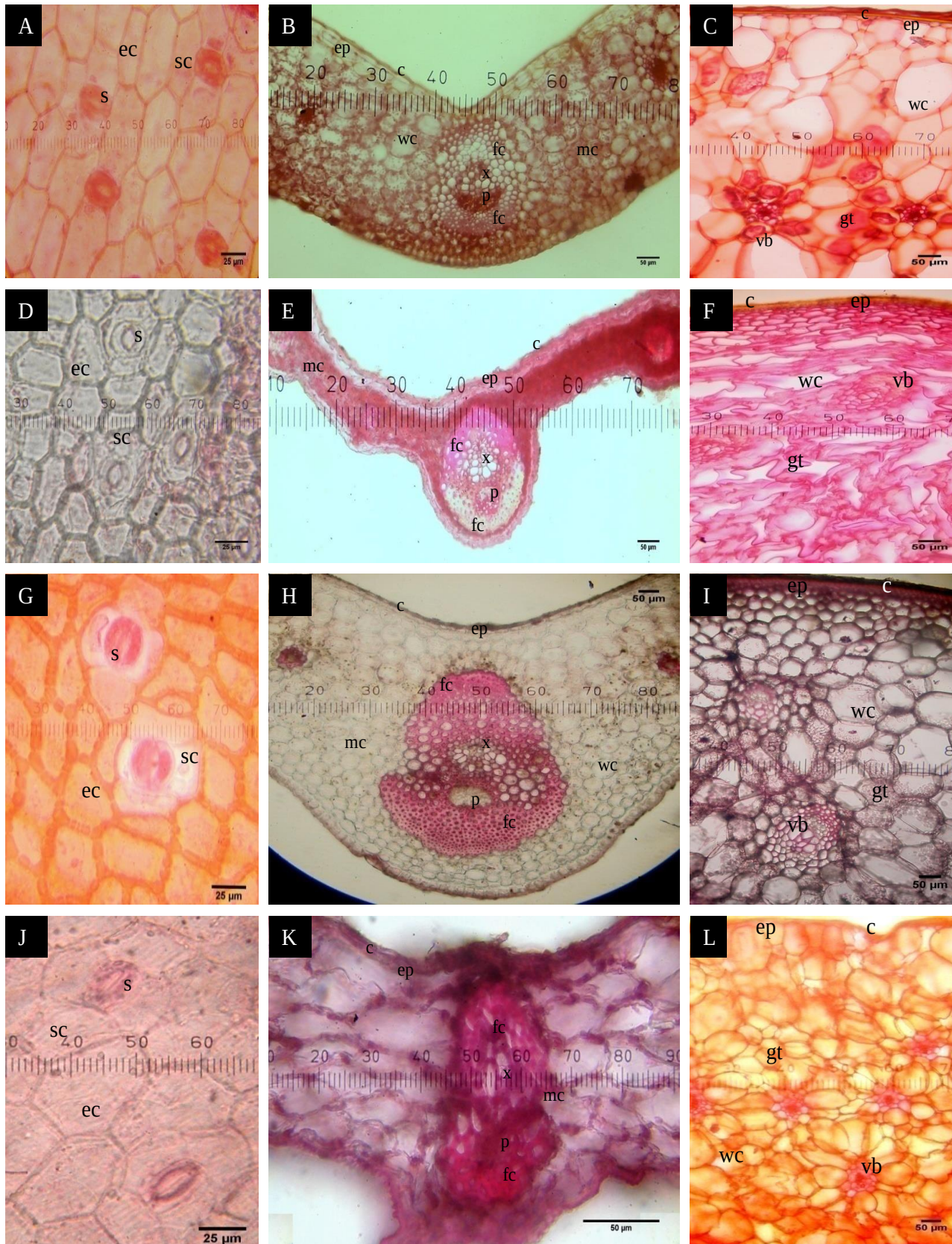


PLATE 3: *D. crepidatum* A. Stomata , B. T.S. Leaf, C. T.S. Stem; ***D. denneanum*** D. Stomata , E. T.S. Leaf, F. T.S. Stem; ***D. densiflorum*** G. Stomata, H. T.S. Leaf, I. T.S. Stem; ***D. denudans*** J. Stomata, K. T.S. Leaf, L. T.S. Stem. Stomata showing stoma (s), subsidiary cell (sc), epidermal cell (ec); T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc), water-storage cell (wc); T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

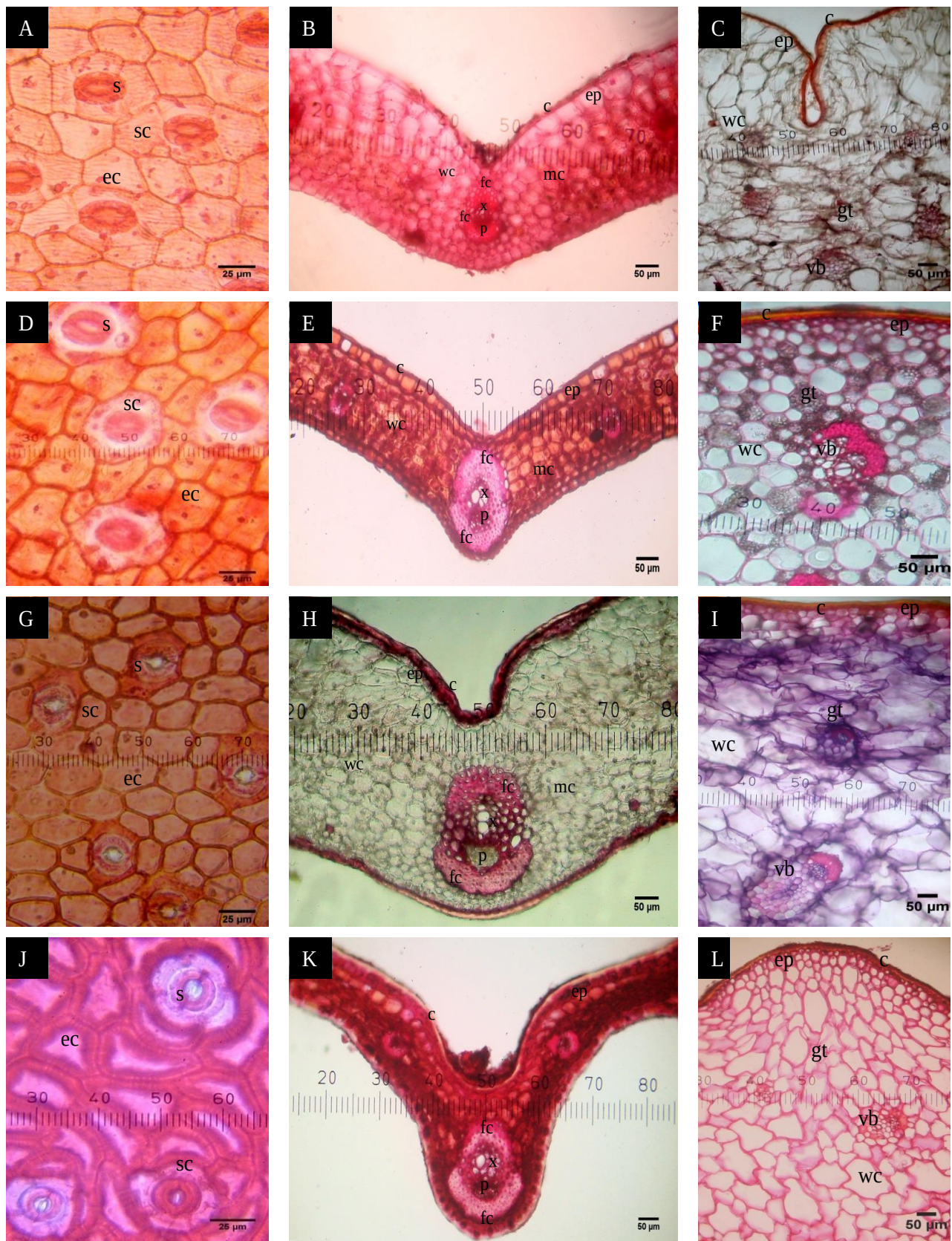


PLATE 4: *D. eriiflorum* A. Stomata , B. T.S. Leaf, C. T.S. Stem; *D. fimbriatum* D. Stomata , E. T.S. Leaf, F. T.S. Stem; *D. fugax* G. Stomata, H. T.S. Leaf, I. T.S. Stem; *D. fuscescens* J. Stomata , K. T.S. Leaf, L. T.S. Stem. Stomata showing stoma (s), subsidiary cell (sc), epidermal cell (ec); T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc), water-storage cell (wc); T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

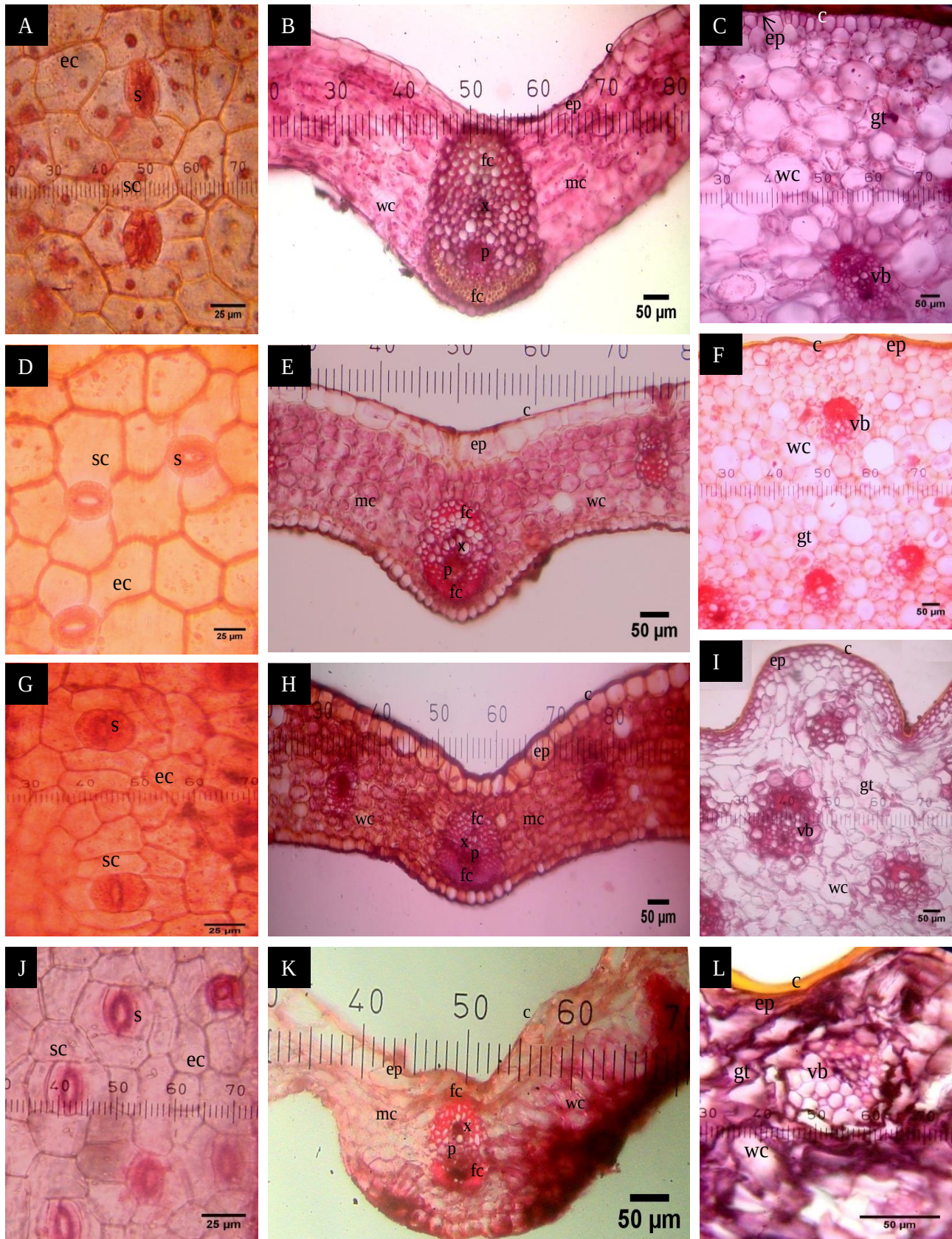


PLATE 5: *D. gibsonii* A. Stomata , B. T.S. Leaf, C. T.S. Stem; ***D. heterocarpum*** D. Stomata , E. T.S. Leaf, F. T.S. Stem; ***D. moniliforme*** G. Stomata, H. T.S. Leaf, I. T.S. Stem; ***D. monticola*** J Stomata , K. T.S. Leaf, L. T.S. Stem. Stomata showing stoma (s), subsidiary cell (sc), epidermal cell (ec); T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc), water-storage cell (wc); T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

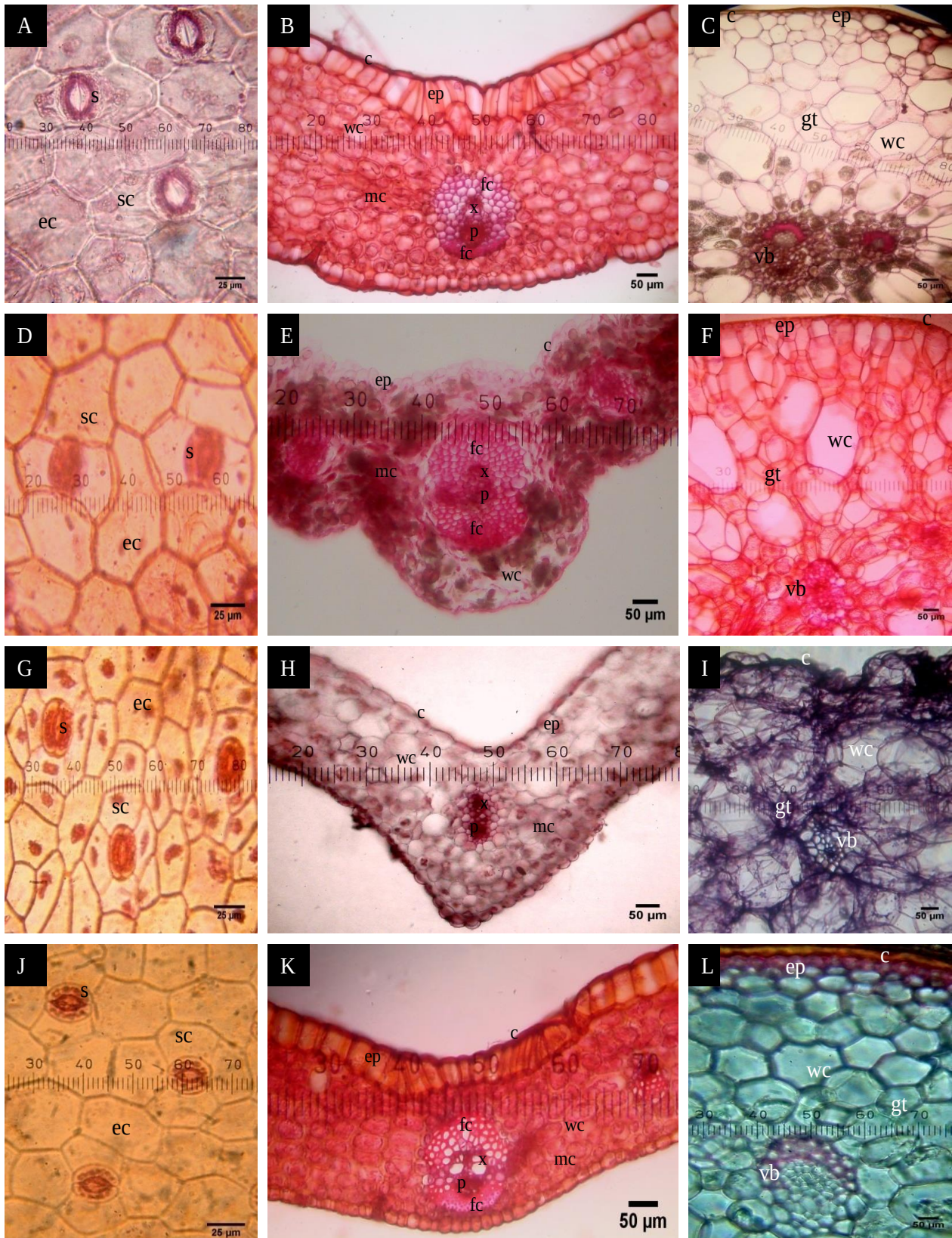


PLATE 6: *D. nobile* A. Stomata, B. T.S. Leaf, C. T.S. Stem; ***D. polyanthum*** D. Stomata, E. T.S. Leaf, F. T.S. Stem; ***D. porphyrochilum*** G. Stomata, H. T.S. Leaf, I. T.S. Stem; ***D. transparens*** J. Stomata, K. T.S. Leaf, L. T.S. Stem. Stomata showing stoma (s), subsidiary cell (sc), epidermal cell (ec); T.S. Leaf showing cuticle (c), epidermis (ep), mesophyll cell (mc), xylem (x), phloem (p), fibre cap (fc), water-storage cell (wc); T.S. Stem showing cuticle (c), epidermis (ep), ground tissue (gt), vascular bundle (vb), water-storage cell (wc).

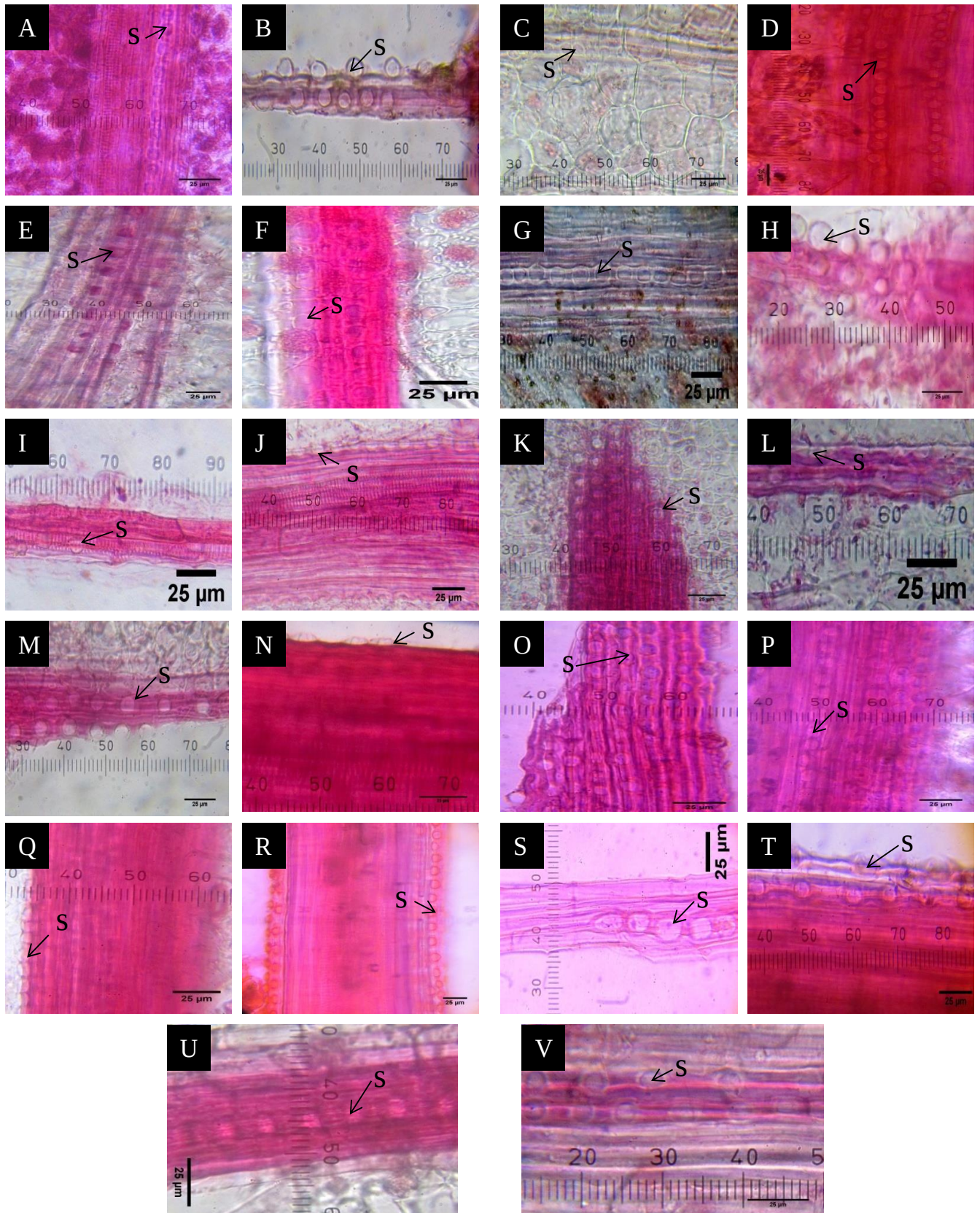


PLATE 7: Stigmata in Leaf surface of *Dendrobium* species (A-V). A. *D. amoenum*; B. *D. amplum*; C. *D. anceps*; D. *D. aphyllum*; E. *D. bicameratum*; F. *D. chrysanthum*; G. *D. crepidatum*; H. *D. denneanum*; I. *D. denudans*; J. *D. eriiflorum*; K. *D. fimbriatum*; L. *D. fugax*; M. *D. fuscescens*; N. *D. gibsonii*; O. *D. heterocarpum*; P. *D. moniliforme*; Q. *D. monticola*; R. *D. moschatum*; S. *D. nobile*; T. *D. porphyrochilum*; U. *D. rotundatum*; V. *D. transparens*. Leaf surface showing stigmata (s).

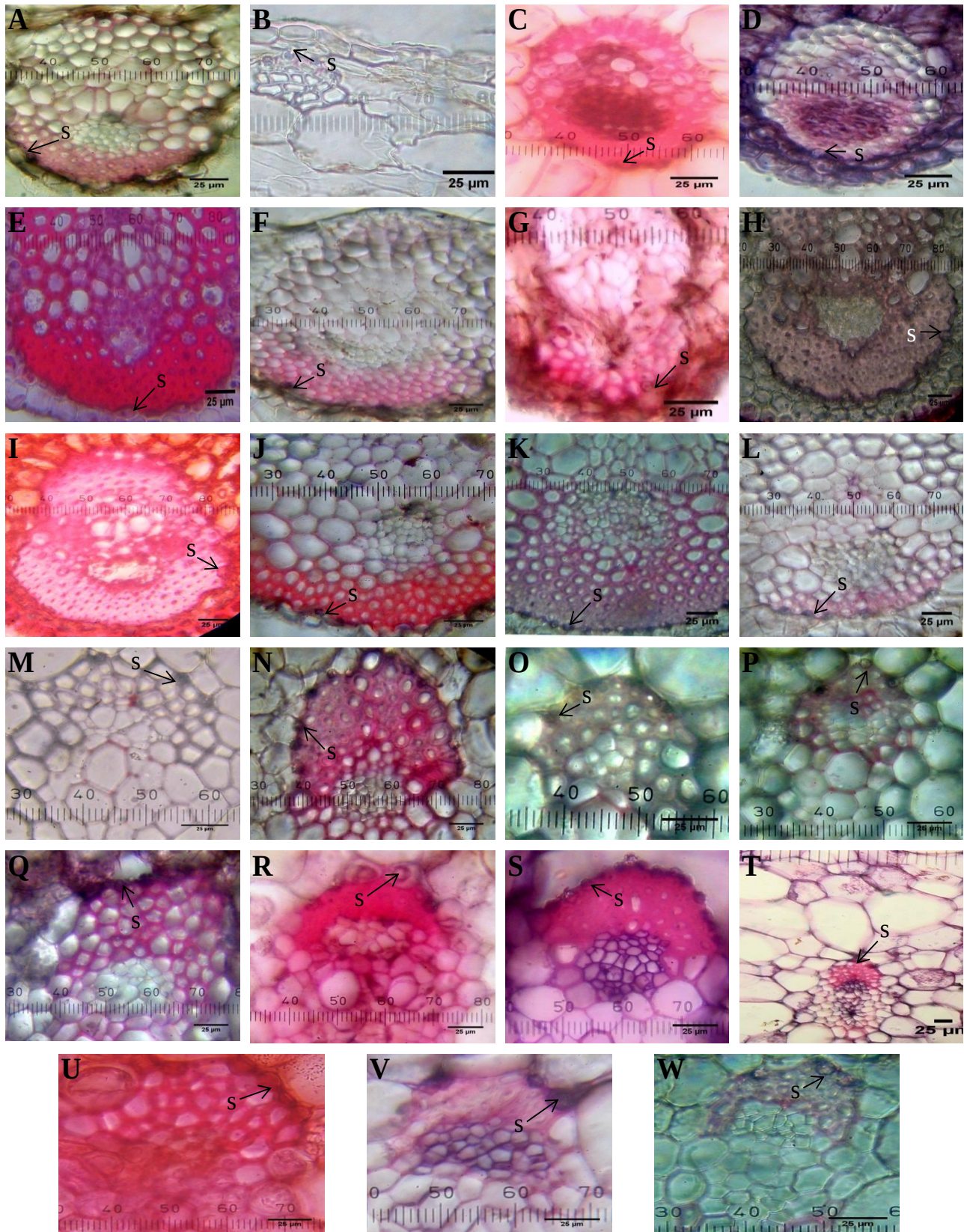


PLATE 8: Stigmata in *Dendrobium* species. T.S. Leaf (A-L) A. *D. amoenum*, B. *D. anceps*, C. *D. aphyllum*, D. *D. bicameratum*, E. *D. chrysanthum*, F. *D. crepidatum*, G. *D. denudans*, H. *D. fugax*, I. *D. fuscescens*, J. *D. gibsonii*, K. *D. moschatum*, L. *D. nobile*; T.S. Stem (M-W) M. *D. amoenum*, N. *D. amplum*, O. *D. aphyllum*, P. *D. bicameratum*, Q. *D. densiflorum*, R. *D. formosum*, S. *D. fugax*, T. *D. longicornu*, U. *D. polyanthum*, V. *D. rotundatum*, W. *D. transparens*. T.S. Leaf showing stigmata (s) and T.S. Stem showing stigmata (s).

Anatomical Key to the species of *Dendrobium*

1a. Leaf with thick cuticle -----	2
1b. Leaf with thin cuticle -----	10
2a. Thick cuticle with homogenous mesophyll in leaf -----	3
2b. Thick cuticle with heterogenous mesophyll in leaf -----	8
3a. Homogenous mesophyll with major vascular bundle at one leaf pole -----	<i>D. anceps</i>
3b. Homogenous mesophyll without major vascular bundle at one leaf pole -----	4
4a. Elongate shaped vascular bundle in stem -----	5
4b. Oval shaped vascular bundle in stem -----	<i>D. densiflorum</i>
5a. Stem hypodermal layers 4 -----	<i>D. denneanum</i>
5b. Stem hypodermal layers < 4 -----	6
6a. Oval shaped vascular bundle in leaf -----	7
6b. Flask-shaped vascular bundle in leaf -----	<i>D. fugax</i>
7a. Barrel shaped epidermal cells in stem -----	<i>D. bicameratum</i>
7b. Rectangular to polygonal shaped epidermal cells in stem -----	<i>D. moniliforme</i>
8a. Fibre cap surrounding xylem and phloem in stem -----	9
8b. Fibre cap surrounding phloem in stem -----	<i>D. rotundatum</i>
9a. Stem vascular bundle 333.0 μm long -----	<i>D. amplum</i>
9b. Stem vascular bundle 243.09 μm long -----	<i>D. fuscescens</i>
10a. Thin leaf cuticle without hypodermis in stem -----	11
10b. Thin leaf cuticle with hypodermis in stem -----	14
11a. Fibre caps surrounding xylem and phloem present in leaf -----	12
11b. Fibre caps surrounding xylem and phloem absent in leaf -----	<i>D. porphyrochilum</i>
12a. Number of vascular bundles 20 in stem -----	<i>D. monticola</i>
12b. Number of vascular bundles > 20 in stem -----	13
13a. Stem vascular bundle 119.88 μm long -----	<i>D. denudans</i>
13b. Stem vascular bundle 199.80 μm long -----	<i>D. eriiflorum</i>
14a. Midrib vascular bundle 506.54 μm long in leaf -----	<i>D. moschatum</i>
14b. Midrib vascular bundle < 506.54 μm long in leaf -----	15
15a. Mesophyll layers 10 in leaf -----	<i>D. crepidatum</i>
15b. Mesophyll layers < 10 in leaf -----	16
16a. Phloem fibre cap 233.10 μm wide in leaf -----	<i>D. gibsonii</i>
16b. Phloem fibre cap < 233.10 μm wide in leaf -----	17
17a. Xylem 16.65 μm long in stem -----	<i>D. transparens</i>
17b. Xylem > 16.65 μm long in stem -----	18
18a. Xylem fibre cap 86.58 μm wide in leaf -----	<i>D. aphyllum</i>
18b. Xylem fibre cap > 86.58 μm wide in leaf -----	19
19a. Stem vascular bundle 289.71 μm long -----	<i>D. polyanthum</i>
19b. Stem vascular bundle < 289.71 μm long -----	20
20a. Hypodermal layers 2 in stem -----	21
20b. Hypodermal layers 5 in stem -----	<i>D. fimbriatum</i>
21a. Oval shaped midrib vascular bundle in leaf -----	22
21b. Circular shaped midrib vascular bundle in leaf -----	<i>D. longicornu</i>
22a. Phloem fibre cap 206.46 μm wide in leaf -----	<i>D. formosum</i>
22b. Phloem fibre cap < 206.46 μm wide in leaf -----	23
23a. Oval shaped vascular bundle in stem -----	24
23b. Elongate shaped vascular bundle in stem -----	<i>D. chrysanthum</i>
24a. Mesophyll layer 7 in leaf -----	25
24b. Mesophyll layer 9 in leaf -----	<i>D. nobile</i>
25a. Mesophyll cell columnar to polygonal in leaf -----	<i>D. amoenum</i>
25b. Mesophyll cell rectangular to polygonal in leaf -----	<i>D. heterocarpum</i>

Cluster analysis

The anatomical data were analyzed to find the interrelationship among the species of genus *Dendrobium*. The analysis results in one dendrogram with AU *p*-value (printed in red colour by default) and BP value (printed in green colour by default). In the dendrogram, AU *p*-value above 95% was the significant clusters.

The dendrogram of cluster analysis of species of *Dendrobium* is presented in Fig. 1. The topology showed that the species of *Dendrobium* were divided into two major clusters: cluster A with AU *p*-value of 45% and BP *p*-value of 19% and cluster B with AU *p*-value of 49% and BP *p*-value of 18% with significant values.

Cluster A was further divided into two clusters: cluster C with a single species *D. anceps* (section Aporum) and cluster D with *D. longicornu*, *D. polyanthum*, *D. porphyrochilum*, *D. denudans* and *D. transparens*. Cluster D was again divided into two clusters: cluster D1 with *D. longicornu* and *D. polyanthum* with AU *p*-value of 60% and BP *p*-value of 24% and cluster D2 with *D. porphyrochilum*, *D. denudans* and *D. transparens* with AU *p*-value of 68% and BP *p*-value of 24%. Cluster D2 was again divided into two clusters: cluster D2a with single species *D. porphyrochilum* (section Stachyobium) and cluster D2b with *D. denudans* and *D. transparens*.

Cluster B was further divided into two clusters: cluster E with AU *p*-value of 66% and BP *p*-value of 3% and cluster F with AU *p*-value of 69% and BP *p*-value of 1%. Cluster E was again divided into two clusters: cluster E1 with *D. moniliforme*, *D. eriiflorum* and *D. monticola* and cluster E2 with *D. bicameratum*, *D. amoenum*, *D. aphyllum* and *D. heterocarpum*. Cluster E1 was again divided into two clusters: cluster E1a with a single species *D. moniliforme* (section Dendrobium) and cluster E1b with *D. eriiflorum* and *D. monticola*. Cluster E2 was again divided into two clusters: cluster E2a with a single species *D. bicameratum* (section Dendrobium) and cluster E2b with *D. amoenum*, *D. aphyllum*

and *D. heterocarpum*. Cluster E2b again divided into two clusters: cluster E2bi with *D. amoenum* (section Dendrobium) and cluster E2bii with *D. aphyllum* and *D. heterocarpum*. Cluster F was divided into two clusters: cluster F1 with *D. rotundatum*, *D. amplum* and *D. fuscescens* (section Sarcopodium) with AU *p*-value of 98% and BP *p*-value of 64% with significant values and cluster F2 with *D. fugax*, *D. formosum*, *D. nobile*, *D. densiflorum*, *D. moschatum*, *D. chrysanthum*, *D. gibsonii*, *D. crepidatum*, *D. denneanum* and *D. fimbriatum* with AU *p*-value of 87% and BP *p*-value of 1%. Cluster F1 again divided into two clusters: cluster F1a with *D. rotundatum* and cluster F1b with *D. amplum* and *D. fuscescens*. Cluster F2 further divided into two clusters: cluster F2a with *D. fugax*, *D. formosum* and *D. nobile* with AU *p*-value of 94% and BP *p*-value of 35% with significant values and cluster F2b with *D. densiflorum*, *D. moschatum*, *D. chrysanthum*, *D. gibsonii*, *D. crepidatum*, *D. denneanum* and *D. fimbriatum* with AU *p*-value of 96% and BP *p*-value of 0% with significant values. Cluster F2a again divided into two clusters: cluster F2ai with *D. fugax* (section Crinifera) and cluster F2aii with *D. formosum* and *D. nobile* with AU *p*-value of 92% and BP *p*-value of 54% with significant values. Cluster F2b again divided into two clusters: cluster F2bi with *D. densiflorum* and *D. moschatum* with AU *p*-value of 98% and BP *p*-value of 85% with significant values and cluster F2bii with *D. chrysanthum*, *D. gibsonii*, *D. crepidatum*, *D. denneanum* and *D. fimbriatum* with AU *p*-value of 81% and BP *p*-value of 0% with significant values. Cluster F2bii again divided into two clusters: cluster F2biii with *D. chrysanthum* and *D. gibsonii* with AU *p*-value of 94% and BP *p*-value of 77% with significant values and cluster F2biv with *D. crepidatum*, *D. denneanum* and *D. fimbriatum* with AU *p*-value of 83% and BP *p*-value of 8% with significant values. Cluster F2biv again divided into two clusters: cluster F2bv with *D. crepidatum* and cluster F2bvi with *D. denneanum* and *D. fimbriatum*.

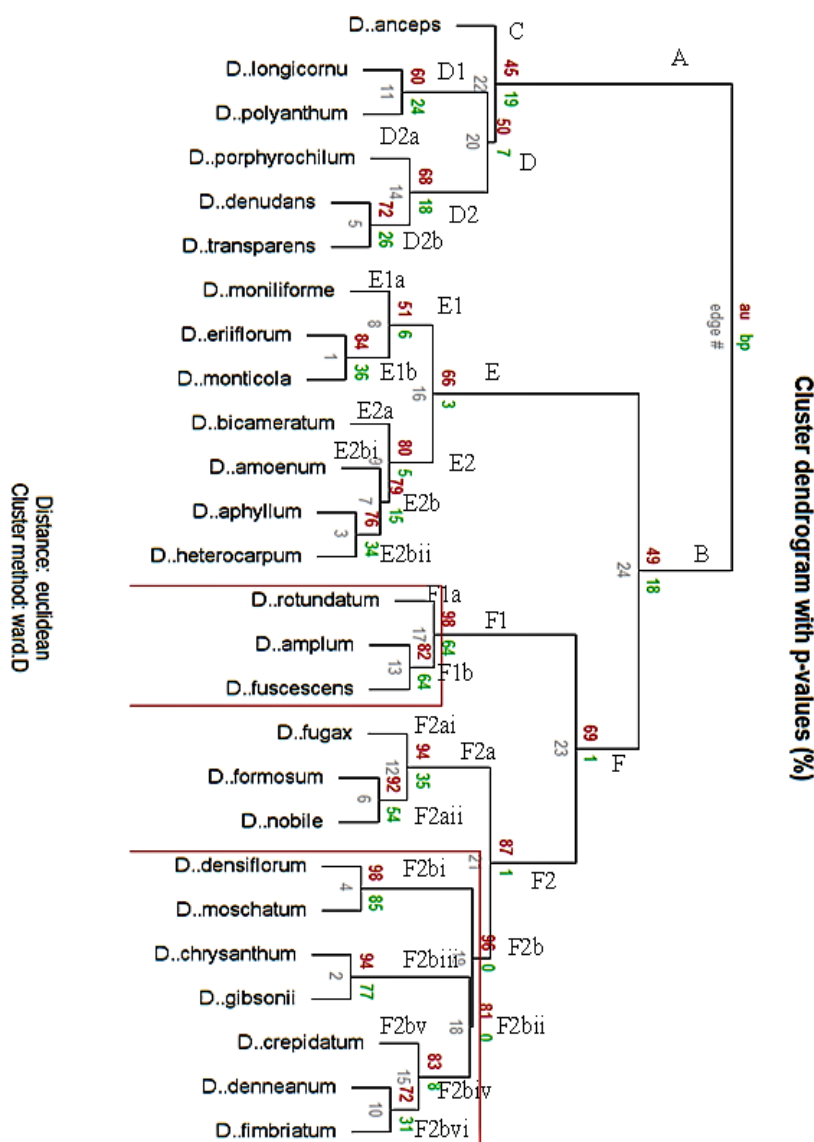


Figure 1. Cluster dendrogram constructed according to pvclust cluster analysis with AU/BP p -values in % and the bootstrapping of 10000. The AU/BP p -values are indicated below the branches. The AU p -values above 95% indicates the significant clusters.

Discussion

The present study revealed that the stomatal complex, stigmata, anatomy of leaves and stems of different species of *Dendrobium* showed variations in stomatal, stigmatal and anatomical characters of stem and leaves.

The stomatal complex of *Dendrobium* showed variation in types of epidermal cells, shape, size and types of stomata, stomatal frequency and stomatal index. All species of *Dendrobium* showed hypostomatic leaf surface. The leaves are found hypostomatic condition in most of orchids (Avadhani *et al.*, 1982). Stomata were found

only on the abaxial surface (hypostomatic). This is because these plants are adapted to aerial habitats to minimize water loss through stomata (Stebbins & Khush 1961). The epidermal cells on the abaxial surface varied from rectangular, squarish, pentagonal, hexagonal to polygonal, irregular with thick or thin walled parenchymatous cells and some species with sclerenchymatous cells. The shape of stomata varied from elliptical, circular to suborbicular. In *Dendrobium* most species had elliptical stomata and few species with circular stomata whereas in *D. amplum* and *D. rotundatum* suborbicular stomata were present. Various modi-

fications of stomatal shape such as elliptical, circular, transversely elliptical and angular are known to exist within Orchidaceae (Rasmussen 1987). Two types of stomatal shape (Stoma I and Stoma II) were reported in *Dendrobium* (Yukawa *et al.*, 1992). In the present study, the presence of two types of stomatal shape i.e. elliptical and circular is supported by the result of Yukawa *et al.*, (1992). In addition, suborbicular stomata were found in *D. amplum* and *D. rotundatum* which are the accepted names of *Epigeneium amplum* and *Epigeneium rotundatum* according to update classification (Chase *et al.*, 2015).

Tetracytic type of stomata had been reported in many monocotyledons (Metcalf, 1961). Mostly three types of stomata paracytic, tetracytic and anomocytic were reported in mostly in monocots (Cheadle, 1953; Stebbins & Khush, 1961). Patel (1979) distinguished five types of stomata i.e. tetracytic (a-tetra-monocyclic, b-tetra-monocyclic and c-tetra-monocyclic), twicytic, perihaplocytic, anisocytic and hexacytic and each type with four to six subsidiary cells. In the present study tetracytic type (a-tetra-monocyclic, b-tetra-monocyclic and c-tetra-monocyclic) was found in most species of *Dendrobium* whereas eupara twi-monocyclic with hexa-monocyclic types was found in one species (*D. anceps*). In the stomatal type the monocyclic means the guard cells of the stomata are surrounded by a single cycle of subsidiary cells (Patel, 1979). Anisocytic stomata were observed in *D. amplum* according to Rasmussen (1987) but it was not observed in our study.

The size of stomata showed a wide variation from 620.97 μm^2 to 1928.48 μm^2 . The largest stoma was found in *D. formosum* and the smallest in *D. fugax*. The stomatal frequency ranged from 46.15 mm^2 to 123.07 mm^2 . The highest stomatal frequency was found in *D. longicornu* and lowest in *D. anceps* and *D. aphyllum*. The reduced stomatal frequency was distinctly related with the extent of leaf succulence and more the succulence lesser the frequency of stomata (Goh *et al.*, 1977). The stomatal index ranged from 3.75 to 12.50. The highest stomatal index was found in *D. formosum* and lowest in *D. anceps*. Similar variation in stomatal index

was reported in orchid species (Saaduet *al.*, 2009).

Stegmata was found in all species of *Dendrobium* except *D. densiflorum*, *D. formosum*, *D. longicornu* and *D. polyanthum*. Presence of stegmata in *Dendrobiinae* was supported by the result of Dressler (1993). Stegmata containing rough surfaced spherical bodies present in *D. anceps* was found similar to the result of Carlsward *et al.*, (1997). Transverse section of leaf showed some variations in cuticle, shape of epidermal cells, hypodermis, mesophyll, vascular bundle and fibre caps in different species of *Dendrobium*. Intermittently domed cuticle was present in *D. anceps*. The result was found similar to the result of Morris *et al.*, (1996). In epidermis of *D. fugax*, cell lumina were found occluded with Saffranin staining in adaxial and abaxial sides. A single layer of hypodermis was present in abaxial side in *D. anceps* and adaxial side in *D. densiflorum* and absent in other species. This result was found similar to the result of Morris *et al* (1996). Fibre bundles were present subtending the hypodermis only in *D. anceps*. Presence of fibre bundle in *D. anceps* is supported by the result of Morris *et al.*, (1996). Mesophyll cells were found homogenous and heterogenous. Heterogenous mesophyll was found in *D. amplum* and *D. rotundatum* and homogenous in remaining species. Palisade cells were columnar in *D. amplum* which is supported by the result of Morris *et al.*, (1996). Vascular bundles were arranged in a single row with large midrib bundle in most of species of *Dendrobium* except in *D. anceps* in which the vascular bundles were arranged in two rows on either side of midline with a major vascular bundle at one pole of leaf section. This result is supported by the result of Carlward *et al.*, (1997). Dome-shaped fibre cap was present at xylem pole of *D. moschatum*. Transverse section of stem showed variations in cuticle, shape of epidermal cells, shape and no. of hypodermal layers, ground tissue layers, shape and no. of vascular bundles and fibre caps in different species of *Dendrobium*.

Cuticle is thin in *D. porphyrochilum* and thick in remaining species. Cuticle is intermittently undulating in *D. anceps*. This result was found similar to the result of Morris *et al.*, (1996). The

epidermal cells vary from rectangular to square to polygonal to barrel shaped in different species of *Dendrobium*. In ground tissue two kinds of water-storage cells *i.e.* pleated or unpleated were present in all *Dendrobium* species. Water-storage cells have been reported in Orchidaceae (Stern & Morris, 1992). Water-storage cells with pleated or unpleated walls lack the secondary thickenings. This result is similar to the result of Morris *et al.*, (1996). Vascular bundle shape and number varies from species to species of *Dendrobium*. Stegmata with rough-surfaced silica bodies were found in stems and leaves of *Dendrobium* species. Presence of stegmata with spherical bodies in this study is supported by the result of Kohl (1889). This result supports the hypothesis of Moller & Rasmussen (1984) in possessing stegmata with spherical silica bodies in all Dendrobieae.

From the present study, the stomatal complex, stegmata, anatomical characters of leaves and stems were found to be taxonomically significant for delimiting the taxa within *Dendrobium* of Nepal.

Cluster analysis

Cluster analysis was carried out to find out the interrelationships among the species of *Dendrobium*. The cluster analysis based on anatomical with micromorphological characters revealed two major significant clusters: cluster A comprising 6 species with AU *p*-value of 45% and BP *p*-value of 19% belonging to sections Aporum, Formosae, *Dendrobium* and *Stachyobium* and cluster B comprising 20 species with AU *p*-value of 49% and BP *p*-value of 18% belonging to sections *Stachyobium*, *Dendrobium*, *Crinifera*, *Formosae* and *Sarcopodium*. The species under cluster A were distinguished by elliptic shaped a-tetra-monocyclic, b-tetra-monocyclic to eupara-twi-monocyclic+hexa-monocyclic stomata, parenchymatous leaf epidermal cells, abaxial leaf hypodermis, homogenous mesophyll, oblong to circular midrib vascular bundle, presence or absence of fibre bundle, presence or absence of fibre cap on midrib vascular bundle of leaf, major vascular bundle at leaf pole, one to three stem hypodermal layer. In cluster B, the species were distinguished by circular to

suborbicular shape with a-tetra-monocyclic, b-tetra-monocyclic, c-tetra-monocyclic to eupara-twi-monocyclic typed stomata, parenchymatous or sclerenchymatous leaf epidermal cells, adaxial leaf hypodermis, presence of homogenous and heterogenous mesophyll, oval, flask-shaped to conical midrib vascular bundle, absence of fibre bundle and major vascular bundle at leaf pole, presence fibre cap on midrib vascular bundle of leaf, one to five stem hypodermal layer.

Cluster A was divided into two clusters: cluster C and cluster D. In cluster A, a separate cluster C was formed by *D. anceps* (section Aporum) as it is differed from cluster D by eupara-twi-monocyclic+hexa-monocyclic stomata, thick cuticle, one layered abaxial leaf hypodermis, major vascular bundle at leaf pole and fibre bundle. In cluster D1 of cluster D, *D. longicornu* (section *Formosae*) was found close to *D. polyanthum* (section *Dendrobium*) as they had elliptic stomata, parenchymatous leaf epidermal cell, thick cuticle, circular midrib vascular bundle and elongate stem vascular bundle. In cluster D2a of cluster D, *D. porphyrochilum* (section *Stachyobium*) was found separated from cluster D2b with *D. denudans* (section *Stachyobium*) and *D. transparens* (section *Dendrobium*) as it had a-tetra-monocyclic stomata, water storage cells in mesophyll, no fibre cap on midrib bundle of leaf and stem vascular bundle. In cluster D2b, *D. denudans* was found close to *D. transparens* as both species had elliptic stomata, thin cuticle, no leaf hypodermis, homogenous mesophyll layers, stem vascular bundle number up to 60.

Cluster B was divided into two clusters: cluster E and cluster F. In cluster E1 of cluster E, *D. moniliforme* (section *Dendrobium*) of cluster E1a was found separated from cluster E1b in having circular shaped a-tetra-monocyclic stomata, thick cuticle and two to three polygonal stem hypodermal layers. In cluster E1b, *D. eriiflorum* (section *Stachyobium*) was found close to *D. monticola* (section *Stachyobium*) because both species had elliptic stomata, thin cuticle, no leaf hypodermis, rectangular stem epidermal cell and no stem hypodermis. In cluster E2a, *D. bicameratum* (section *Dendrobium*) differed from

cluster E2b in having stomatal pore more than 28 μm , thick cuticle of leaf and elongate stem vascular bundle. In cluster E2bi, *D. amoenum* (section Dendrobium) differed from cluster E2bii in having b-tetra-monocyclic stomata with length up to 33 μm , rectangular to polygonal stem epidermal cell and larger xylem in stem vascular bundle. In E2bii, *D. aphyllum* (section Dendrobium) was found close to *D. heterocarpum* (section Dendrobium) as both species had a-tetra-monocyclic stomata, thin cuticle, parenchymatous leaf epidermal cell, stegmata, no leaf hypodermis, oval midrib vascular bundle, oval stem vascular bundle and raphide bundles in stem.

In cluster F, cluster F1 with *D. rotundatum*, *D. amplum* and *D. fuscescens* (section Sarcopodium) form a significant cluster with AU *p*-value of 98% and BP *p*-value of 64% with significant values. *D. rotundatum* of cluster F1a was found separated from cluster F1b in having suborbicular c-tetra-monocyclic stomata, water storage cell and calcium oxalate crystals in mesophyll and no xylem fibre cap in stem vascular bundle. *D. amplum* and *D. fuscescens* of cluster F1b were placed closely as both species had thick cuticle, sclerenchymatous leaf epidermal cell, stegmata, no leaf hypodermis, heterogenous mesophyll layers, flask-shaped midrib vascular bundle and two to three layers of polygonal stem hypodermis. As *D. rotundatum*, *D. amplum* and *D. fuscescens* were more closely related to each other, these three species may be merged into single species with further additional research. In cluster F2, *D. fugax* (section Crinifera) of cluster F2ai differed from cluster F2aii in having eupara-twi-monocyclic stomata, thick cuticle, more than ten homogenous mesophyll layers, flask-shaped midrib vascular bundle, barrel-shaped stem epidermal cell and elongate stem vascular bundle. In cluster F2aii, *D. formosum* (section Formosae) was found close to *D. nobile* (section Dendrobium) with AU *p*-value of 94% and BP *p*-value of 35% as both species had c-tetra-monocyclic stomata, eight to ten homogenous mesophyll layers, calcium oxalate crystals in mesophyll, oval midrib vascular bundle and two to three layers of polygonal stem hypodermis, oval stem vascular bundle. In

cluster F2b, cluster F2bi formed a significant cluster with *D. densiflorum* and *D. moschatum* (section Dendrobium) with AU *p*-value of 98% and BP *p*-value of 85% with significant values. *D. densiflorum* was found close to *D. moschatum* as both species had a-tetra-monocyclic stomata, more than ten homo-genous mesophyll layers, conical midrib vascular bundle, oval stem vascular bundle, stem vascular bundle no. more than 70 and raphide bundles in stem. *D. densiflorum* and *D. moschatum* were closely interrelated, with further research, these two species may be merged into a single species.

In cluster F2biii, *D. chrysanthum* (section Dendrobium) was found close to *D. gibsonii* (section Dendrobium) as both species had a-tetra-monocyclic stomata, thin cuticle, no leaf hypodermis, eight to ten homogenous mesophyll layers, oval midrib vascular bundle, two to three stem hypodermal layers, no xylem fibre cap in stem vascular bundle. Cluster F2biv again divided into two clusters: cluster F2bv and cluster F2bvi. Cluster F2bv with *D. crepidatum* (section Dendrobium) differed from cluster F2bvi with *D. denneanum* and *D. fimbriatum* in having elliptic shaped b-tetra-monocyclic stomata, parenchymatous leaf epidermal cell, phloem fibre cap layers more than 5 in midrib bundle, one stem hypodermal layer, stem vascular bundle number less than 61. In cluster F2bvi, *D. denneanum* was found close to *D. fimbriatum* as both species had circular shaped a-tetra-monocyclic stomata, sclerenchymatous leaf epidermal cell, no leaf hypodermis, barrel-shaped stem epidermal cell, four to five layers of rectangular to polygonal stem hypodermis and no xylem fibre cap in stem vascular bundle.

D. amplum, *D. fuscescens* and *D. rotundatum* belong to section Sarcopodium, came under genus *Epigeneium* previously but now it was merged into genus *Dendrobium* s.l. on the basis of molecular data (Schuiteman & Adams, 2014). The merging of genus *Epigeneium* into genus *Dendrobium* s.l. was seemed to be good as they formed a distinct significant cluster within genus *Dendrobium* s.l. This indicated that the present result of cluster analysis based on anatomical characters correlated with molecular data.

D. fugax of section Crinifera came under genus *Flickingeria* in previous classification, but in update classification, the genus *Flickingeria* was merged into genus *Dendrobium* s.l. based on the molecular data (Schuiteman & Adams, 2014). The inclusion of genus *Flickingeria* into genus *Dendrobium* s.l. was seemed correct as *D. fugax* showed close relationship with other species of *Dendrobium*. This cluster analysis result revealed that the analysis result based on anatomical characters with micromorphological characters correlate with molecular data.

In the present study, according to result of cluster analysis based on anatomical characters with micro-morphological characters, *Dendrobium* species of Nepal can be divided into new 6 sections with closely interrelated species. Sections are as follows:

Section I. includes species with eupara-twi-monocyclic+hexa-monocyclic stomata, one layered abaxial leaf hypodermis, major vascular bundle at leaf pole and fibre bundle. ----- *D. anceps*

Section II. includes species with elliptic stomata and small stem vascular bundle less than 100 μm ---- *D. longicornu*, *D. polyanthum*, *D. porphyrochilum*, *D. denudans* and *D. transparens*

Section III. includes species with oval midrib vascular bundle and no xylem fibre cap in stem vascular bundle -----*D. moniliforme*, *D. eriiflorum*, *D. monticola*, *D. bicameratum*, *D. amoenum*, *D. aphyllum* and *D. heterocarpum*

Section IV. includes species with circular or suborbicular stomata, sclerenchymatous leaf epidermal cell, heterogenous mesophyll layer and rectangular to square stem epidermal cell -- ----- *D. rotundatum*, *D. amplum* and *D. fuscescens*

Section V. includes species with stomatal index more than 10%, xylem fibre cap in midrib vascular bundle more than 150 μm in width and polygonal stem hypodermal cell -----
----- *D. fugax*, *D. formosum* and *D. nobile*

Section VI. includes species with a-tetramonocyclic stomata -----*D. densiflorum*, *D. moschatum*, *D. chrysanthum*, *D. gibsonii*, *D. crepidatum*, *D. denneanum* and *D. fimbriatum* but b-tetramonocyclic stomata - *D. crepidatum*, no leaf hypodermis but with one layered adaxial leaf hypodermis - *D. densiflorum*, large stem vascular bundle width more than 130 μm but less than 100 μm - *D. crepidatum* and no stegmata but present - *D. densiflorum*.

Conclusion

The present study was based on anatomical characters of leaves and stems of *Dendrobium* species of Nepal Himalaya. Based on characters such as stomatal complex, stegmata and anatomical characters of leaves and stems, an anatomical key was prepared to delimit the taxa within genus *Dendrobium*.

Based on anatomical with micromorphological characters, the cluster analysis was carried out in species of *Dendrobium* to find out the inter-relationships among the species of *Dendrobium*. With the result of cluster analysis, *Dendrobium* of Nepal was divided into 6 sections: section I with *D. anceps*, section II with *D. longi-cornu*, *D. polyanthum*, *D. porphyrochilum*, *D. den-udans*, *D. transparens*, section III with *D. monili-forme*, *D. eriiflorum*, *D. monticola*, *D. bicameratum*, *D. amoenum*, *D. aphyllum*, *D. heterocarpum*, section IV with *D. rotundatum*, *D. amplum*, *D. fusce-scens*, section V with *D. fugax*, *D. formosum*, *D. nobile* and section VI with *D. densiflorum*, *D. moschatum*, *D. chrysanthum*, *D. gibsonii*, *D. crepidatum*, *D. denneanum* and *D. fimbriatum*.

The present study represents the first attempt to bring the cluster analysis of *Dendrobium* of Nepal based on anatomical with micromorphological characters. The proposed classification based on the cluster analysis is slightly similar to classification of Schuiteman & Adams (2014).

Due to unavailability of the modern equipment like Scanning Electron Microscope (SEM), Transmission Electron Microscope (TEM) and DNA sequences, a detailed study of the species could not be carried out. However, the result obtained from the present study will provide the working hypothesis for further study.

Therefore, it is recommended that additional researches should be needed to fully resolve the relationships between several species of *Dendrobium*.

Acknowledgements

Authors are thankful to Suraj Balami for his help in processing cluster analysis, National Herbarium and Plant Laboratories (KATH) and Tribhuvan University Central Herbarium (TUCH) for their cooperation and allowing to studying the herbarium specimens housed over there. My sincere thanks go to Patan Multiple Campus and Amrit Campus for providing the laboratories facilities.

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Cite this article as:

Baba Maiya Pradhan and Devendra M. Bajracharya. Anatomical Study of *Dendrobium* (Orchidaceae) of Nepal. *Annals of Plant Sciences*. 9.7 (2020) pp. 3916-3948.



<http://dx.doi.org/10.21746/aps.2020.9.7.1>

Subject Editor : M. Mahendra Nath, Sri Venkateswara University, Tirupati.

Source of support: Nil; Conflict of interest: Nil.



Morphological diversity within *Dendrobium* (Orchidaceae) of Nepal

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Abstract: The morphological diversity within *Dendrobium* Sw., comprising 29 species of Nepal Himalaya, is presented. The paper provides detailed information about the range of diversity in vegetative and reproductive characteristics. An artificial key to the species is provided for their identification. According to the updated classification of Orchidaceae, genera like *Epigeneium* and *Flickingeria* of subtribe Dendrobiinae are merged into genus *Dendrobium* sensu lato. In the present investigation, the morphological diversity within 29 species of *Dendrobium* viz. *D. amoenum*, *D. amplum*, *D. anceps*, *D. aphyllum*, *D. bicameratum*, *D. chrysanthum*, *D. crepidatum*, *D. darjeelingense*, *D. denneanum*, *D. densiflorum*, *D. denudans*, *D. eriiflorum*, *D. fimbriatum* var. *oculatum*, *D. formosum*, *D. fugax*, *D. fuscescens*, *D. gibsonii*, *D. heterocarpum*, *D. longicornu*, *D. moniliforme*, *D. monticola*, *D. moschatum*, *D. nobile*, *D. plicatile*, *D. polyanthum*, *D. porphyrochilum*, *D. rotundatum* and *D. transparens* of Nepal Himalaya were studied.

Keywords: *Dendrobium*; Orchidaceae; Morphological diversity

Introduction

Dendrobium Sw. is the second largest genus of the family Orchidaceae and was established by Olof Swartz in 1799. *Dendrobium moniliforme* (L.) Sw. is the type for the genus *Dendrobium* (Holttum, Brieger & Cribb 1979). *Dendrobium* Sw. comes under subtribe Dendrobiinae, and it consists of about 1500 species worldwide (Schuitman 2017). According to Dressler (1993) subtribe Dendrobiinae comprises 6 genera (*Cadetia*, *Dendrobium*, *Diplocaulibium*, *Epigeneium*, *Flickingeria* and *Pseuderia*) and 1147 species. The subtribe Dendrobiinae consists of 900 species of *Dendrobium*, 12 species of *Epigeneium* and 70 species of *Flickingeria* (Dressler, 1993). Among them, 26 species of *Dendrobium* and 2 species of *Epigeneium* have been reported from Nepal (Rajbhandari & Rai, 2017). But according to update classification, genera *Epigeneium* and *Flickingeria* were merged into genus *Dendrobium* s.l. (Schuiteman & Adams, 2014). The species of *Dendrobium* show great variation in vegetative and floral characters. Based on variations, *Dendrobium* species are divided into 30 sections (Schuitman &

Adams 2014). *Dendrobium* species of Nepal Himalaya come under 6 sections out of 30 sections. The morphological variations within 29 species of *Dendrobium* of Nepal Himalaya belonging to 6 sections are presented here.

The genus *Dendrobium* ranges from Sri Lanka throughout tropical Asia and pacific region, north to Japan, east to Tahiti and south to New Zealand and absent in Africa and America (Schuiteman and Adams 2014). The genus *Dendrobium* is characterized by epiphytic, lithophytic or rarely terrestrial habits, presence of cane-like stem with pseudo-bulb covered with or without sheathing leaf bases, distichous or duplicate leaves, spiral flowers with basally jointed lips with prominent spurs formed by the column foot and naked pollinia.

The genus *Dendrobium* belongs to the subtribe Dendrobiinae, tribe Malaxideae, subfamily Epidendroideae, family Orchidaceae (Chase *et al.* 2015). Various generic delimitations and infrageneric systems have been proposed by Kranzlin 1910, Schlechter 1912, Brieger 1981,

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Seidenfaden 1985, Clements 2006, Wood 2006, Schuitman and Adams 2014 based on the morphological and molecular characters after the establishment of *Dendrobium* by Swartz in 1799.

The exploration of the orchid flora of Nepal Himalaya begins in 1802 with the collections by Buchanan-Hamilton. D. Don published "Prodromus Florae Nepalensis" in 1825 based on the plant collections of Buchanan-Hamilton and Wallich. Wallich published "Tentamen Florae Nepalensis" in 1824-1826. Buchanan-Hamilton (1802-1803) described *Epidendron moschatum* (*Dendrobium moschatum*) in his unpublished manuscript from Nepal Himalaya. Hara, Stearn, and Williams (1978) enumerated 26 species of *Dendrobium* and 3 species of *Epigeneium* from Nepal. Banerji and Pradhan (1984) enlisted 21 species of *Dendrobium* and 2 species of *Epigeneium* from Nepal. Press, Shrestha, and Sutton (2000) enumerated 26 species of *Dendrobium* and 3 species of *Epigeneium* from Nepal. White and Sharma (2000) described 22 species of *Dendrobium*, 1 species of *Epigeneium* and 1 species of *Flickingeria* from Nepal.

Raskoti (2009) enlisted 26 species of *Dendrobium*, 2 species of *Epigeneium* and 1 species of *Flickingeria* from Nepal Himalaya. Rokaya, Raskoti, Timsina and Munzbergova (2013) enlisted 31 species of *Dendrobium*, 3 species of *Epigeneium* and 2 species of *Flickingeria* from Nepal Himalaya.

Rajbhandari and Rai (2017) enlisted 26 species of *Dendrobium* and 2 species of *Epigeneium* from Nepal Himalaya. Shrestha, Bhattarai and Bhandari (2018) enumerated 30 species of *Dendrobium*, 3 species of *Epigeneium* and 2 species of *Flickingeria* from Nepal Himalaya.

Materials and Methods

Study sites and sample collection

In this study, the plant materials were collected from West, Central, and East Nepal based on those regions mentioned in the herbaria and the available literature. Altogether 29 species of *Dendrobium* viz. *D. amoenum* Wall. ex Lindl., *D. amplum* Lindl., *D. anceps* Sw., *D. aphyllum* (Roxb.) C.E.C. Fisch., *D. bicameratum* Lindl., *D. chrysanthum* Wall. ex Lindl., *D. chryseum* Rolfe, *D. crepidatum* Lindl. & Paxton, *D. darjeelingense* Pradhan, *D. denneanum* Kerr, *D. densiflorum* Wall., *D. denudans* D. Don, *D. eriiflorum* Griff., *D. fimbriatum* Hook., *D. formosum* Roxb. ex Lindl., *D. fugax* Rchb. f., *D. fuscescens* Griff., *D. gibsonii* Paxton, *D. heterocarpum* Wall. ex Lindl., *D. longicornu* Lindl., *D. moniliforme* (L.) Sw., *D. monticola* P.F. Hunt & Summerh., *D. moschatum* (Buch.-Ham.) Sw., *D. nobile* Lindl., *D. plicatile* Lindl., *D. polyanthum* Wall. ex Lindl., *D. porphyrochilum* Lindl., *D. rotundatum* (Lindl.) Hook. f. and *D. transparens* Wall. ex Lindl. were studied in the present study.

Methodology

The study was based on the collected live specimens and voucher specimens deposited at different herbaria like KATH, TUCH, BM, TI, E, and K. The specimens were collected from different localities of Nepal Himalaya. The collected live specimens as well as voucher specimens, were studied for morphological variations existing within them. The collected live specimens were identified by tallying with protologues, valid taxonomic literature, and type specimens deposited at different herbaria of the world. The type specimens (Holotype, Isotype, Lectotype, and Paratype) were determined based on protologue texts. The type specimens were acquired from different online websites and personal contact.

Results and Discussion

Morphology

In-plant taxonomy, morphological characters are essential for identifying different species. The wide range of morphological variations helps delimitate and identify plants up to the lowest taxonomic hierarchy level.

Range of vegetative structures

a. Habit and Habitat

The habit of different species of *Dendrobium* is sympodial with elongated cane-like stems or pseudobulbs. All species are perennial, epiphytic, erect or pendulous herbs and some are lithophytic also. Epiphytic with lithophytic species are *D. amoenum*, *D. denneanum*, *D. eriiflorum*, *D. fimbriatum*, *D. fuscescens*, *D. monticola*, and *D. plicatile*. The height of plants varies from 2 cm to 70 cm, the smallest plant being *D. porphyrochilum* (2 cm) and the largest being *D. amplum* (70 cm). All species are adapted to a wide variety of habitats from high altitudes to humid lowland forests. Most species are distributed from tropical, subtropical to temperate regions ranging from 200-2500 m, and 2 species like *D. fimbriatum* and *D. formosum* are distributed in tropical regions only (Fig. 1) (Table 1).

b. Root and Rhizome

Roots of *Dendrobium* are developed from base of stem or pseudobulb and from rhizome. In most species roots are developed from nodes allowing the development of adventitious growth. The roots are fasciculate, thick and covered by shiny, silver-grey velamen. Rhizome is found in some *Dendrobium* species such as *D. amplum*, *D. fugax*, *D. fuscescens*, *D. plicatile*, *D. rotundatum*. Rhizomes are creeping, branched and covered with sheaths. Roots are developed from nodes of rhizome.

c. Stem/Pseudobulb

Most *Dendrobium* species has elongated cane-like stems, and few species had distinct pseudobulbs like *D. amplum*, *D. fugax*, *D. fuscescens*, *D. plicatile*, *D. rotundatum*, *D. monticola* and *D. porphyrochilum*. The size of stems or pseudobulbs varies from few centimeters to nearly about a meter. Stems are erect or pendant with few to many nodes. Species like *D. amoenum*, *D. amplum*, *D. aphyllum*, *D. chrysanthum*, *D. chryseum*, *D. crepidatum*, *D. fugax*, *D. fuscescens*, *D. gibsonii*, *D. plicatile*, *D. polyanthum*, *D. rotundatum* has pendant stems and remaining species with erect stems. Stems are branched or unbranched and covered with leaf sheaths. Unbranched stems are found in species like *D. aphyllum*, *D. bicameratum*, *D. chrysanthum*, *D. chryseum*, *D. crepidatum*, *D. darjeelingense*, *D. fimbriatum*, *D. gibsonii*, *D. longicornu*, *D. moniliforme*, *D. moschatum*, *D. nobile*, *D. polyanthum* and branched stems in remaining species. In *D. anceps* the stems are compressed, flattened without any fleshy internodes and leaves are present all along the stem. In *D. densiflorum* the stems are stout, clavate, compressed and quadrangular with leaves at apex. In *D. bicameratum* the stems are slender and swollen towards the apex. In *D. longicornu* and *D. formosum* the stems are short to long, slender or robust, sheaths are hirsute. In *D. darjeelingense*, *D. denudans*, *D. eriiflorum* the stems are long, slender and fusiform tapering towards the apex. Pseudobulb varies in shape in different species. In *D. monticla* and *D. porphyrochilum* the pseudobulbs are small, elongate and cylindrical. Pseudobulbs are large, ellipsoid in *D. amplum*, fusiform in *D. fugax* and *D. plicatile*, cylindric-ovoid in *D. fuscescens*, ovoid in *D. rotundatum*. In the remaining *Dendrobium* species, the stems are short, long, erect, or pendulous with few to many nodes.

d. Leaves and Leaf sheaths

Leaves of *Dendrobium* show variation in orientation, shape and size. Leaves are arranged distichously along the stem or one to many leaves at apex of pseudobulb. *D. fugax* and *D. plicatile* have single leaves at apex of pseudobulb. *D. amplum*, *D. fuscescens* and *D. rotundatum* have two leaves at apex of pseudobulb. *D. monticola* and *D. porphyrochilum* have three to four leaves developed apically at pseudobulb. The remaining *Dendrobium* species have more than four leaves. Leaves are lanceolate, linear-lanceolate, elliptic-lanceolate, oblong-lanceolate, ovate-lanceolate, oblong, oblong-lanceolate, or oblong-elliptic. Leaves are membranous, coriaceous, fleshy or subleathery. The apex of leaf is acute, obtuse or acuminate, bilobed or emarginated. The leaf surface is glabrous in most species and puberulous in *D. longicornu*. The size of leaves varies from 2.5 to 20.0 cm in length and 0.5 to 5.0 cm in width. Leaf margins are entire in all species of *Dendrobium*. Leaf-sheaths are present in all species of *Dendrobium*. Leaf-sheaths are covered with blackish hairs in *D. longicornu* and *D. formosum* and the remaining species of *Dendrobium* have glabrous leaf sheaths.

Range of reproductive structures

e. Inflorescence

The inflorescence of *Dendrobium* is axillary, terminal, lateral or subterminal raceme. It arises from short or long peduncles borne on nodes of leafy or leafless stems. The peduncles are slender and sheathed. The rachis is slender, short or long. Inflorescence is erect or pendulous. In *D. anceps* the inflorescence is axillary raceme with one flower. Inflorescence is short, capitate raceme, lateral or subterminal on leafless stem, subdensely 4-6 flowered, rachis weakly zigzag in *D. bicameratum*. Inflorescence is axillary raceme, pendant, borne

on apex of stem, densely many-flowered, rachis long in *D. densiflorum*. Inflorescence in *D. formosum* is terminal or lateral raceme with 1-5 flowers on leafy stem, borne at nodes near the stem's apex. In *D. longicornu* the inflorescence is terminal or axillary raceme with 1-3 flowers on leafy stem. The inflorescence is lateral or subterminal raceme with many flowers on long rachis in *D. darjeelingense*, *D. denudans*, *D. monticola*, *D. porphyrochilum*. In remaining *Dendrobium* species, the inflorescence is raceme with few to many flowers borne on nodes of leafy or leafless stems. Length of peduncle and rachis varies in all species of *Dendrobium* (Table 1).

f. Floral Bracts

Floral bracts vary in shape, size and texture in all species of *Dendrobium*. The shapes of floral bracts are ovate, oblong, lanceolate and triangular in all species of *Dendrobium*. The apex of floral bract is acute, obtuse, acuminate and subacute. Margin is entire and surface is glabrous or hirsute. Floral bracts are membranous or scarious. The size of floral bract ranges from 0.2-2.0 cm in length and 0.1-1.2 cm in width. The number of veins in floral bract varies from one to seven in different species (Table 2).

g. Flowers

The flowers of *Dendrobium* are very showy, resupinate, ephemeral or long-lived. Flowers vary in shape, size and colour. The size of flowers varies from 0.8-10.0 cm across. *D. anceps*, *D. bicameratum*, *D. darjeelingense*, *D. denudans*, *D. eriiflorum*, *D. monticola*, *D. porphyrochilum* have smaller flowers as compared to flowers in remaining species of *Dendrobium*. Largest flower is present in *D. formosum* and smallest in *D. porphyrochilum*. The flowers are yellow or white in most species and in remaining species the flowers are creamy,

yellowish green or light greenish white. Pedicel with ovary varies in length in different species of *Dendrobium*. The longer pedicel with ovary is found in most of species and shorter in few species of *Dendrobium* (Table 1) (Plate 1).

h. Sepals

Dorsal sepals are lanceolate, oblong, elliptic, oblong-lanceolate, ovate-lanceolate, elliptic-oblong or ovate-oblong in all species of *Dendrobium*. The apex of dorsal sepal is acute, obtuse, acuminate and subacute. Margin of dorsal sepal is entire and surface is glabrous. The size of dorsal sepal ranges from 0.5-4.7 cm in length and 0.15-1.6 cm in width in all species of *Dendrobium*. Dorsal sepals vary in number of veins from 3-10 in different species of *Dendrobium* (Table 3). Lateral sepals are lanceolate, elliptic, ovate, triangular, oblong, oblong-lanceolate, falcate-lanceolate, ovate-lanceolate in all species of *Dendrobium*. The apex of lateral sepal is acute, obtuse, acuminate and subacute. Margin of lateral sepal is entire and surface is glabrous. The size of lateral sepal ranges from 0.7-5.5 cm in length and 0.2-1.6 cm in width in all species of *Dendrobium*. Lateral sepals vary in number of veins from 3-10 in different species of *Dendrobium* (Table 4).

i. Mentum

Lateral sepals adnate to the foot of column to form mentum. The shape of mentum varies in all species of *Dendrobium*. In species like *D. amoenum*, *D. aphyllum*, *D. chryseum*, *D. denudans*, *D. eriiflorum*, *D. formosum*, *D. fugax*, *D. heterocarpum*, *D. monticola*, *D. moschatum*, *D. nobile*, *D. plicatile*, *D. transparens* the mentum is conical shaped. Mentum is rounded in *D. amplum*, *D. chrysanthum*, *D. denneanum*, *D. densiflorum*, *D. fimbriatum*, *D. moniliforme*, *D. polyanthum*, *D. porphyrochilum*, *D. rotundatum*. Mentum is saccate in *D. anceps* and *D. fuscescens*, subglobose in *D. crepidatum* and *D.*

gibsonii, urceolate in *D. bicameratum*, spur-like in *D. darjeelingense* and long, funnel shaped in *D. longicornu* (Fig. 2).

j. Petals

Shape and size of petals vary in all species of *Dendrobium*. Shape of petals varies from ovate, elliptic, obovate, oblong, lanceolate, linear-lanceolate, oblong-lanceolate, ovate-lanceolate, oblong-elliptic, elliptic-obovate, oblong-ovate to ovate-orbicular. The apex of petals varies in all species of *Dendrobium*. The apex of petal is acute, subacute, obtuse, acuminate, emarginate, rounded and cuspidate. The margin of petal is entire and surface is glabrous in all species of *Dendrobium*. The size of petals ranges from 0.4-5.0 cm in length and 0.1-3.3 cm in width. No. of veins ranges from 3-7 in different species of *Dendrobium* (Table 5).

k. Lip

The lip is attached to the column foot. The lip varies greatly in shape, size, and margins in all species of *Dendrobium*. The morphological characters of lip are of utmost importance in taxonomy to distinguish the genus at the infraspecific level. The lip characters are considered as most distinguishing characters for the delimitation of species of *Dendrobium*. The lip is simple or tri-lobed. There is variation in shape of simple lip, midlobe and side lobes in trilobed lip and presence or absence of ornamentation in lip. The lip size varies from 0.4-6.00 cm in length and 0.25-3.5 in width in different species of *Dendrobium*. There is variation in the ornamentation on the lip surface of *Dendrobium* (Table 6). The lip can be distinguished into following types on the basis of structure of simple and trilobed lip of *Dendrobium* (Fig. 3).

Type A. Lip simple without side lobes. There is variation in shape, margin and apex of lip in

different species of *Dendrobium*. The following types are differentiated based on shape, margin and apex of lip.

a. Lip orbicular-oblong, obovate and subglobular, margin denticulate and fimbriate with apex rounded in *D. chrysanthum*, *D. polyanthum*, *D. fimbriatum* and *D. moschatum*.

b. Lip orbicular, suborbicular and subreniform, margin ciliolate, fimbriate and lacerate with apex emarginated and retuse in *D. crepidatum*, *D. aphyllum*, *D. chryseum*, *D. denneanum*, *D. densiflorum* and *D. gibsonii*.

c. Lip trowel-shaped and elliptic, margin undulate and entire with apex acute and subacute in *D. heterocarpum* and *D. porphyrochilum*.

d. Lip ovate-oblong, margin entire with apex obtuse in *D. nobile*.

Type B. Lip trilobed with side lobes and midlobe. There is variation in shape, margin and apex of midlobe of lip in different species of *Dendrobium*. Following types are differentiated on the basis of shape, margin and apex of midlobe of lip.

a. Lip oblong-ovate, obovate, oblong-lanceolate, subelliptic and elliptic-obovate, margin crenulate, lacerate, undulate and entire with apex acute in *D. darjeelingense*, *D. denudans*, *D. eriiflorum*, *D. moniliforme*, *D. monticola* and *D. transparens*.

b. Lip oblong-ovate and broadly triangular, margin undulate and fimbriate-lacerate with apex obtuse in *D. amoenum* and *D. longicornu*.

c. Lip pandurate, margin crenulate with apex mucronate in *D. amplum*.

d. Lip ovate-oblong, obovate-oblong and ovate, margin undulate with apex emarginated and retuse in *D. fuscescens*, *D. rotundatum* and *D. formosum*.

e. Lip oblong-obovate, subovate and broadly triangular, margin undulate and entire with apex truncate and subtruncate in *D. fugax*, *D. plicatile* and *D. bicameratum*.

f. Lip wedge-shaped, margin crenulate with apex bilobed in *D. anceps*.

Ornamentation on lip

Ornamentation on lip varies in different species of *Dendrobium*. Following types of ornamentation are found in lip of *Dendrobium*.

Type i. Without ornamentation on disc of lip: *D. moschatum*.

Type ii. Ridges on disc of lip: *D. chrysanthum*, *D. crepidatum*, *D. denudans*, *D. eriiflorum*, *D. formosum*, *D. longicornu* and *D. porphyrochilum*.

Type iii. Lamellae on disc of lip: *D. amplum*, *D. fugax*, *D. fuscescens*, *D. monticola* and *D. plicatile*.

Type iv. Callus on disc of lip: *D. bicameratum*, *D. moniliforme* and *D. polyanthum*.

Type v. Clawed at base of lip: *D. chryseum*, *D. denneanum*, *D. densiflorum*, *D. fimbriatum* and *D. nobile*.

Type vi. Sub-villous disc of lip: *D. amoenum*.

Type vii. Papillary hairs on disc of lip: *D. aphyllum*, *D. gibsonii* and *D. heterocarpum*.

Type viii. Central distinct veins from base to apex of lip: *D. transparens*.

Type ix. Shallow depression ending near apex of lip: *D. anceps*.

Type x. Keels from base to apex of lip: *D. darjeelingense* and *D. rotundatum*.

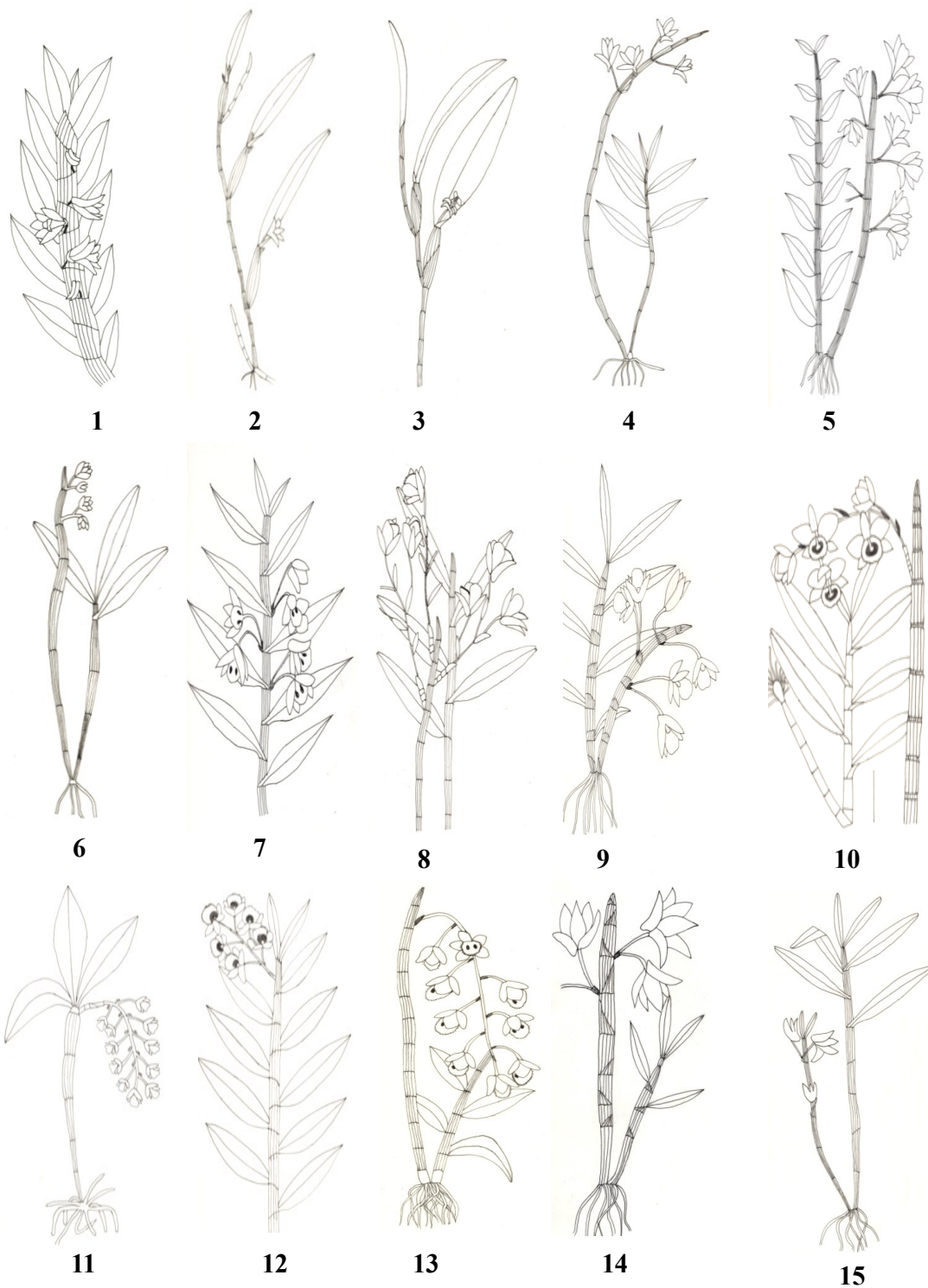


Fig. 1. Habit of *Dendrobium* species.

1. *D. anceps* 2. *D. fugax* 3. *D. plicatile* 4. *D. amoenum* 5. *D. aphyllum* 6. *D. bicameratum* 7. *D. chrysanthum* 8. *D. chryseum* 9. *D. crepidatum* 10. *D. denneanum* 11. *D. densiflorum* 12. *D. fimbriatum* 13. *D. gibsonii* 14. *D. heterocarpum* 15. *D. moniliforme*.



Fig. 1 contd.

16. *D. moschatum* 17. *D. nobile* 18. *D. polyanthum* 19. *D. transparens* 20. *D. formosae* 21. *D. longicornu* 22. *D. amplum* 23. *D. fuscescens* 24. *D. rotundatum* 25. *D. darjeelingense* 26. *D. denudans* 27. *D. eriiflorum* 28. *D. monticola* 29. *D. porphyrochilum*.

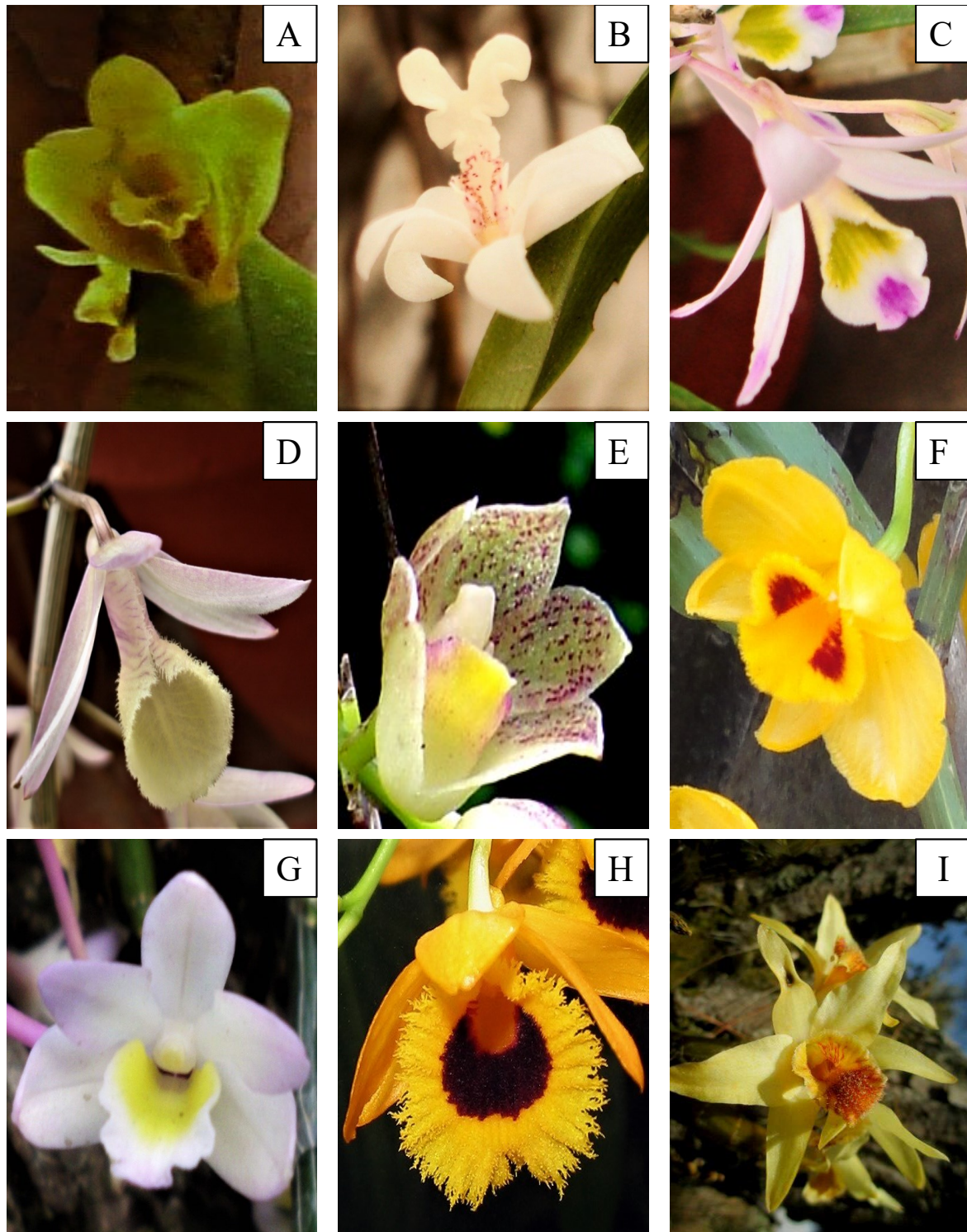
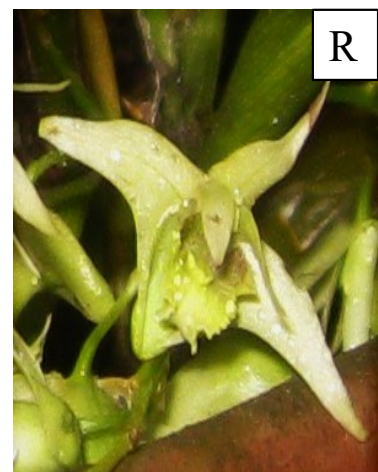
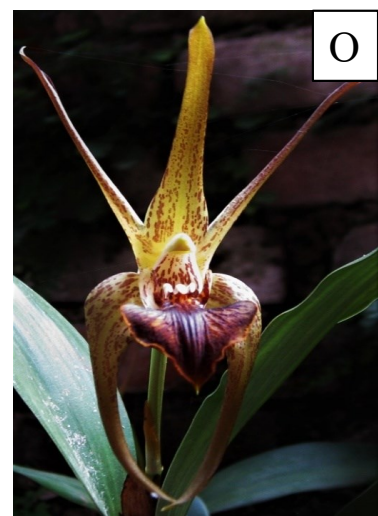
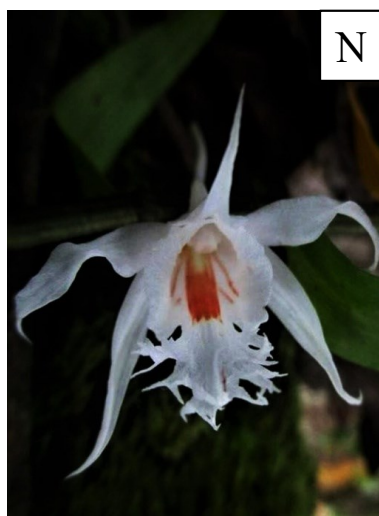


Plate 1. Flowers of *Dendrobium* species

A. *D. anceps*; B. *D. fugax*; C. *D. amoenum*; D. *D. aphyllum*; E. *D. bicameratum*; F. *D. chrysanthum*; G. *D. crepidatum*; H. *D. fimbriatum* var. *oculatum*; I. *D. heterocarpum*.

**Plate 1. contd.**

J. *D. moniliforme*; K. *D. moschatum*; L. *D. nobile*; M. *D. transparens*;
N. *D. longicornu*; O. *D. amplum*; P. *D. rotundatum*; Q. *D. denudans*; R.
D. eriiflorum.

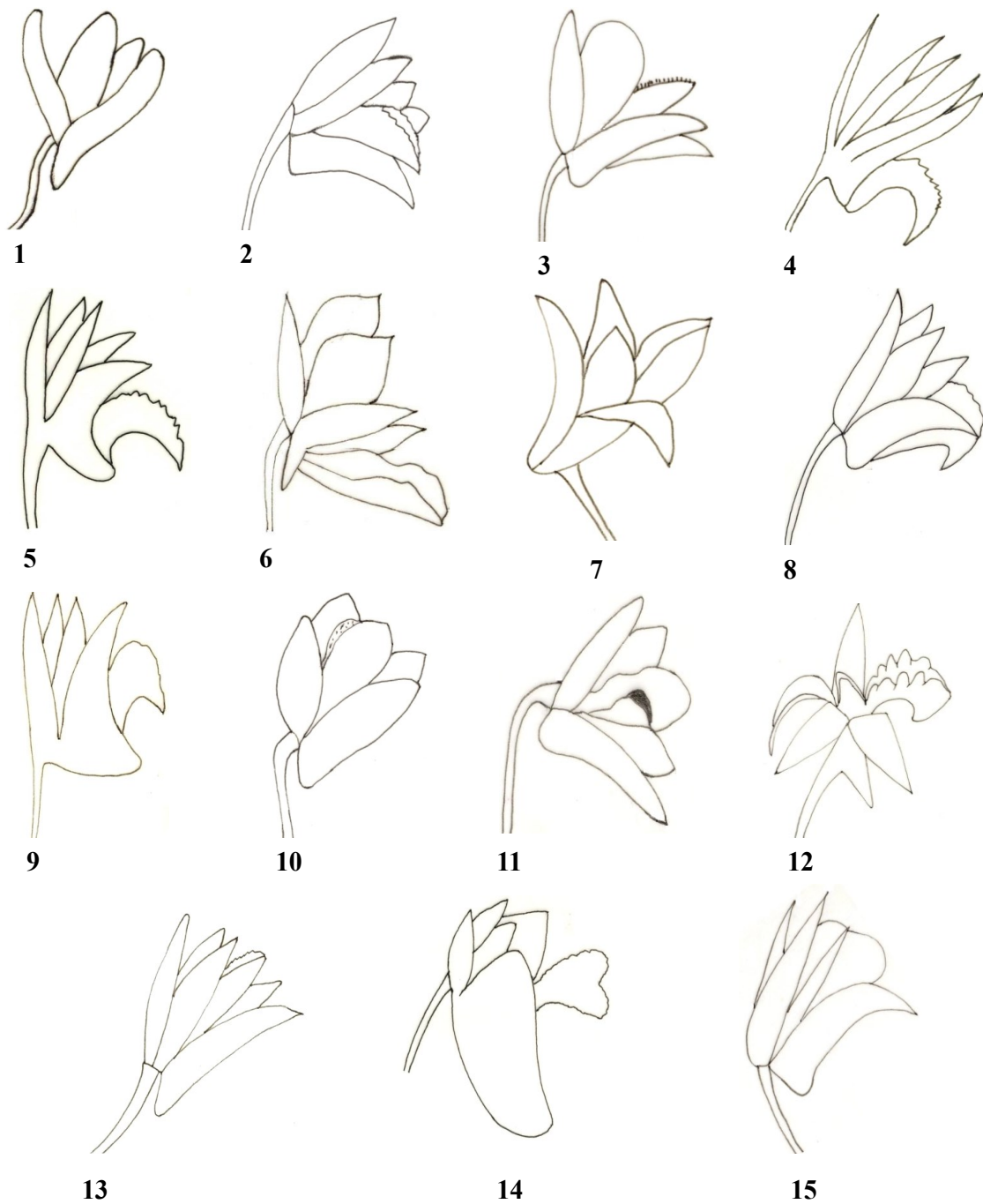
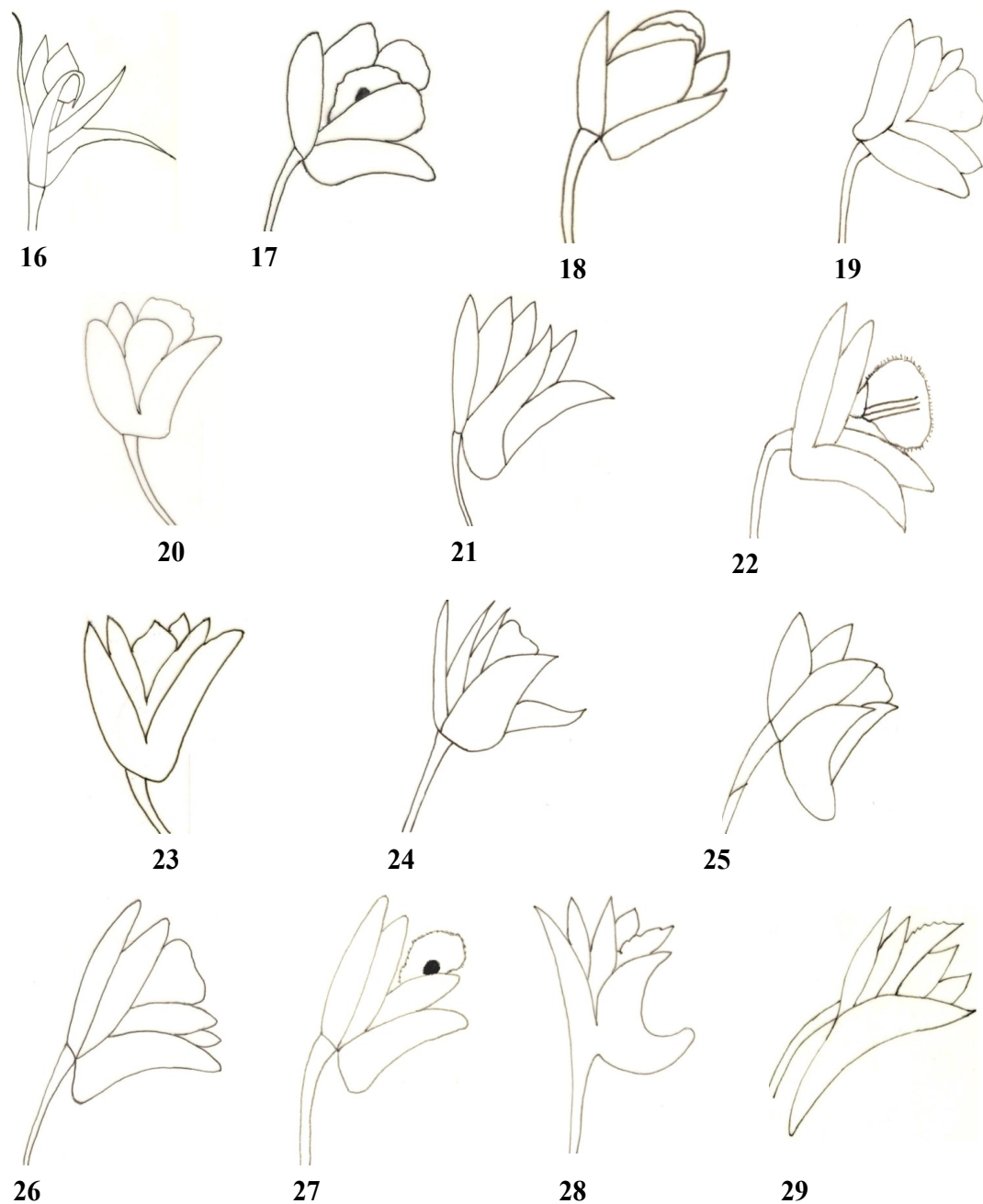


Fig. 2. Mentum of *Dendrobium* species.

1. *D. amoenum* ; 2. *D. aphyllum*; 3. *D. chryseum*; 4. *D. denudans*; 5. *D. eriiflorum*; 6. *D. formosum*; 7. *D. fugax*; 8. *D. heterocarpum*; 9. *D. monticola*; 10. *D. moschatum*; 11. *D. nobile* ;12. *D. plicatile*; 13. *D. transparens*; 14. *D. anceps*; 15. *D. fuscescens*.

**Fig. 2. contd.**

16. *D. amplum*; 17. *D. chrysanthum*; 18. *D. denneanum*; 19. *D. densiflorum*; 20. *D. fimbriatum*; 21. *D. moniliforme*; 22. *D. polyanthum*; 23. *D. porphyrochilum*; 24. *D. rotundatum*; 25. *D. bicameratum*; 26. *D. crepidatum*; 27. *D. gibsonii*; 28. *D. darjeelingense*; 29. *D. longicornu*.

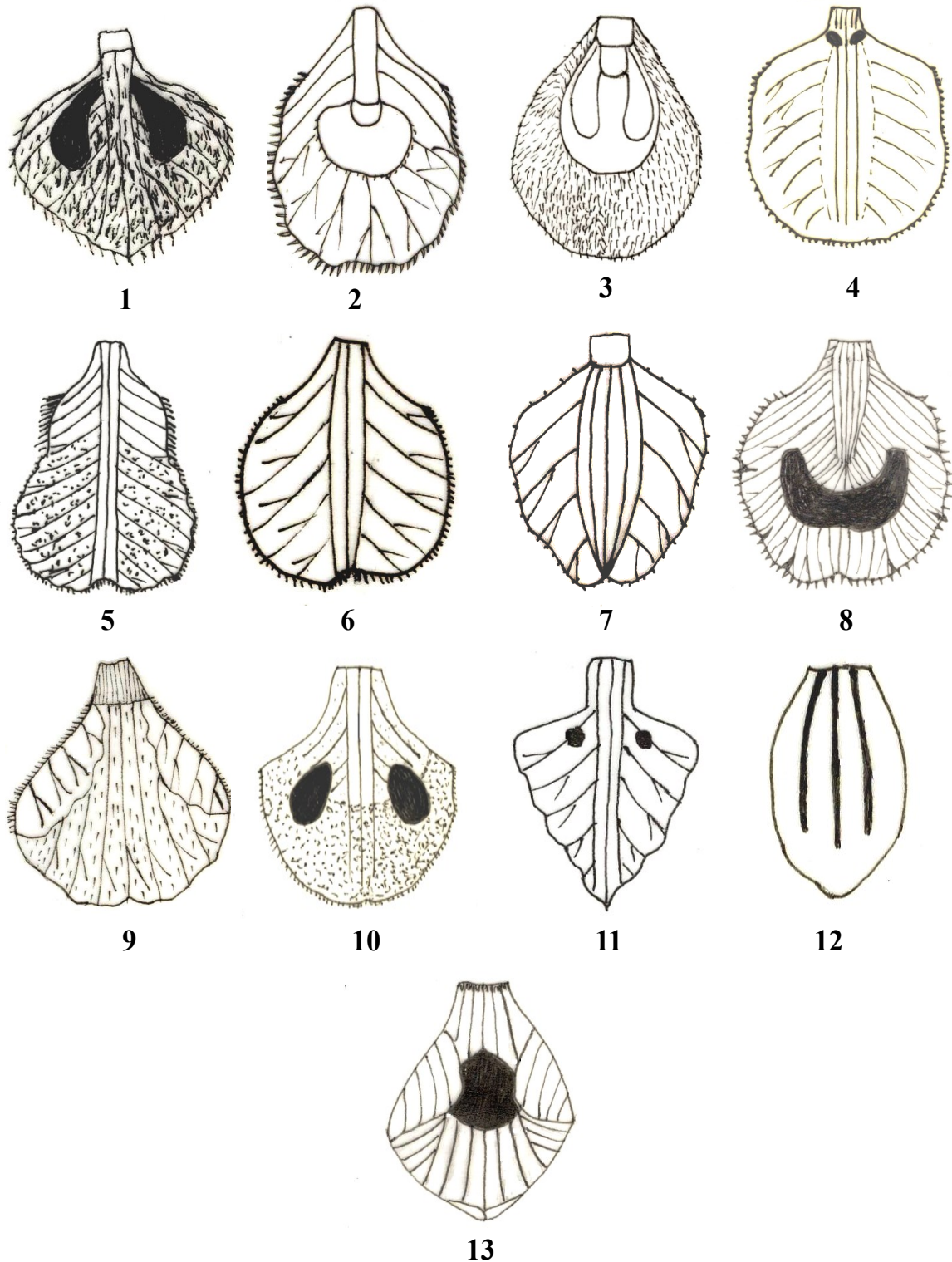


Fig. 3. Lip of *Dendrobium* species.

1. *D. chrysanthum*; 2. *D. fimbriatum*; 3. *D. moschatum*; 4. *D. polyanthum*; 5. *D. aphyllum*; 6. *D. chryseum*; 7. *D. crepidatum*; 8. *D. denneanum*; 9. *D. densiflorum*; 10. *D. gibsonii*; 11. *D. heterocarpum*; 12. *D. porphyrochilum*; 13. *D. nobile*.

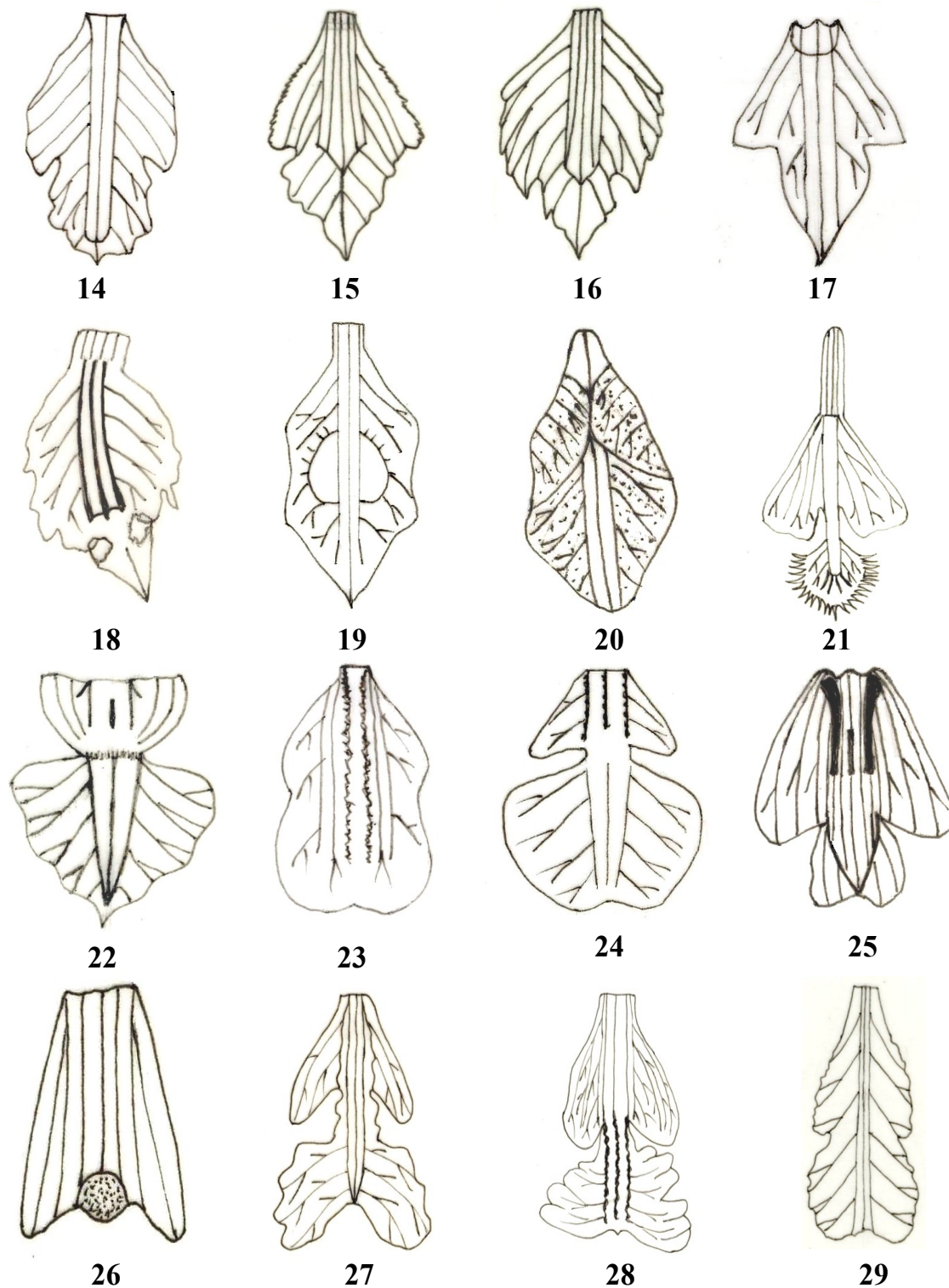


Fig. 3. contd.

14. *D. darjeelingense*; 15. *D. denudans*; 16. *D. eriiflorum*; 17. *D. moniliforme*; 18. *D. monticola*; 19. *D. transparens*; 20. *D. amoenum*; 21. *D. longicornu*; 22. *D. amplum*; 23. *D. formosum*; 24. *D. fuscescens*; 25. *D. rotundatum*; 26. *D. bicameratum*; 27. *D. fugax*; 28. *D. plicatile*; 29. *D. anceps*.

1. Column, Anther and Pollinia

Column is sub-terete to clavate, straight or curved in all species of *Dendrobium*. Column varies from 0.1 – 2.9 cm in length in different species of *Dendrobium*. Longer column is found in *D. longicornu*, *D. amplum*, *D. formosum*, *D. rotundatum*, *D. aphyllum* and *D. fuscescens*, shorter in remaining species of *Dendrobium*. Filaments are fused along the style length to form column. The base of column extends ventrally to form column foot. Lateral sepals are attached to column foot to form mentum. Column foot varies from 0.14 – 2.8 cm in length in different species of *Dendrobium*. Column foot is longer in *D. longicornu*, *D. formosum*, *D. amplum*, *D. anceps* and *D. transparens* and shorter in remaining species of *Dendrobium*. Column foot with 2 calli at lower end with thickened line is present in *D. amoenum*, at right angle to column in *D. amplum* and *D. eriiflorum*, bilocular in *D. bicameratum*, margin with fine papillose in *D. monticola*, transverse ridge at lower end in *D. chrysanthum*, slightly winged in *D. rotundatum* and simple in remaining species. The anther is inserted on filament near stigma base with base of operculum. A single fertile anther is present at apex of column and attached by short connective on clinandrium. The anther is two chambered, oblong or bilobed, rounded, emarginated or retuse at the apex, surface glabrous or papillous, yellow or white, anther cap entire, dentate, erose, hairy. The anther contains four pollinia in two pairs. Pollinia are oblong or ellipsoid, usually subequal. They are mostly yellow and pale-yellow in few species. The caudicle or viscidia is absent in pollinia.

The stigma is three-lobed, two lateral lobes are fertile while the posterior lobe is modified into rostellum. The rostellum is small, lamellate, narrow or wide. The stigmatic cavity is entire in

most *Dendrobium* species but bilobed in *D. amplum*, *D. formosum* and *D. porphyrochilum* and four-lobed in *D. densiflorum*.

Keys to species of *Dendrobium* Sw. of Nepal Himalaya

- 1a. Plants with pseudobulbs ----- 2
- 1b. Plants with cane-like stems ----- 11
- 2a. Plants small, stems or pseudobulbs with few internodes, leaves 2 or 3 to many, leaf deciduous or persistent, leafy throughout or at apical part, flowers small, few to many arising apically or laterally, lip simple or trilobed ----- 3
- 2b. Pseudobulbs with one or few internodes, leaves one or two, flower solitary or two in between leaves or at apex of pseudobulb, flower long-lived or ephemeral ----- 7
- 3a. Plants with elongate stems ----- 4
- 3b. Plants with cylindrical or elongate pseudobulbs ----- 6
- 4a. Stems 4-15 cm long, deciduous leaves, 8-many flowered, lip trilobed, obovate, disc with 3 ridges with triangular apex, margin of sidelobes lacerate ----- **26. *D. denudans***
- 4b. Stems 7-21 cm long, leaves deciduous or persistent, flowers more than ten, lip trilobed, oblong-ovate, margin of sidelobes entire or pectinate-serrate ----- 5
- 5a. Stems 20-21 cm long, leaves deciduous, flowers 16-20, lip with 3 keels from base to apex, side lobes margin entire ----- **25. *D. darjeelingense***
- 5b. Stems 7-12 cm high, leaves persistent, flowers many, lip with a mesial ridge from base to apex, side lobes margin pectinate-serrate ----- **27. *D. eriiflorum***
- 6a. Plants 1-2 cm high, pseudobulb cylindrical, flowers 7-12, lip simple with 3 obscure ridges of variable lengths from base to apex, margin entire ----- **29. *D. porphyrochilum***
- 6b. Plants 4-6 cm high, pseudobulb elongate, flowers 3-8, lip 3-lobed with irregular, orbicular and triangular apex, margin inciso-serrate ----- **28. *D. monticola***
- 7a. Pseudobulbs with one internode, leaves two, flower solitary in between leaves, flower long-lived ----- 8

- 7b. Pseudobulbs with few internodes, leaves one, one to three flowers at apex of pseudobulb, flower ephemeral or long-lived- 10
- 8a. Flowers 2.0-3.4 cm across, midlobe of lip suborbicular to subreniform ----- 9
- 8b. Flowers 7.5 cm across, midlobe of lip subrhomboid, disc with 3 parallel mesial ridges -----
-----**22. *D. amplum***
- 9a. Flowers 5.0 cm across, midlobe of lip suborbicular, disc with 3 crenulate lamellae between side lobes ----- **23. *D. fuscescens***
- 9b. Flowers 3.4 cm across, midlobe of lip subreniform, disc with a triangular thickened keel ---
-----**24. *D. rotundatum***
- 10a. Leaf 14.0-16.0 x 2.0-2.5 cm, flower white with pink purple spots, lip oblong ovate, 1.3 x 0.6 cm -----
-----**2. *D. fugax***
- 10b. Leaf 10.0-20.0 x 3.0-5.0 cm, flower milky yellow tinged with purplish red spots, lip subovate, 1.5 x 0.8 cm -----**3. *D. plicatile***
- 11a. Stems compressed, flattened with fleshy and equitant leaves throughout, flowers small, 1.2 cm across, solitary on the leafy stems, lip simple, densely pubescent except at basal part -----
-----**1. *D. anceps***
- 11b. Stems tufted, erect, cylindrical, clavate, subclavate, pendulous, leaves membranous, subleathery or leathery, persistent or deciduous, flower small to large, lip simple or tri-lobed -----**12**
- 12a. Stems erect, suberect, stout, cylindrical, clavate, subclavate, leaves membranous, leathery, persistent or deciduous, inflorescence axillary or lateral, lip tri-lobed or simple----- **13**
- 12b. Stems pendulous, cylindrical, leaves membranous, fleshy, leathery, subleathery, deciduous, persistent, inflorescence lateral or axillary, lip simple or trilobed ----- **24**
- 13a. Stems clavate, subclavate, leaves membranous, leathery, deciduous, persistent, inflorescence lateral, axillary, one-many flowered, flower 1.0-4.5 cm across, lip simple, trilobed ----- **14**
- 13b. Stems erect, suberect, cylindrical, stout, fractiflex, leaves membranous, leathery, deciduous, persistent, inflorescence lateral or axillary, 1-12 flowered, flower 2.5-10.0 cm across, lip simple or trilobed ----- **17**
- 14a. Stems subclavate, leaves leathery, deciduous, inflorescence axillary, 1-3 flowered, flower 4.5 cm across, pale yellow, lip simple -- **14. *D. heterocarpum***
- 14b. Stems clavate, leaves membranous, leathery, deciduous, persistent, inflorescence lateral, axillary, 4-many flowered, flower 1.0-4.0 cm across, lip simple, trilobed ----- **15**
- 15a. Stems clavate, leaves membranous, leathery, persistent, deciduous, inflorescence lateral, subterminal, 4-6 flowered, flower 1.0-5.5 cm across, lip simple, trilobed ----- **16**
- 15b. Stems clavate, 4-angled with 3-5 leaves at apex, leaves leathery, persistent, inflorescence axillary, many flowered, flower 2.5 - 4.0 cm across, flower light yellow, lip simple -----**11. *D. densiflorum***
- 16a. Stems clavate, leaves membranous, deciduous, inflorescence lateral, 4-6 flowered, flower 1.0 cm across, flower yellow with dull red in circular heads, lip trilobed -----**6. *D. bicameratum***
- 16b. Stems clavate, leaves leathery, persistent, inflorescence subterminal, 5 flowered, flower 4.0-5.5 cm across, flower dark yellow, lip simple, tomentose with dark, purple reniform patch -**10. *D. denneanum***
- 17a. Stems erect, stout, fractiflex, leaves leathery, persistent, inflorescence lateral, axillary, terminal, subterminal, 1-12 flowered, flowers 3.5-19.0 cm across, lip simple, trilobed----- **18**
- 17b. Stems erect, suberect, cylindrical, leaves membranous, leathery, deciduous, persistent, inflorescence lateral, axillary, 1-8 flowered, flowers 1-6 cm across, lip simple, trilobed ----- **21**
- 18a. Stems erect, stout, fractiflex, leaves leathery, persistent, inflorescence axillary, lateral or terminal, 1-5 flowered, flower 3.5-10.0 cm across, lip trilobed -
----- **19**
- 18b. Stems erect, stout, leaves leathery, persistent, inflorescence lateral, subterminal, 1-12 flowered, flowers 4.0-7.0 cm across, lip simple, trilobed ----- **20**
- 19a. Stems fractiflex covered by short coarse deciduous black hairs, leaves leathery, persistent, inflorescence axillary, 1-3 flowered, flower 3.5 cm across, white with orange yellow lip, lip trilobed, margin fimbriate----- **21. *D. longicornu***
- 19b. Stems stout, young stem clothed in fine black hairs, inflorescence lateral or terminal, 1-5 flowered, flower 8.0-10.0 cm across, lip trilobed, margin

undulate disc with two yellow tuberculate ridges, margin undulate ----- **20.D. formosum**

20a. Inflorescence 8-12 flowered, flower 6.5-7.0 cm across, lip with purplish-brown blotches on either sides, margin cucullate and fimbriate -----

----- **16. D. moschatum**

20b. Inflorescence 1-4 flowered, flower 6.0-7.0 cm across, lip with large purple blotch in the center, margin cucullate and entire----- **17. D. nobile**

21a. Stems erect, cylindrical, leaves membranous, leathery, deciduous, inflorescence lateral, axillary, 1-3 flowered, flowers 2.5-3.4cm across, lip simple, trilobed ----- 22

21b. Stems erect, suberect, leaves leathery, deciduous, persistent, inflorescence, lateral, axillary, 2-8 flowered, flowers 4.0-6.0 cm across, lip simple --- ----- 23

22a. Inflorescence lateral, 1-3 flowered, flower 2.5 cm across, lip trilobed, white with yellowish green central spot near the base of mid-lobe, margin entire ----- **15. D. moniliforme**

22b. Inflorescence axillary, 2-3 flowered, flower 3.4 cm across, lip trilobed, white with purple patch at middle, margin fimbriate ----- **19. D. transparens**

23a. Stems erect, leaves leathery, deciduous, inflorescence lateral, 2-4 flowered, flowers 4.0-6.0 cm across, lip with 2-lobed purple blotch, margin denticulate ----- **8. D. chryseum**

23b. Stems suberect, leaves leathery, persistent, inflorescence axillary, 6-8 flowered, flowers 4.5-5.5 cm across, lip deep orange-yellow with dark purple blotch on the disc, margin deeply fimbriate -----

----- **12.D. fimbriatum**

24a. Leaves membranous, fleshy, deciduous, persistent, inflorescence lateral, axillary, 1-4 flowered, flowers 2.0-5.0 cm across, lip simple, trilobed ----- 25

24b. Leaves leathery, subleathery, deciduous, persistent, inflorescence lateral, 2-12 flowered, flowers 2.0 -5.0 cm across, lip simple ----- 28

25a. Leaves membranous, deciduous, persistent, inflorescence lateral, axillary, 1-4 flowered, flowers 2.0-5.0 cm across, lip simple, trilobed ----- 26

25b. Leaves fleshy, deciduous, inflorescence lateral, 1-3 flowered, flowers 4.0 cm across, lip simple, pale

yellow or cream with purple veins at base -----

----- **5.D. aphyllum**

26a. Leaves membranous, deciduous, persistent, inflorescence lateral, 2-4 flowered, flowers 2.0-5.0 cm across, lip simple -----27

26b. Leaves membranous, deciduous, inflorescence axillary, 1-3 flowered, flowers 2.0-3.0 cm across, lip trilobed, white with purplish blotch at apex and green yellow at centre, margin undulate -----

----- **4.D. amoenum**

27a. Leaves membranous, persistent, inflorescence lateral, 2-4 flowered, flowers 5.0 cm across, lip simple, golden yellow with purplish red blotch on each side, margin denticulate -----

----- **7. D. chrysanthum**

27b. Leaves membranous, deciduous, inflorescence lateral, 2-3 flowered, flowers 2.0-5.0 cm across, lip simple, pinkish yellow at apex and white at base with purple veins, margin denticulate -----

----- **18. D. polyanthum**

28a. Leaves leathery, persistent, inflorescence lateral, 6-12 flowered, flowers 3.0 cm across, lip simple, orange yellow with a rounded deep purple blotch on each side, margin fimbriate -----

----- **13.D. gibsonii**

28b. Leaves subleathery, deciduous, inflorescence lateral, 2-3 flowered, flowers 2.0-5.0 cm across, lip simple, pale purplish pink above middle, yellow below middle, margin undulate -----

----- **9. D. crepidatum.**

Table 1: Distribution range and comparative morphological characters in *Dendrobium*

S.N.	Taxa	Altitude (m)	Length of Stem/Pseudobulb (cm)	Length of Internode (cm)	Leaf texture	Leaf size l x w (cm)	Inflorescence position	Length of peduncle (cm)	Length of rachis (cm)	No. of flowers/ inflorescence	Length of Pedicel with ovary (cm)	Flower size (cm)	Colour of Flower	Pollinia	
														Shape	Size (mm)
1	<i>D. amoenum</i>	200 – 2000	24.0-75.0	2.5-3.0	Membranous	4.4-10.9 x 0.6-1.8	Axillary	0.6	Absent	Two-three	2.8-3.0	2.0-3.0	White with tinged of purple	Elliptic	1.45 x 1.25
2	<i>D. amplum</i>	1300-2100	60.0-64.0	3.0-5.5	Coriaceous	9.0-18.0 x 2.2-5.0	Terminal	2	Absent	one	5	7.5	Yellowish brown, lip deep purple with bronze edges	Oblong	2.4 x 2.0
3	<i>D. anceps</i>	200-1400	15.0-56.0	2.0-2.5	Fleshy	2.5-3.5 x 0.8-1.2	Axillary	0.2	Absent	one	0.6	1.2	Yellowish green with pink lines	Oblong lanceolate	1.0 x 0.8
4	<i>D. aphyllum</i>	200-1500	20.0-50.0	2.5-3.0	Fleshy	4.0-6.0 x 1.5-3.0	Axillary	0.2	Absent	one-three	3.0	4	White with pale purplish red	Elliptic	2.3 x 2.3
5	<i>D. bicameratum</i>	1400-2400	10.0-26.0	1.7-3.0	Membranous	5.0-8.0 x 1.2-2.5	Lateral or subterminal	0.5	0.3-0.8	four-six	0.8	1	Yellow with dull red in circular heads	Oblong	1.2 x 0.7
6	<i>D. chrysanthum</i>	1300-2000	25.0-70.0	3.0-3.2	Membranous	8.5-20.0 x 2.5-4.5	Lateral	0.1	Absent	two-four	7	5	Golden yellow with purplish red blotch	Oblong	1.6 x 1.2
7	<i>D. chryseum</i>	1200-2100	25.0-50.0	2.0-5.0	Coriaceous	10.0-14.0 x 2.0-4.0	Lateral	4.0-6.0	3.0-10.0	two-four	3.5-5.0	4.0-6.0	Yellow orange with purple blotch	N.O.	N.O.
8	<i>D. crepidatum</i>	600-1400	14.0-20.0	2.0-2.5	Subleathery	5.5-9.5 x 1.0-1.6	Lateral	0.3	Absent	two-three	3.5	2.5	White with pale purplish pink	Oblong	2.0 x 1.6
9	<i>D. darjeelingense</i>	1500-2000	20.0-21.0	1.5-2.0	Membranous	6.0 x 1.2	Terminal or axillary	1-1.5	4	sixteen-twenty	0.4	1	Creamy with light greenish tinge	Oblong	0.5 x 0.2
10	<i>D. denneanum</i>	600-2500	40.0-65.0	2.0-3.0	Coriaceous	8.5- 12.0 x 1.5-2.5	Subterminal	1.5-2.0	7.0-12.0	five	2.0-4.0	4.0-5.5	Dark yellow	Ovate oblong	2.0 x 1.8
11	<i>D. densiflorum</i>	900-1500	20.0-40.0	2.5-3.8	Coriaceous	10.0-16.0 x 2.0-3.5	Axillary	4	10 to 12	more than ten	2.5-3.0	2.5-4.0	Light Yellow	Ovate oblong	1.6 x1.1
12	<i>D. denudans</i>	1000-2200	4.0-15.0	1.0-2.0	Membranous	6.0-10.0 x 1.0-1.5	Axillary	2.5-3.0	5.0-7.0	eight-many	0.6-0.9	1.0-2.0	Creamy to pale green with red-purple lines	Oblong	1.1 x 1.0
13	<i>D. eriiflorum</i>	1500-2100	7.0-12.0	1.6-2.0	Membranous	4.0-6.8 x 0.3-0.6	Terminal or axillary	2.5-3.0	3.0-10.0	more than ten	0.7	1.5	Light greenish white	Oblong lanceolate	1.1 x 1.0

14	<i>D. fimbriatum</i>	500-1000	55.0-70.0	2.5-5.0	Coriaceous	12.5-14.0 x 1.4-3.5	Axillary	2	5.0-8.0	six-eight	2.5-3.0	4.5-5.5	Orange-yellow	Oblong	2.0 x 1.5
15	<i>D. formosum</i>	500-1000	18.0-21.0	1.8-2.0	Coriaceous	5.5-8.0 x 2.0-2.8	Terminal or lateral	4.0-4.5	Absent	one-five	5.5	8.0-10.0	White with attractive yellow inner lip	Oblong	2.5 x 1.0
16	<i>D. fugax</i>	500-1600	21.0-29.0	2.0-3.0	Coriaceous	14.0-16.0 x 2.0-2.5	Terminal	1	Absent	one-two	0.6	2	White sprinkled with pink-purple spots	Oblong	1.1 x 1.0
17	<i>D. fuscescens</i>	600-1800	42.0-46.0	3.0-4.0	Coriaceous	7.5-9.0 x 1.7-2.0	Terminal	0.3-0.4	Absent	one	2.5-3.0	4.5-5.0	Purplish-brown	N.O.	N.O.
18	<i>D. gibsonii</i>	900-2000	25.0-48.0	2.0-3.0	Coriaceous	9.0-18.5 x 2.0-4.0	Lateral	1.0-2.0	9.0-13.0	six-twelve	4.7	3	Orange yellow with a rounded deep purple blotch on each side	Oblong	2.0 x 1.5
19	<i>D. heterocarpum</i>	900-2130	15.0-25.0	2.0-3.0	Coriaceous	7.0-12.0 x 1.0-2.0	Axillary	0.4	Absent	one-three	2.5	4.5	Pale yellow	Oblong	2.0 x 1.6
20	<i>D. longicornu</i>	1300-2900	13.0-36.0	2.5-3.0	Coriaceous	4.0-6.0 x 0.7-1.6	Axillary	0.5	Absent	one-three	2.5	3.5	White with orange yellow lip	Oblong elliptic	2.0 x 1.4
21	<i>D. moniliforme</i>	1700-2500	15.0-25.0	1.5-3.0	Membranous	3.5-8.0 x 0.5-1.3	Axillary	0.3	0.9	one-three	1.2	2.0-2.5	White with yellowish green spot	Oblong	1.1 x 1.2
22	<i>D. monticola</i>	1700-2200	4.0-6.0	1.0-1.5	Membranous	2.5-3.0 x 0.4-0.6	Terminal	1.5	2.5	three-eight	0.6	1.5	White with purplish red stripes	N.O.	N.O.
23	<i>D. moschatum</i>	200-1200	78.0-150.0	3.0-4.5	Coriaceous	7.5-14.5 x 1.5-5.5	Lateral	3.5-5.0	16.0-26.0	eight-twelve	5	6.5-7.0	Pale yellow with purplish brown blotches on lip	Oblong	2.0 x 1.6
24	<i>D. nobile</i>	400-1500	25.0-40.0	2.0-2.5	Coriaceous	8.0-13 x 1.5-2.5	Lateral	0.5-1.5	Absent	one-four	3.5-4.0	6.0-7.0	White at base, mauve above	Oblong	2.0 x 1.5
25	<i>D. plicatile</i>	500-2400	20.0-28.0	0.7-0.8	Coriaceous	10.0 -20.0 x 3.0-5.0	Terminal	0.7	Absent	one-three	0.6	2	Milky yellow tinged with purplish red spots	N.O.	N.O.
26	<i>D. polyanthum</i>	400-1400	10.0-25.0	1.5-2.0	Membranous	7.0-10.0 x 2.0-3.0	Lateral	0.2	Absent	two-three	2.0-2.5	6	Pink-purple	Ellipsoid	2.2 x 2.5
27	<i>D. porphyrochilum</i>	1800-2500	1.0-2.0	0.5	Membranous	2.5-5.0 x 0.5-0.8	Terminal	3	4.0-5.0	seven-twelve	0.7	0.8-1.0	Creamy or yellowish green	N.O.	N.O.
28	<i>D. rotundatum</i>	1300-2500	40.0-48.0	2.5-5.0	Coriaceous	4.0-13.5 x 1.2-2.8	Terminal	0.5	Absent	one	2.5	3.4	Pale yellowish brown	Oblong	1.8 x 1.7
29	<i>D. transparens</i>	700-2100	24.0-40.0	2.0-2.5	Membranous	5.0-10.5 x 1.5-2.0	Axillary	0.1	Absent	eight-twelve	3.5	3.4	White with pink flooded	Oblong	1.0 x 0.8

Note: N.O. = Not observed.

Table 2: Comparative Bract Structures in *Dendrobium*

S.N.	Taxa	Length (cm)	Width (cm)	Shape	Veins	Apex	Distinguished Characters
1	<i>D. amoenum</i>	0.7	0.2	Ovate-lanceolate	3	Acute	Membranous, much shorter than ovary
2	<i>D. amplum</i>	1.7	0.5	Ovate-oblong	5	Acute	Large, scarious
3	<i>D. anceps</i>	0.35	0.2	Oblong	5	Obtuse	Much shorter than ovary
4	<i>D. aphyllum</i>	0.3	0.25	Ovate	1	Acute	Pale-white and membranous
5	<i>D. bicameratum</i>	0.6	0.4	Oblong-ovate	3	Acute	Sheathing the shortly stalked ovary
6	<i>D. chrysanthum</i>	0.4	0.25	Ovate-triangular	1	Acute	Small and scarious
7	<i>D. chryseum</i>	1.5-2.0	0.4-0.5	Ovate-lanceolate	5	Obtuse	Membranous
8	<i>D. crepidatum</i>	0.4	0.2	Ovate	1	Acute	Small, thin and membranous
9	<i>D. darjeelingense</i>	0.4	0.1	Triangular	3	Acute	Small and membranous
10	<i>D. denmeanum</i>	2	0.6	Oblong	7	Acute	Large and membranous
11	<i>D. densiflorum</i>	1.9	1	Oblong	7	Obtuse	Large, membranous, twisted, margin revolute
12	<i>D. denudans</i>	0.3	0.15	Lanceolate	1	Acute	Minute and membranous
13	<i>D. eriiflorum</i>	0.4	0.15	Ovate-lanceolate	1	Acuminate	Minute and membranous
14	<i>D. fimbriatum</i>	0.4	0.3	Ovate-triangular	5	Acute	Small and membranous
15	<i>D. formosum</i>	0.5	0.2	Ovate	5	Subacute	Much shorter than ovary and sheathing
16	<i>D. fugax</i>	1	1.2	Triangular	1	Acute	Small, membranous
17	<i>D. fuscescens</i>	1	0.5	Ovate-lanceolate	5	Acute	Small, scarious, shorter than pedicel with ovary
18	<i>D. gibsonii</i>	0.5-0.7	0.2-0.3	Lanceolate	5	Acute	Minute, membranous and cymbiform
19	<i>D. heterocarpum</i>	0.6	0.4	Ovate	3	Obtuse	Broad and convolute
20	<i>D. longicornu</i>	1.5	0.5	Ovate-lanceolate	5	Acute	Concave and hairy abaxially
21	<i>D. moniliforme</i>	0.6	0.3	Ovate	3	Acute	Pale white with brown spots
22	<i>D. monticola</i>	0.35	0.2	Ovate	1	Acute	Small and membranous
23	<i>D. moschatum</i>	1.5	0.7	Lanceolate	5	Obtuse	Leathery
24	<i>D. nobile</i>	0.5-0.9	0.4-0.6	Oblong-ovate	5	Obtuse	Scarious
25	<i>D. plicatile</i>	0.1	0.12	Triangular	1	Acute	Small and membranous
26	<i>D. polyanthum</i>	0.8	0.5	Ovate	1	Obtuse	Minute and memebrous
27	<i>D. porphyrochilum</i>	0.2-0.4	0.1-0.12	Lanceolate	1	Acuminate	Minute, longer than pedicel with ovary
28	<i>D. rotundatum</i>	1	0.6	Ovate	5	Acute	Small, scarious
29	<i>D. transparens</i>	1.1	0.7	Lanceolate	5	Acute	Scarious, much shorter than stalked ovary

Table 3: Comparative Structure of Dorsal Sepals in *Dendrobium*

S.N.	Taxa	Length (cm)	Width (cm)	Veins	Shape	Apex	Distinguished characters
1	<i>D. amoenum</i>	2.4	0.7	5	Oblong-lanceolate	Obtuse	White with tinged of purple
2	<i>D. amplum</i>	4.7	0.7	10	Lanceolate	Acuminate	Yellowish brown with dark brown spots
3	<i>D. anceps</i>	0.5	0.4	5	Elliptic	Sub-acute	Erect, tip folded inward
4	<i>D. aphyllum</i>	2.8	0.8	5	Oblong-lanceolate	Sub-acute	White with pale purplish red lines
5	<i>D. bicameratum</i>	0.9	0.6	5	Ovate-oblong	Sub-acute	Concave, broad
6	<i>D. chrysanthum</i>	2.2	1.2	7	Elliptic	Obtuse	Concave, entire, incurve apical half
7	<i>D. chryseum</i>	2.5	0.9	5	Oblong-lanceolate	Subacute	Concolor yellow
8	<i>D. crepidatum</i>	1.4	0.7	5	Oblong-lanceolate	Obtuse	Entire, spotted (tinged with light purple)
9	<i>D. darjeelingense</i>	0.8	0.2	3	Lanceolate	Acuminate	Entire, creamy tinged with light green
10	<i>D. denneanum</i>	1.8	1	7	Oblong	Acuminate	Entire, dark yellow
11	<i>D. densiflorum</i>	2	1.1	7	Ovate-oblong	Obtuse	Light yellow
12	<i>D. denudans</i>	1.2	0.25	3	Linear-lanceolate	Acuminate	Creamy to pale green
13	<i>D. eriiflorum</i>	1.2	0.25	5	Lanceolate	Acuminate	Light greenish white
14	<i>D. fimbriatum</i>	2.4	1	5	Elliptic-oblong	Obtuse	Entire, light orange-yellow
15	<i>D. formosum</i>	4.2	1.2	7	Elliptic-oblong	Acuminate	Erect, slightly concave
16	<i>D. fugax</i>	1.3	0.4	5	Elliptic-oblong	Sub-acute	White sprinkled with pink-purple spots
17	<i>D. fuscescens</i>	2.8	0.8	10	Ovate-lanceolate	Acuminate	Purplish-brown
18	<i>D. gibsonii</i>	1.6	1	6	Elliptic	Obtuse	Entire, slightly incurved, base slightly zigzag
19	<i>D. heterocarpum</i>	2.8	0.7	5	Oblong-lanceolate	Sub-acute	Pale yellow
20	<i>D. longicornu</i>	2.5	0.7	7	Ovate-lanceolate	Acuminate	Keeled
21	<i>D. moniliforme</i>	1.5	0.5	5	Broadly lanceolate	Acute	Subfalcate
22	<i>D. monticola</i>	1	0.2	3	Lanceolate	Acuminate	White
23	<i>D. moschatum</i>	3.2	1.6	7	Oblong	Obtuse	Pale yellow
24	<i>D. nobile</i>	3.1	0.9	7	Oblong-lanceolate	Obtuse	White at base mauve above
25	<i>D. plicatile</i>	0.9	0.25	5	Ovate-lanceolate	Acuminate	Rolled inside, milky yellow tinged with purple red spots
26	<i>D. polyanthum</i>	2.2	0.6	5	Lanceolate	Sub-acute	Pink-purple
27	<i>D. porphyrochilum</i>	0.6	0.15	3	Lanceolate	Obtuse	Creamish-green
28	<i>D. rotundatum</i>	3	1	7	Ovate-lanceolate	Acute	Pale yellowish brown
29	<i>D. transparens</i>	3.2	0.5	5	Lanceolate	Obtuse	White with pink flooded

Table 4: Comparative Structure of Lateral Sepals in *Dendrobium*

S.N.	Taxa	Length (cm)	Width (cm)	Veins	Shape	Apex	Distinguished Characters
1	<i>D. amoenum</i>	2.9	0.8	5	Lanceolate	Acute	Broader than dorsal sepal
2	<i>D. amplum</i>	4.6	0.7	10	Lanceolate	Acuminate	Falcate, broadly based
3	<i>D. anceps</i>	0.8	0.5	5	Elliptic	Obtuse	Tip folded inward, falcate, pink-spotted
4	<i>D. aphyllum</i>	2.9	0.7	5	Oblong-lanceolate	Subacute	White with pale purplish red lines
5	<i>D. bicameratum</i>	0.7	0.75	5	Triangular	Subacute	Concave
6	<i>D. chrysanthum</i>	2.2	1.1	7	Ovate-triangular	Obtuse	Concave, base broad and oblique, incurve apical half
7	<i>D. chryseum</i>	2.7	0.9	5	Oblong-lanceolate	Subacute	Concolor yellow
8	<i>D. crepidatum</i>	1.5	0.6	5	Ovate-oblong	Obtuse	Midrib thick, spotted (tinged with light purple)
9	<i>D. darjeelingense</i>	0.8	0.25	5	Ovate-lanceolate	Acute	Obliquely curved
10	<i>D. denneanum</i>	2.2	0.8	5	Oblong	Acuminate	Subfalcate
11	<i>D. densiflorum</i>	2.1-2.4	1.0-1.2	7	Oblong-elliptic	Obtusely acute	Light yellow
12	<i>D. denudans</i>	1.2	0.4	5	Lanceolate-triangular	Acuminate	Falcate
13	<i>D. eriiflorum</i>	1.2	0.3	5	Lanceolate	Acuminate	Falcate, broadly based
14	<i>D. fimbriatum</i>	2.4	1	5	Ovate-lanceolate	Obtuse	Small outgrowth at lower side of apex
15	<i>D. formosum</i>	4	1.6	7	Oblong-lanceolate	Acuminate	Subfalcate, keeled, spreading
16	<i>D. fugax</i>	1.4	0.5	5	Oblong-elliptic	Subacute	Adnate at base to form mentum
17	<i>D. fuscescens</i>	2.8	1.0	10	Ovate-lanceolate	Acuminate	Base broad, slightly falcate
18	<i>D. gibsonii</i>	1.6	0.9	5	Oblong	Obtuse	Slightly incurved, entire
19	<i>D. heterocarpum</i>	2.8	0.7	7	Lanceolate	Acute	Pale yellow
20	<i>D. longicornu</i>	5.5	1	7	Lanceolate	Acuminate	Adnate to form a long spur-like mentum, keeled, recurved
21	<i>D. moniliforme</i>	1.6	0.6	5	Lanceolate	Acute	Subfalcate
22	<i>D. monticola</i>	0.9	0.35	5	Falcate-lanceolate	Acute	Base broad, contracted above middle part
23	<i>D. moschatum</i>	3.2	1.6	7	Oblong	Acute	Pale yellow
24	<i>D. nobile</i>	3.2	0.8	7	Oblong-lanceolate	Acute	Base oblique, margin incurved slightly
25	<i>D. plicatile</i>	0.9	0.25	5	Ovate lanceolate	Acuminate	Obliquely ovate-lanceolate
26	<i>D. polyanthum</i>	2.3	0.5	5	Lanceolate	Subacute	Base oblique
27	<i>D. porphyrochilum</i>	0.8	0.2	3	Lanceolate	Obtuse	Slightly broader than dorsal sepal
28	<i>D. rotundatum</i>	3.0	1.3	7	Ovate	Acute	Subfalcate, adnate to column foot
29	<i>D. transparens</i>	3.3	0.5	5	Lanceolate	Acuminate	White with pink flooded

Table 5: Comparative Structure of Petals in *Dendrobium*

S.N.	Taxa	Length (cm)	Width (cm)	Veins	Shape	Apex	Distinguished Characters
1	<i>D. amoenum</i>	2.6	1.2	5	Ovate	Obtuse	Broader than dorsal sepal, entire
2	<i>D. amplum</i>	4.8	0.3	5	Linear-lanceolate	Acute	Wide spreading
3	<i>D. anceps</i>	0.4	0.2	5	Elliptic	Obtuse	Much shorter than sepals, entire
4	<i>D. aphyllum</i>	3.1	1.2	5	Oblong-elliptic	Obtuse	Broader than sepals, entire
5	<i>D. bicameratum</i>	0.9	0.5	5	Elliptic	Obtuse	As long as sepal, yellowish with dull red spots and stripes
6	<i>D. chrysanthum</i>	2.4	1.7	7	Obovate	Rounded	Concave slightly, margin erose minutely
7	<i>D. chryseum</i>	2.5	1.4	3	Elliptic-obovate	Obtuse	Broader than sepal, major lateral veins branched
8	<i>D. crepidatum</i>	1.5	0.9	5	Obovate	Obtuse	Broader than sepal, entire, spotted (tinged with light purple)
9	<i>D. darjeelingense</i>	0.7	0.15	3	Oblong-lanceolate	Acute	Smaller than sepal
10	<i>D. denneanum</i>	2.5	1.2	3	Ovate	Obtuse	Broader than sepal, lateral veins branched
11	<i>D. densiflorum</i>	1.5-2.0	1.3-1.6	7	Ovate-orbicular	Obtuse	Shortly clawed, margin erose
12	<i>D. denudans</i>	1.3	0.12	3	Linear-lanceolate	Acuminate	Smaller than sepal in breadth
13	<i>D. eriiflorum</i>	1.1	0.18	3	Linear-lanceolate	Acute	Lying parallel above column
14	<i>D. fimbriatum</i>	2.4	1.5	5	Oblong-elliptic	Obtuse	Broader than sepal, margin slightly erose
15	<i>D. formosum</i>	5	3.3	7	Obovate	Cuspidate	Larger than sepal, truncate, margin undulate
16	<i>D. fugax</i>	1.1	0.2	3	Oblong-ovate	Subacute	Narrower than sepals
17	<i>D. fuscescens</i>	2.7	0.3	5	Linear-lanceolate	Acute	Petal spreading
18	<i>D. gibsonii</i>	1.7	1.3	5	Elliptic	Emarginate	Margin slightly undulate
19	<i>D. heterocarpum</i>	2.8	1	5	Ovate-lanceolate	Acute	Equal to dorsal sepal, entire, many secondary veins
20	<i>D. longicornu</i>	2.5	0.5	3	Linear-lanceolate	Acute	As long as dorsal sepal
21	<i>D. moniliforme</i>	1.6	0.7	5	Ovate-lanceolate	Acute	As long as sepal, entire
22	<i>D. monticola</i>	0.8	0.15	3	Linear-lanceolate	Acuminate	Smaller than sepal
23	<i>D. moschatum</i>	3.5	1.8	7	Ovate	Obtuse	Larger than sepal
24	<i>D. nobile</i>	3.5	2	7	Oblong-ovate	Obtuse	Margin slightly incurved
25	<i>D. plicatile</i>	0.9	0.2	3	Lanceolate	Subacute	Narrower than sepals, rolled inside
26	<i>D. polyanthum</i>	2.2	0.4	5	Oblong	Obtuse	Pink purple petals
27	<i>D. porphyrochilum</i>	0.5	0.1	3	Oblong-lanceolate	Acute	Pale yellow green with red veins
28	<i>D. rotundatum</i>	2.8	0.8	7	Oblong-lanceolate	Acuminate	As long as dorsal sepal
29	<i>D. transparens</i>	3.3	1.3	5	Oblong	Obtuse	White flushed with pink

Table 6: Comparative Structure of Lips in *Dendrobium*

S.No.	Taxa	Lip											Distinguished Characters on disc
		Structure					Side Lobe			Mid Lobe			
		Outline	Length (cm)	Width (cm)	Shape	Colour	Shape	Apex	Margin	Shape	Apex	Margin	
1	<i>D. amoenum</i>	Tri-lobed	2.8	1.4	Oblong-ovovate	White with purplish blotch at apex, greenish yellow at middle	Rounded	Obtuse	Convolute	Oblong-ovate	Obtuse	Undulate	Sub-villous on disc
2	<i>D. amplum</i>	Tri-lobed	2.7	1.7	Pandurate	Dark purple with bronze edges	Short, Rounded	Obtuse	Entire	Sub-rhomboid	Mucronate	Crenulate	Disc with 3 lamellae, outer 2 having an erect tooth at bases, middle one shorter and toothless
3	<i>D. anceps</i>	Tri-lobed	1.2	0.4	Cuneately oblong	Yellowish green with pink spotted	Oblong	Obtuse	Entire at lower part, crenulate at apex	Obovate	Bilobed	Crenulate	Shallow thickened depression ending near apex
4	<i>D. aphyllum</i>	Simple	3.4	2.6	Suborbicular	Pale yellow or cream at apex, purple veined at base	–	–	–	Convolute forming a tube at base	Rounded, emarginate	Fimbriate	Disc hairy
5	<i>D. bicameratum</i>	Tri-lobed	0.5	0.45	Triangular	Yellow marked with dull red	Triangular	Acute	Entire	Rectangular	Truncate	Entire	Disc with cushion-shaped callus
6	<i>D. chrysanthum</i>	Simple	2.2	2.4	Orbicular-oblong	Golden yellow with purplish red blotch	–	–	–	Reniform	Rounded	Denticulate	Thick and broad ridge extending from base to middle
7	<i>D. chryseum</i>	Simple	2.8	2.4	Suborbicular	Yellow orange with 2-lobed purple blotch	–	–	–	Suborbicular	Rounded	Fimbriate	Minutely pubescent to tomentose on adaxial side, clawed at base

8	<i>D. crepidatum</i>	Simple	1.4	1.1	Orbicular	Pale purplish-pink above middle, yellow below middle	–	–	–	Obovate, incurved sides at base	Retuse	Undulate, ciliate	A transverse ridge at the claw
9	<i>D. darjeelingense</i>	Tri-lobed	0.6	0.3	Oblong-ovate	Red lined in cream tinged with light green	Triangular	Acute	Entire	Obovate	Acute	Undulate, crenulate	3 keels from base to apex
10	<i>D. denneanum</i>	Simple	2.2	2	Orbicular	Dark yellow with dark purple reniform patch	–	–	–	Reniform, convolute in basal part	Retuse	Undulate, fimbriate	Clawed at base, tomentose
11	<i>D. densiflorum</i>	Simple	2.2	2.1	Orbicular-rhomboid	Orange yellow	–	–	–	Orbicular-rhomboid, convolute in basal half	Retuse	Revolute, lacerate	Clawed at base
12	<i>D. denudans</i>	Tri-lobed	1.1	0.5	Obovate	Pale green with radiating red-purple lines	Oblong	Acute	Lacerate	Obovate	Acute	Serrate-crisped	Disc with 3 ridges having a triangular apex ending at mid-lobe
13	<i>D. eriiflorum</i>	Tri-lobed	0.8	0.7	Oblong-ovate	Light greenish-white spotted with dull purple	Elongate, narrow	Acute	Pectinate-serrate	Orbicular	Acute	Undulate	Disc with a mesial ridge running from base to apex of mid-lobe
14	<i>D. fimbriatum</i>	Simple	3	2.2	Suborbicular	Deep orange yellow with dark purple blotch	–	–	–	Suborbicular	Rounded	Deeply fimbriate	Shortly clawed, base with purple red stripes, densely pubescent adaxially
15	<i>D. formosum</i>	Tri-lobed	6	3.5	Obcuneate	White with yellow marks	Rounded	Obtuse	Entire	Orbicular	Retuse, apiculate	Undulate	Disc with two yellow tuberculate central ridges
16	<i>D. fugax</i>	Tri-lobed	1.3	0.6	Oblong-obovate	White sprinkled with pink-purple spots	Oblong	Truncate	Erose-crisped	Oblong-elliptic	Truncate	Undulate	Disc with two plicate lamellae extending from base to apex
17	<i>D. fuscescens</i>	Tri-lobed	1.8	1.6	Ovate-oblong	Purplish-brown	Oblong	Obtuse	Undulate	Sub-orbicular	Emarginate to Mucronate	Undulate	Disc with 3 crenulate lamellae between side lobes, middle lamella shorter

18	<i>D. gibsonii</i>	Simple	1.5	1.7	Sub-reniform	Orange yellow with deep purple blotch on each side	–	–	–	Orbicular	Emarginate	Fimbriate	Deep purple blotch, papillary hairs with short fringed edges on both sides of disc
19	<i>D. heterocarpum</i>	Simple	2.8	1.6	Trowel-shaped	Pale yellow with reddish purple radiating lines	–	–	–	Ovate-oblong	Acute	Undulate	Disc papillose-pubescent
20	<i>D. longicornu</i>	Tri-lobed	5.1	2.3	Broadly triangular (spreading)	White streaked orange yellow	Rounded	Truncate	Slightly wavy	Sub-orbicular	Obtuse	Fimbriate	A broad central ridge from base to mid-lobe ending into 4 branches
21	<i>D. moniliforme</i>	Tri-lobed	1.5	0.9	Oblong-lanceolate	White with yellowish green central spots	Rounded, incurved near middle	Rounded	Entire, slightly wavy	Ovate-elliptic	Acute	Entire	Disc with an elongated callus
22	<i>D. monticola</i>	Tri-lobed	0.8	0.45	Subelliptic	White with purplish red stripes in side lobes	Rounded	Acuminate	Inciso-serrate	Ovate triangular	Acute	Undulate, recurved	disc with irregular, orbicular, triangular apex, 3 lamellate ridged projections in centre
23	<i>D. moschatum</i>	Simple	3	1.7	Calceolate	Pale yellow with purplish brown blotches on either sides	–	–	–	Sub-globular	Rounded	Cucullate, fimbriate	No callus
24	<i>D. nobile</i>	Simple	3.5	2.2	Ovate-oblong	White at base becoming mauve at apex with large purple blotch	–	–	–	Ovate-oblong	Obtuse	Cucullate, entire	Shortly clawed, upper half cucullate, lower half incurved, densely pubescent
25	<i>D. plicatile</i>	Tri-lobed	1.5	0.8	Subovate	White with yellowish white lamallae	Subovate	Rounded	Entire	Flabellate	Sub truncate	Undulate	Disc with two or three lamellae extending from base to apex of mesochile.
26	<i>D. polyanthum</i>	Simple	2.5	2	Obovate, convolute at base	Pinkish yellow at apex white at base with purple veins	–	–	–	Obovate	Rounded	Denticulate	Short claw, callus at base,

27	<i>D. porphyrochilum</i>	Simple	0.4	0.25	Elliptic	Purplish brown with yellowish green margin	–	–	–	Elliptic	Subacute	Entire	3 obscure ridges of variable lengths from base to apex
28	<i>D. rotundatum</i>	Tri-lobed	1.9	1.2	Obovate-oblong	Brownish yellow	Sub-ovate	Obtuse	Slightly undulate	Sub-reniform	Emarginate	Undulate	Midlobe with a triangular thickened keel adaxially, disc with 3 crenulate lamellae between side lobes, middle one shorter
29	<i>D. transparens</i>	Tri-lobed	3.6	1.8	Elliptic-obovate	White with purple patch at middle	Broad, convolute	Rounded	Erose	Sub-orbicular	Acute	Undulate	Disc hairy with 3 distinct veins running from base to apex

Acknowledgments

The authors are thankful to National Herbarium and Plant Laboratories (KATH) and Tribhuvan University Central Herbarium (TUCH) for their cooperation and allowing to studying the herbarium specimens housed over there. My sincere thanks go to Patan Multiple Campus and Amrit Campus for providing the laboratories facilities.

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Cite this article as:

Baba Maiya Pradhan and Devendra M. Bajracharya. Morphological Diversity within Dendrobium (Orchidaceae) of Nepal. *Annals of Plant Sciences*. 9.12 (2020) pp. 4074-4102.

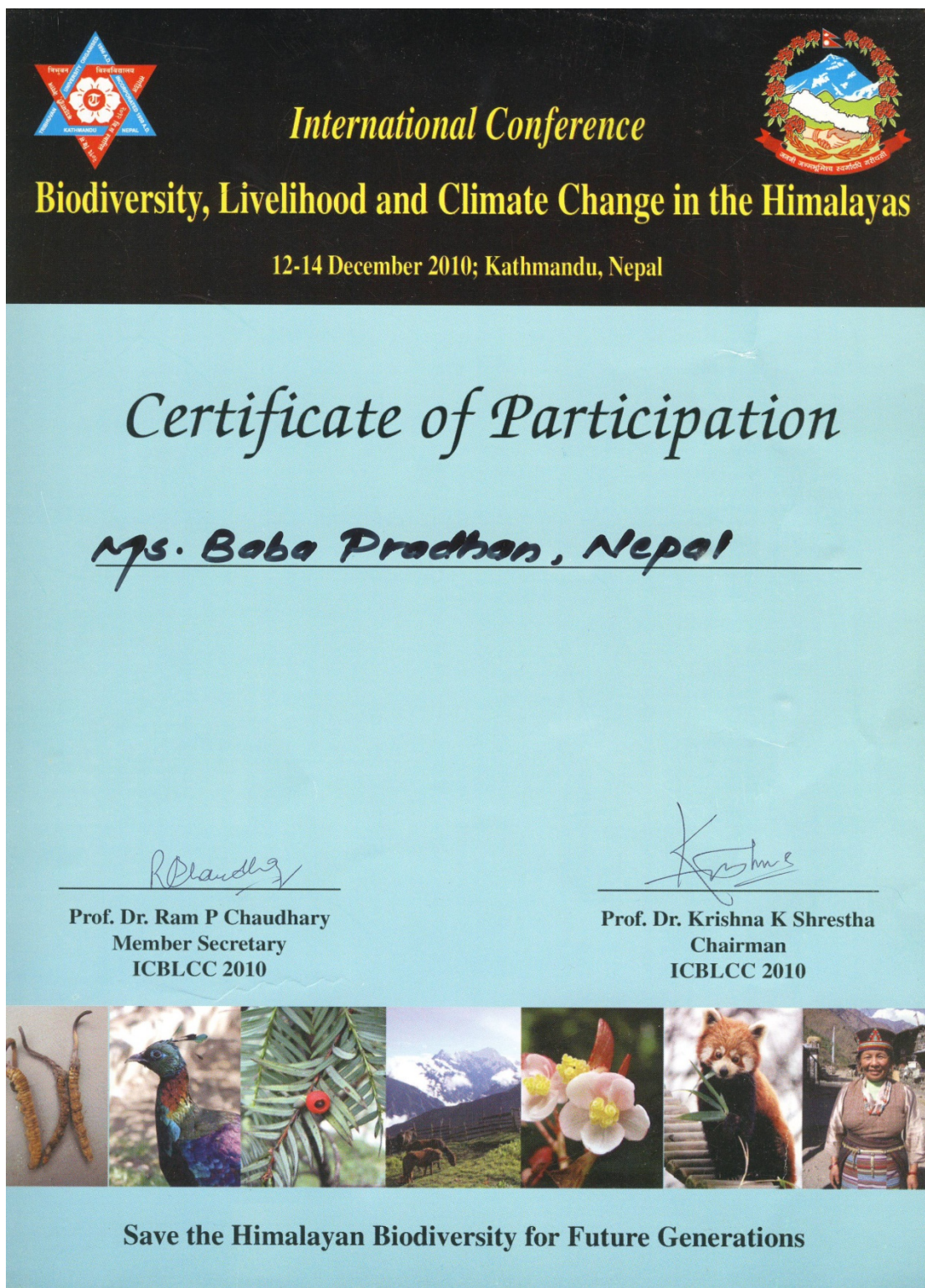
 <http://dx.doi.org/10.21746/aps.2020.9.12.1>

Subject Editor: Prof. Bir Bahadur, Dept. of Botany, Kakatiya University, Warangal, India

Source of support: Nil; **Conflict of interest:** Nil.

Appendix VI. Conference and Training Workshop attended

- I. International Conference on Biodiversity, Livelihood and Climate Change in the Himalayas: 12-14 December 2010, Kathmandu, Nepal.



II. The 6th National Conference on Science and Technology: 25-27 September 2012,
Kathmandu, Nepal.



Nepal Academy of Science and Technology

CERTIFICATE

Awarded to

BABA MAIYA PRADHAN

for actively participating in the

SIXTH NATIONAL CONFERENCE

ON

SCIENCE AND TECHNOLOGY

September 25-27, 2012 (Ashwin 9-11, 2069)

Kathmandu, Nepal

Ramila Raut
Ramila Raut
Chief, Promotion Division

Prakash Ch. Adhikari
Prof. Dr. Prakash Chandra Adhikari
Secretary

Prof. Dr. Surendra Raj Kafle
Prof. Dr. Surendra Raj Kafle
Vice Chancellor

III. Research Methodology Training Workshop: 8-13 June 2014, Kathmandu, Nepal.



Research Methodology Training Workshop

CERTIFICATE

This certificate is awarded to **Baba Maiya Pradhan** for participating the PhD Research Methodology Training workshop organized by Central Department of Botany, IoST, Tribhuvan University and supported by University Grants Commission (UGC), Bhaktapur. This program was held from 25 - 30 Jestha 2071 (8 - 13 June 2014).


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IV. International Conference on Biodiversity, Climate Change Assessment and Impacts on Livelihood: 10-12 January 2017, Kathmandu, Nepal.



V. Research Methodology for PhD Scholars Training Program: 20-26 June, 2017,
Kathmandu, Nepal.

